FLORIDA DEPARTMENT OF TRANSPORTATION

AN ELECTRONIC FIELD BOOK PROCESSING SYSTEM HANDBOOK

A Complete Reference For Use
With The Electronic Field Book
Data Processing System

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TRADEMARKS

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Chapter One - Introduction

The Electronic Field Book system was designed to provide the field surveyor with a vehicle to accurately and efficiently gather data for design surveys, topographic surveys, boundary surveys and other similar types of projects. The Electronic Field Book system itself consists of series of command menus and data screens that allow the operator to interact with the system.

The Electronic Field Book system command menus provide the operator access to the various command system modules, while the data screens provide the operator with an interface to actually electronically gather and save the field survey data. As each bit of field survey data is recorded by the Electronic Field Book system, it is “stamped” with the date and time of the recording. This provides a complete record that binds the field survey data together with a complete record of each field observation performed in a particular project.

If one is using EFBP in conjunction with Florida Department of Transportation's (FDOT) Electronic Field Book (EFB) survey data collection system, one is strongly urged to contact FDOT on references on use of EFB. Successful use of EFBP is enhanced when one has a strong understanding of the system which was used to collect the survey field data.

Once the field survey data has been gathered it must then be “processed”, i.e. the collected field angles and distances must be reduced to create coordinates and/or elevations for all of the observed points. This act of processing includes the editing of the field survey data to remove errors and correct blunders, a vertical least squares adjustment of the field survey data, a horizontal least squares adjustment of the field survey data, the generation of coordinates for each observed point and the updating of the project database with the generated coordinates.

The Electronic Field Book Processing (EFBP) system uses a wide variety of mathematical techniques in surveying and statistics. Every user does not need to fully understand the theoretical basis for these techniques. Understanding the information which is contained in the various processing report files is more important. Most users can simply refer to this handbook for answers to most questions that deal with production issues.

There are times however when a user may want to look at some broader background descriptive information on certain algorithms in EFBP. If the user has a desire to explore these technical issues, it is suggested that they consult the Electronic Field Book Technical Reference Handbook.

The purpose of this Electronic Field Book Processing handbook is to act as a guide for the individual responsible for processing survey data and the use of the processing software system. The Electronic Field Book Processing (EFBP) system is the “engine” for the numerical processing of raw survey data (horizontal circle readings, zenith circle readings, slope distances, height of instrument, height of target, level rod readings, taping, calibrations, point names) into coordinate information. EFBP does not process attribute information (feature codes, zones, remarks/comments, chains/linework, straight vs. curve line geometry, etc.) but carries this information into an ASCII readable file format so that it can be read with the coordinate information into computer aided drafting, mapping, and design systems. The use of EFBP in this fashion is often termed as “processing” one’s data.

This handbook has been produced to assist the user with this data processing phase and the analysis of the processing results. During the course of processing, a multitude of reports are produced for the user to review. One purpose of this handbook is to provide the user with a detailed explanation of what is contained in each report and how the information may be used to analyze the validity of the field survey data. Several computer applications have been developed to aid in the processing of the data and each of these programs is also explained in this handbook.

About This Handbook

This handbook assumes that the reader has some basic land surveying background and has access to common land surveying textbooks as this handbook is not intended to eliminate the reader’s need for this type of information. This handbook also assumes that the user is familiar with PC computers and the operation of the Electronic Field Book data collection system as extensive use of the MS-DOS file naming convention is used. Both EFB and EFBP files usually consist of a project name before the period and a one (1) to three (3) character extension which alerts the user as to what type of data is contained in the file. This handbook typically makes reference to files by using only a period followed by the file extension (.CTL as an example), while it is assumed that the project name always exists before the period.

A chapter in the handbook will be devoted to a review of DOS computer basics and one will also be devoted to the Electronic Field Book data collection system. Each of these chapters is intended to act only as a reference and if the reader desires to explore either subject in greater detail, it is suggested that reader consult one of the many books written covering DOS or the Electronic Field Book User’s Guide.

While a new EFBP user will find the reading of this information, in a systematic start-to-finish fashion, beneficial, users of EFBP will most often find themselves using the table of contents and/or the index to move quickly to information that is immediately desired.

The contents of this Electronic Field Book Processing Handbook is organized as follows :

- ***Chapter One*** presents a discussion of EFBP is with specific regard to its use with the Florida Department of Transportation's Electronic Field Book (EFB) survey data collection software. The initial discussion of EFBP will make constant reference to and make example of information which is contained in a standard format in the .OBS file.

- ***Chapter Two*** discusses the basic principles of EFB including object names, EFB data records, taping, object geometry, object attributes, zones and survey chains.

- ***Chapter Three*** is a discussion of the basic concepts of least squares analysis with an emphasis being placed on the error estimation of one's measurements which includes a basic discussion of state plane coordinate systems and their impact on EFBP and other software systems.

- ***Chapter Four*** details the creation and format of the observation file which is the basis for processing raw field survey data.

- ***Chapter Five*** discusses the management of control coordinate information using a computer program referred to as CTL. This program has a wide variety of options for making control coordinate management as efficient a system as possible.

- ***Chapter Six*** discusses the processing options which are presented in menu for by EFBP. EFBP works in a non-interactive batch process once the desired options are accepted in the initial menu - i.e. you start it up and let it run to completion.

- ***Chapter Seven*** details the first of the reports generated by EFBP. This chapter covers the raw data abstracting report or the .GEN file.

- ***Chapter Eight*** details the second of the reports generated by EFBP. This chapter covers the .1D least squares report which deals with the vertical adjustment of the data.

- ***Chapter Nine*** details the third of the reports generated by EFBP. This chapter covers the .2D least squares input files, the .LSA and .2SD files, and the .2D report which deals with the horizontal adjustment of the data.

- ***Chapter Ten*** details the files which contain the final processed coordinate information. This chapter covers the .XYZ and .SOE files.

- ***Chapter Eleven*** details processing error messages including an extensive series of examples of how the EFBP reports are used in troubleshooting the survey data and recognizing what needs to be corrected.

- ***Chapter Twelve*** discusses the use of four utility programs which are included in the EFBP system and a description of executable EFBP program files, required system data files, and input/output files for EFBP.

- ***Chapter Thirteen*** contains a general processing strategy.

- ***Chapter Fourteen*** contains example output files from a typical EFBP processing session.

- ***Chapter Fifteen*** contains the EFB Processing Handbook Glossary.

Conventions

The following conventions are used within this handbook :

concept	important concepts will be highlighted for easy recognition
italics	words which appear in italics emphasize important details
[ENTER]	words enclosed in square brackets represent keyboard key strokes

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Chapter Two - The Electronic Field Book and Processing

The ***Electronic Field Book*** system has been designed to provide the field surveyor with a vehicle to accurately and efficiently gather data for design surveys, topographic surveys, boundary surveys and other similar types of projects. What must be remembered however, is that the Electronic Field Book *system was not designed to replace the surveyor - it was created to assist him*. A knowledgeable field surveyor is the most critical element in making the office system more efficient. Proper field surveying practices must still be followed as there is nothing that will effectively replace them.

The Electronic Field Book (EFB) was developed for field survey data collection by the Florida Department of Transportation. While EFB relies exclusively on the Electronic Field Book Processing (EFBP) system for coordinate production, EFBP accepts other field system's survey measurements if the data is translated to the ASCII raw data file format which is read by EFBP. This ASCII file is commonly referred to as the Observation or ***.OBS file***. The .OBS file and its format must be completely understood before any effort is made to process survey data using EFBP.

The Electronic Field Book system itself consists of series of command menus and data screens that allow the operator electronically describe the survey field collection process. With the correct interface serial cable, it is possible to automatically record data from a total station or an electronic level. The command menus also allow manual input of these numerical values at any time. To effectively use EFB, one must be aware of how EFBP and the computer aided drafting/mapping/design software use the data. As each element of field survey data is recorded by the Electronic Field Book system, it is “stamped” with the date and time of the recording. This provides a complete record which binds the field survey data together with a complete record of each field observation performed in a particular project.

EFB Data Files

Regardless of where the segment was created, whether it was created on an office computer or on a data collector “in the field”, the same files will be used to store the field survey data. Six (6) separate files are maintained by the Electronic Field Book system during field data collection and each will bear the project/segment name. The only difference in each file will be the extension. The extension is the key to indicating the function of and the type of information contained in each file.

The EFB files are described as follows, where “filename” represents the actual project/segment name :

filename.EFB This is the file which contains all of the field survey observations made during the data collection process. This file is an XML file, and should not be edited by the user except through the EFB interface.

filename.XML This is the file represents the survey data in a LandXML 1.2 schema format. Information about the LandXML schema can be optained at http://www.LandXML.org

Point Name Conflicts

As objects are located by the field survey crew, names are created and assigned to them by the Electronic Field Book system. As each name is used, the Electronic Field Book system adds it to a listing of every name previously used in the current survey data segment. This list is created and maintained by the Electronic Field Book system to help prevent a name from being used twice. Using names over again would create duplicate point names which would have the potential to create conflicts within the project survey. When a new object is located and assigned a name, the Electronic Field Book data processing system first checks the name list to insure that it is not creating a duplicate name.

In the event that the operator does wish to reuse a point name the Electronic Field Book system will display a message indicating that an existing point name is being used and the operator may reuse the name. Reusing a point name occurs when multiple observations are made to the same point.

It is incumbent of the operator to avoid name conflicts when dealing with multiple segments of work with EFB. A function in EFB exists to seed a subsequent segment of used point and chain names from a previous segment. This function will help the user continue work in subsequent data collection and help to avoid name conflicts.

Object Names

Object names act as the sole method of identifying the elements which are located using the Electronic Field Book system and these located objects can include both points and survey chains. The names used by the Electronic Field Book system are unique in that each name consists of two separate parts, namely a ***prefix*** and a ***suffix*** which when combined, defines the object's name. The prefix can be alphanumeric though common practice is to keep it all letters. The first and last characters of the prefix are not allowed to be numeric when using EFB. The suffix will consist of only numbers, and is assigned to the prefix by the Electronic Field Book system to create a unique point name that will be assigned to one and only one object. In the Electronic Field Book system, *the name prefix and suffix combined cannot exceed eight (8) typed characters*.

During the data collection process, it is up to the Electronic Field Book operator to select the desired name prefix and enter it into the Electronic Field Book. The system will then assign the next available suffix to the specified point name. If a seven (7) character prefix is entered by the operator, only one (1) available character remains to be used as the system assigned suffix. What this means is that if a seven (7) character prefix is used, only nine (9) of these objects may be so named. In this manner, the Electronic Field Book system controls which names are used and does not allow the same name to be assigned to two different objects. There are, however, several very important name limitations which must be considered during Electronic Field Book data collection.

To successfully utilize EFBP, the concept of station naming, or point naming, must be fully understood. The rule is quite simple: once a station or point has been named, that name must always be used during any subsequent measurement to it or instrument occupation of that point. This rule relates to both side shots and traverse, or, redundant stations. This rule is required because EFBP is trying to assign one unique set of coordinates to that point name. Multiple coordinate values for the same point name are not allowed.

Object Name Length

EFBP allows up to eight alphanumeric characters for a point name. Unlike the implemented EFB system, when working with EFBP, point names can be made up of totally numeric or totally alpha characters. There is no need for any numeric values in the point names. If numeric names or suffixes are used, there is no need for sequential order and gaps in the object numbering system are allowed. Thus station names like 1, 1012, COE, or DAC are permitted. A job can have point numbers 1 to 110, then a gap, and then continue from point number 320 to 378. EFBP also treats upper and lower case letters as different, meaning that to EFBP, a point with the name COE is completely different from a point named Coe. While EFBP will accept a point name which contains a space in it, the practice is not recommended.

The following are two examples of potential point naming problems :

(1) The same physical point gets assigned two different names. An example of this occurrence is a sideshot which is made to a rebar which represents evidence of a property corner. This particular property corner was measured, or located, from two separate traverse points. If from one setup it was called C1 and from the other setup it was called C2 after EFBP has processed the data, the user will be presented with slightly different coordinates for C1 and C2. If the property corner was named C1 from *both* setups, EFBP will use all of the recorded observed data in a least squares solution for the statistically "best fit" coordinates for the property corner. Many data collectors and office survey software systems force the user to give a new point name to the initial point when closing a loop traverse. This practice would create no identification of the closure to EFBP, thus when closing to the initial point, it is given its initial name.

(2) Two different physical points are assigned the same name during data collection. An example of this occurrence would be where the point name A23 was assigned to a traverse point on the northerly edge of a job, and by mistake, a station on the southerly edge of the job was also named as A23. In this scenario, the user has told EFBP that these two unique stations are the same point, and thus EFBP's processing reports will show some very poor closures.

EFBP does not use the point name by itself to figure out if the point is a traverse or sideshot station. As an example, two different trees were assigned the point name of TREE12. During processing, EFBP does not look at the name TREE12 and figure out that trees are usually never measured to twice. EFBP does use the name to recognize that TREE12 was observed twice and is thus classified as a redundant point. The user would ultimately look at the processing report files, see that TREE12 is listed in the least squares report, and realize one of those shots needs to be assigned a different point name or possibly deleted. Once the proper correction has been made, the data would have to be processed again. EFBP (and EFB) do not dictate to the user how to perform a survey as many data collection and processing systems do. However, EFBP and EFB do force the user to adopt and use the point naming logic of "one point name per one field survey point", as this is the key to EFBP recognizing how the survey was performed.

Object Name Suffix Sequence

In the Electronic Field Book system *the name prefix is entered by the operator while the numeric suffix is added by the Electronic Field Book system*. As the Electronic Field Book system adds the numeric suffixes to the name prefixes, it adds them in numerical order. The numeric suffix of one (1) is added to the first occurrence of a given name prefix, two (2) is added to the second occurrence and so forth. What this does is prohibit the operator from arbitrarily assigning numeric suffixes to name prefixes to create object names.

Object Name Characters

While the Electronic Field Book system will allow the operator to enter a prefix which begins with a number, one must remember the purpose of the Electronic Field Book system. Field data is being collected and assigned object names using the Electronic Field Book system. This field data will then require additional processing to develop coordinates. These object names and coordinates will in turn be entered into some type of computerized coordinate geometry system. It might be quite possible that the coordinate geometry system will not recognize object names which begin with a number, thus rendering the collected field data useless.

A common practice employed while using the Electronic Field Book system is to begin each point name with the segment designation or a field crew designator. In the latter case, each field crew is assigned a letter which is used to separate their named objects from all of the other crews information. This practice virtually guarantees that there will be not object name conflicts but it does add one (1) additional character to each name. This practice also facilitates utilizing multiple crews on the same project.

Reference Names

Field survey data which is collected with the Electronic Field Book system must be processed on a computer in order to generate point coordinates. In order to properly process this survey data, some sort of control information must be included in the data collection. This information would include Florida Department of Transportation control monuments, local control monuments, or bench marks. In many instances, it is necessary to include the OFFICIAL designation of the control monument, i.e. it’s name. This is especially true when using the results of previous collected survey data and it’s associated monumentation. An example of this would be relying upon control information which was gathered in a previous segment.

Control monuments established by the United States Coast and Geodetic Survey, National Geodetic Survey, U.S. Army Corps of Engineers, Departments of Transportation, or other organizations are often designated with a name, which is stamped on the monument itself. The Electronic Field Book system has the capability to use these designations during the data collection process, but they are used as “reference” to the point name.

EFB has a unique method of control station naming that EFBP's control station manager computer program CTL can take advantage of. It is important to note that one does not have to use a reference name at all, if desired. A ***reference name*** is a second name which can be assigned to a point which designates that the point is an existing control station, or that the coordinates generated for it may be used as control in a later part of the survey. A reference name can be up to sixteen (16) alphanumeric characters, and is not prefix/suffix in nature like EFB station names.

An example of the use of a reference name would be assigning its organizational name designation as a reference name. Organizations could be the National Geodetic Survey, Department of Transportation, Army Corps of Engineers, other government agencies, private control surveys, etc. The reason for assigning reference names can go beyond simply documenting the official name of the point. The use of reference names allows multiple crews, all working on the same project, to assign different field names (prefix/suffix combinations as discussed previously), to control points. The control program may then assign control coordinates to those points via the reference name. Examples of the use of reference names are presented in Chapter 5.

Another and perhaps more important use of a ***reference name*** is to indicate to the data processor, both the individual analyzing the data and the program used to process, which observed points possibly contain control information. In the Electronic Field Book system, control points represent points whose geographic position or coordinates are already known and available. Reference names are use to identify control points.

If reference names are not used, the field survey names are used in linking coordinates in the control file (.CTL file) to the measurements contained in the observation file (.OBS file). Thus, a user can use EFBP without ever considering the use of reference names.

Reference Names and Processing

When the collected field survey data is brought back into the office, the Electronic Field Book data processing programs will read through the incoming data, looking for control points. The most common method of indicating control points is by the use of a reference name. If a point is used by the Electronic Field Book system operator as a control point it should also have a reference name assigned to it. The data processing routines will treat point names and reference names as two (2) separate and distinct entities. The reference name is used for communicating the stamped, or "official", designation of a control point, bench mark or other similar object to others who may subsequently use the same control point. The reference name is the way to associate common points between all other data sources and past or future surveys.

Any control points which were established during the field data collection process should also have been given a reference name. This is done since the control point may be used again at some later date, and the Electronic Field Book operator will need to be able to "reference" back to work previously performed. This is the process by which the Electronic Field Book operator may use control points established in previous segments or update the control database, once the processing of the data is completed.

EFB Records

Field survey data which is collected using the Electronic Field Book system is stored in the .EFB file as a series of records. The EFB file may be exported to other formats, including a LandXML 1.2 schema file, and a classical EFB Observation file (.OBS extension) and an a EFB Control file (.CTL extension). THE OBS and CTL contents and formatting will be discussed, since those files represent the input to the EFB Processing software, EFBP.

Header Record

The ***Header record*** in an EFB collected .OBS file contains the units of measure (feet or meters), the segment name, and optional remarks about the project. Note that EFBP reads the units of measure from the control .CTL file. The units or measure in the header are used in the field by EFB to identify the units for storing distances which are electronically derived from the total station, target and setup heights, and eccentricities. The header is at the top of the .OBS file, and only one header exists per .OBS file. EFBP will process in absence of a header record.

Calibration Record

The ***Calibration record*** is also not required for successful use of EFBP however, EFB does force storage, or recording, of a calibration record. Most of the calibration record is information which is not used by EFBP such as temperature, atmospheric pressure, weather code, observer's initials, notekeeper's initials, rodperson's initials, instrument brand and model, instrument serial number, EDM absolute error, EDM ppm error, stadia constant, level test indicator, axis test indicator, and comments indicator.

Many users of EFBP have thought it corrects distances for temperature and pressure. This is not true! The operator should be dialing those corrections into the instrument, and EFB will then be storing values that are corrected for temperature and pressure systematic errors. Different instrument manufacturers use different error models for the correction, and thus it is better that the correction is performed at the time of data collection, by the instrument.

Some users have also mistakenly thought EFBP uses the EDM constant and ppm errors in the calibration for error estimation in the least squares analysis. Again this is not true as that information is defined in the initial options menu of EFBP.

Calibrations allows the user to perform a peg test on the level, or a horizontal and vertical axis test on a total station. The peg test is not numerically used by EFBP as the user is supposed to adjust the level's cross hair based on the test results. The total station axis test contains a user defined number of direct and reverse pointings on the same well defined point which allows EFBP to determine operator pointing error and systematic errors in the vertical and horizontal circles. The systematic errors are corrected for in all subsequent measurements in the .OBS file under the influence of a particular calibration. EFBP can operate with no calibration. If multiple calibrations exist in an .OBS file, the calibration derived systematic error corrections are applied to all subsequent measurements until the next calibration is reached. The new values are used until the next calibration is reached, and so forth. If multiple unique calibrations are stored in immediate succession, the last one is used in correction of the subsequent measurement information.

Setup Record

The instrument ***Setup record*** is used by EFBP to obtain the occupied station name and height of instrument. The height of the instrument is irrelevant if 2-D survey observations are made or if differential leveling is being performed.

Other attribute type information that can be entered about the setup is the geometry of the occupied point (point/straight or curve), attribute, zone, comments, feature code, and reference name. This information is not used in numerical processing (EFBP) but becomes *critical* when the data enters a subsequent graphics system. Reference names are used in managing control coordinates L program and are not used directly by EFBP.

Observation Record

The ***HVD Observation record*** contains information related to each field observation. Each of these field observations are made up of a variety of types of measurement. Typically each measurement will consist of a horizontal circle reading or direction, a vertical direction and a distance. The Electronic Field Book system does not really measure angles but rather “plate” readings from the electronic encoder disk contained in the total station. It is during the data processing stage that these “plate” readings are reduced to create the actual angles between points.

Several varied combinations of horizontal direction measurement, vertical direction measurement, distance measurement, as well as location by station and offset, are supported by the Electronic Field Book system. The operator has complete control over the ***Mode*** used to make the observation.

Angle & Distance Location Modes

In the angle and distance mode of operation, the letter **‘H’** represents a measurement in the horizontal direction to a point from an instrument set-up, the letter **‘V’** represents a measurement in the vertical, or zenith, direction from an instrument set-up, and the letter **‘D’** represents a distance measurement from the instrument set-up to the object. The Electronic Field Book system supports a variety of combinations of these measurements.

The following are the supported angle & distance observation modes :

HVD	***VD***
HD	***H***
HV	***D***

Making an observation in each survey mode records a specific combination of elements which will be used during the data processing steps to generate coordinates for the observed points.

HVD when in this mode, the HVD mode, the Electronic Field Book system instructs the total station to measure the horizontal circle reading, the vertical circle reading and the slope distance to the target. The horizontal circle reading, the vertical circle reading and the slope distance to the target will then be displayed by the total station and electronically transmitted to the Electronic Field Book system for recording.

HD when in this mode, the HD mode, the Electronic Field Book system instructs the total station to measure the horizontal circle reading, the vertical circle reading and the slope distance to the target. However, the total station will use the vertical circle reading to reduce the slope distance to a horizontal distance. The horizontal circle reading and horizontal distance to the target will then be displayed by the total station and electronically transmitted to the Electronic Field Book system for recording.

HV when in this mode, the HV mode, the Electronic Field Book system instructs the total station to measure the horizontal circle reading and the vertical circle reading. The horizontal circle reading and the vertical circle reading will then be displayed by the total station and electronically transmitted to the Electronic Field Book system for recording.

H when in this mode, the H mode, the Electronic Field Book system instructs the total station to measure only the horizontal circle reading. The horizontal circle reading will then be displayed by the total station electronically transmitted to the Electronic Field Book system for recording.

VD when in this mode, the VD mode, the Electronic Field Book system instructs the total station to measure the vertical circle reading and the slope distance to the target. The vertical circle reading and the slope distance to the target will then be displayed by the total station and electronically transmitted to the Electronic Field Book system for recording.

D when in this mode, the D mode, the Electronic Field Book system instructs the total station to measure the vertical circle reading and the slope distance to the target. However, the total station will use the vertical circle reading to reduce the slope distance to a horizontal distance. The horizontal distance to the target will then be displayed by the total station and electronically transmitted to the Electronic Field Book system for recording.

Target Height

The ***Height Of Target*** is measured vertically from ground point to the prism. Note, this is unimportant for a 2-D survey, but measuring target and instrument heights for all setups is a recommended procedure.

Telescope Orientation

The ***Telescope Orientation*** is recorded with each observation and is labeled as D (direct) or R (reverse). A direct orientation assumes zenith circle readings between 0 and 180 degrees, while a reverse orientation assumes zenith circle readings between 180 and 360 degrees. This is critical when EFBP reduces horizontal circle readings to horizontal angles, and in applying calibration corrections. Observations recorded in H mode requires a D or R on a shot (the only time this needs to be hand entered as EFB recognizes it from the zenith circle) as EFBP needs to know what orientation the instrument was in for correct processing. If a zenith angle is being recorded EFB will store the correct D (or R) in the .OBS file.

Multiple Pointings

During the course of the field survey the Electronic Field Book system operator may be required to measure several “sets” of angles to a control point. A set is defined as one (1) recorded observation with the telescope in direct mode and one (1) recorded observation with the telescope in reverse mode. When using the Electronic Field Book system this is referred to as turning multiple pointings. Measuring each “set” of angles would require advancing the position set value after each “set” of has been completed. The practice of turning multiple positions of the horizontal reading circle and making multiple observations of a point requires that the point’s name be re-used each time the same point is observed from any one given instrument setup location.

The position set number indicates the number of times that the horizontal reading circle has been physically moved or advanced. Since the advancement of the circle is a mechanical operation which is found only in repeating and some directional theodolites, the position set number will increase by one (1) unit increment steps, beginning with position number 1. Once the position set has been advanced during any one (1) instrument setup, it is physically impossible to exactly get the circle back to a previous setting, and therefore, precludes de-incrementing the position set number.

Repetition

During field data collection, it is possible to observe that same point multiple times from the same instrument location using the same position set number. An example of this practice would be the re-observing of a backsight during radial location. If the same point is observed numerous times from the same setup, the processing routines will compute an average observation based upon all of the individual observations.

Eccentricity

In some cases when attempting to locate an object during the field data survey, it is impossible for the rodman to physically occupy, or, place the target at the center of the object that is being located. An example of this would be a tree, as the center of the trunk is normally used to indicate the tree's position, but, the target *can not* be physically placed at the center of the tree trunk. For this reason the Electronic Field Book system allows the operator to employ ***eccentricity*** when locating an object.

To understand how *eccentricity* works think of a right triangle laying on the ground (see Figure 2-1). The hypotenuse of the right triangle extends from the instrument's location to the object which is being located and this line defines what the Electronic Field Book system refers to as the "line of sight".

The measured field angle, or direction, which is used to locate the object is not made along the line of sight, but rather along the "adjacent" side of the right triangle. The target will actually be placed by the rodman along the adjacent side or along this "sighted line" and should be placed with the aid of a right angle prism or a "90 glass".

The remaining opposite side of the right triangle represents the *eccentric distance*. This opposite side of the right triangle is perpendicular to, or at right angles, to the adjacent side of the right triangle.

A reasonable maximum eccentric distance has been suggested by the Florida Department of Transportation as "the greatest distance the rodman could measure with ordinary equipment while maintaining orthometric orientation to the object and instrument" and should not exceed thirty (30) feet or nine (9) meters.

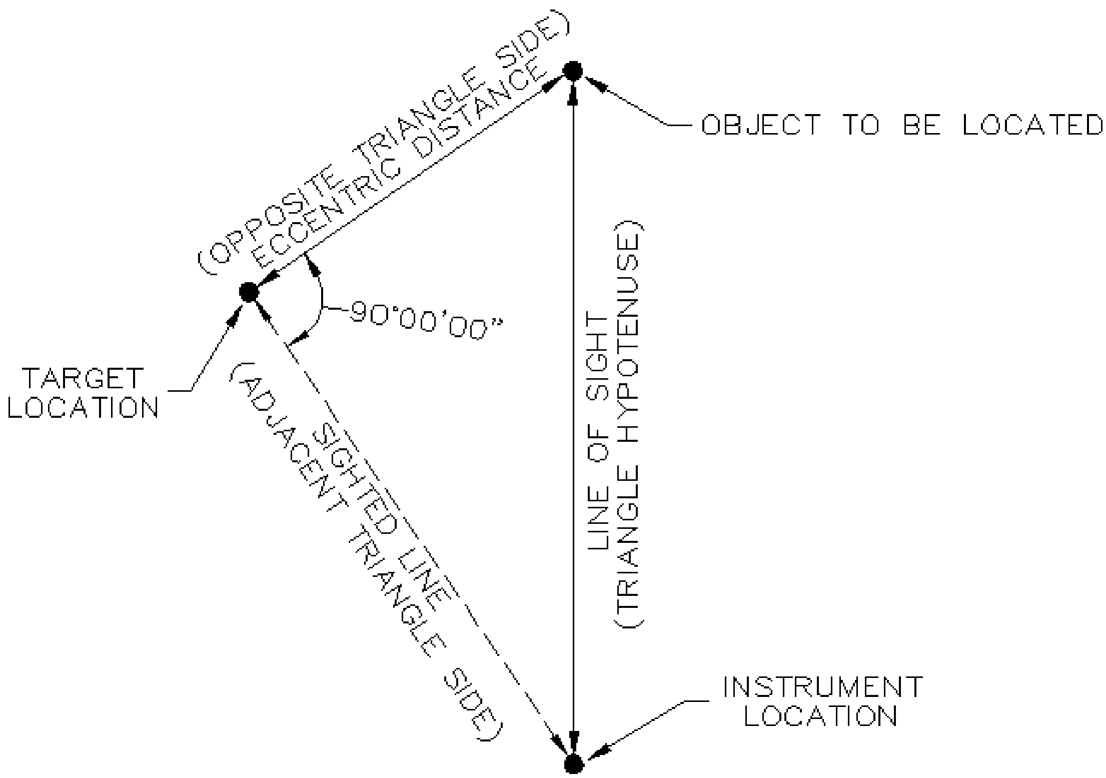

Figure 2-1 = Eccentricity Right Triangle

Eccentricity may be used for any HVD or HD mode observations but consideration needs to be given to which objects are located in this manner. Obviously, eccentricity is ideal for location trees, utility poles or some building corners but should ***not*** be used for location property corners, bench marks or other similar important objects.

Eccentricity is the measured distance from the target to the object and the *eccentricity direction* is designated by the Electronic Field Book system as either *Left, Right, Front* or *Back*. The line of sight which is projected between the instrument and the object to be located defines the *primary* *axis* and a *secondary axis* passes through the object to be located with the secondary axis being perpendicular to the primary axis.

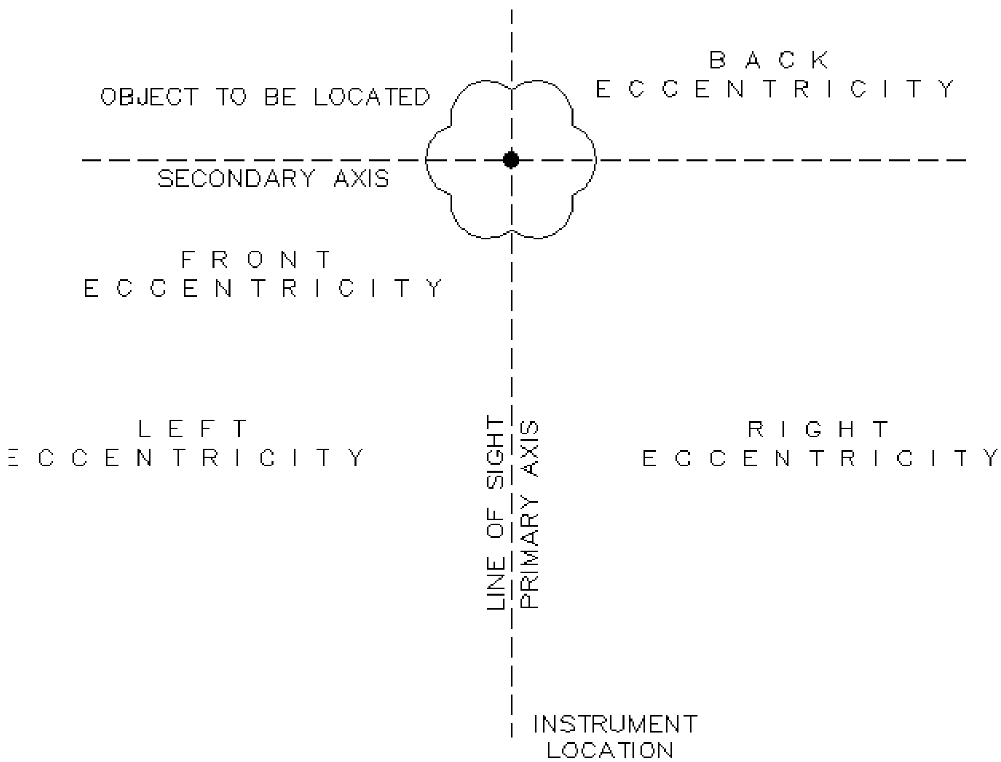

Figure 2-2 = Eccentricity Directions

Level Modes

Location of field survey data by way of station and offset location is possible with the Electronic Field Book system, however, all of the required information must be hand-entered into the Electronic Field Book system (unless using the Wild electronic level).

The ***SOR Observation record*** contains this type of information. In the level mode of operation, the letter **'S'** represents a particular station value on a baseline, the letter **'O'** represents an offset distance from the baseline and the letter **'R'** represents the route or baseline name. The Electronic Field Book system supports single wire as well as three (3) wire rod readings.

The Electronic Field Book system supports the following survey observation modes :

SOR
SO
R

Making an observation in each level mode records a specific combination of elements which will be used during the data processing steps to generate coordinates for the observed points.

SOR when in this mode, the SOR mode, the Electronic Field Book system is expecting the operator to enter a station value, an offset distance and a route or baseline name.

SO when in this mode, the SO mode, the Electronic Field Book system is expecting the operator to enter a station value and an offset distance.

R when in this mode, the S mode, the Electronic Field Book system is expecting the operator to enter rod readings.

EFBP does not convert the station-offset information to horizontal coordinates because in many situations the entire geometry chain/baseline does not yet have required information such as curve parameters. The subsequent graphics/design software is assumed to be able to process the station-offset information into coordinate form. The station-offset data is transferred by EFBP to a station-offset-elevation (.SOE) file that is readable by graphics/design software.

Object Geometry

The geometry of a point equates to the point's potential linear relationship to other points when included in a survey chain. For Electronic Field Book surveying every point located *must* have a ***geometry*** type associated with it and the Electronic Field Book system supports the following geometry forms :

Point (*P*) Geometry which defines a single location for an object, having only one (1) set of coordinates, or, it's relationship to other points when included in a chain list as being on a tangent line, or at the PI or two (2) tangent lines. Point (P) geometry is the default setting for any point collected by the Electronic Field Book system.

Curve (*C*) Geometry which defines a point as being on a *circular* arc or on a *smooth* curve (spline) passing through a series of non-linear points, when included in a chain list.

Therefore, identifying the geometry of the points which located in the field is minimized to either 'P', for point or 'C', for curve.

Point Geometry

In the Electronic Field Book system a point geometry, indicated by the letter ***‘P’***, indicates that the point currently being located will at no time be used as a point on, or, a point which defines a curve.

Curve Geometry

In the Electronic Field Book system a curve geometry, represented by the letter ***‘C’***, indicates that the point currently being located *is* part of a curve and the ‘C’ geometry would be used to indicate any point lying on a curve. More importantly, curve geometry is used to indicate points which define points critical to creating and computing a curve such as the PC's, POC's, PT's, etc. Correct use of curve geometry allows the operator to create chains which include curves.

Feature Codes

The ultimate goal of data collection is to use the recorded survey data to produce an accurate map. Upon this map will be various graphically depicted objects such as trees, water and gas valves, meters, edges of pavement, fences and underground utility lines and these objects usually have specific symbols and line type and color symbology associated with them. ***Feature codes*** have no effect on the processing results. They are instead, the mechanism which tell the CAD program what line pattern to use, what symbol to use to represent an object, what color to display it in, and which layer or level to place it on.

EFB allows up to eight (8) alphanumeric characters. This is usually linked to some symbology library when viewing data. Note, this is a point feature code, which is different from a chain feature code. Many points that are parts of chains (edge of pavement) require no point symbology and thus receive no point feature code, but are part of a chain which has a chain feature code and thus links to line type symbology.

Comments may be included with feature codes. These comments are any extended textual information about the point which was measured which is beyond the definition of the feature code. If TREE was being used as a feature code, the comment may include tree type, diameter, crown diameter, etc.

Attributes

Field survey data is collected and processed to create a surface called a ***Triangular Irregular Network*** **(TIN)**, which is a series of triangles which are created from the computed coordinates of the observed data. A TIN model could be created exclusively from cross section observations, without the benefit of additional random ground observations or without including the three dimensional chains which would represent the break lines. The TIN model which would result from this type of data would be weaker because there would be no data *along* breaks in the terrain, and the computer program will interpolate between the point on the cross section lines, which may be several hundred feet apart.

Random points may represent the locations of planimetric objects in a TIN. If a tree is located by the field survey crew and the rodman held the base of the target pole at the ground adjacent to the tree, the elevation computed from that observation may be used in a TIN. Every observation made in the field has the ***potential*** to create a point which may be used in the TIN.

Since every point located during the field data collection process has the potential to be included in the TIN model some method must be employed to give the Electronic Field Book operator control over what objects should be included in the TIN and what objects should not be included. This is accomplished using point ***attributes***.

The Florida Department of Transportation defines an attribute as:

> **"a sub-classification of a point to inform the processing programs what relationship that point's elevation ordinate has to a surface."**

In other words, the ***attribute*** of a point is used by the Electronic Field Book system operator to indicate how the elevation computed for that point will be related to a particular surface.

The Electronic Field Book system currently uses four attributes:

Ground Attribute
Feature Attribute
User Attribute

Point attributes and chain attributes perform the same function, which is to indicate if an object (either a point or a chain) is to be used in a DTM.

These various attributes are defined as follows:

Ground A ***Ground attribute*** is indicated by the letter 'G' and is used to designate a point whose computed elevation is to be used in a TIN model. Examples of 'G' attribute points would be random ground points, top of bank points, edge of pavement points and toe of slope points. These 'G' attribute points are often connected together in a chain to describe a terrain break line, the three dimensional (3D) geometry of an object along the surface.

A chain with a 'G' attribute would be the connected top of bank or edge of pavement points. These 'G' attribute chains would be used to compute a TIN model. The 'G' attribute is the default attribute however, once a different attribute is selected, the new attribute will act as the default attribute until it is changed again or the operator exits from the Electronic Field Book system.

Feature A ***Feature attribute*** is indicated by the letter 'F' and is used to designate a point whose computed elevation is ***not*** to be used in a TIN model. Examples of 'F' attribute points would be tree locations, power poles, man hole covers or water valves. These 'F' attribute points are often connected together in a chain to describe a terrain break line or the three dimensional geometry of an object along the surface.

A chain with a 'F' attribute would a connected series of power pole points which would represent the overhead power lines. These 'F' attribute chains would not be used to compute a TIN model. It is possible however, to combine the attributes of points and chains as 'G' points may be used in a 'F' attribute chain and vice versa. For example, two (2) 'G' points could represent pipe inverts and they could be used to create a 'F' attribute chain that represent the pipe itself. The two (2) points would be valid TIN points but the chain would not be a valid TIN chain.

User A ***User attribute*** is indicated by the letter 'U' and is used to designate a point whose computed elevation may or may not be used in a TIN model. Examples of 'U' attribute points would be points which have a special meaning to the operator such as utility information or property boundary data. Depending upon how the 'U' attribute is applied by the operator during the field data collection process, the related points may or may not need to be included in the TIN model.

Attributes do not have any effect on the coordinates which are computed during processing, but it is important that the individual processing the data understands the role which attributes play. It is easy to correct an incorrect attribute during processing if one is detected.

Zones

Zones are a method of segregating the field survey data in order to facilitate an extended query and/or utilization purposes. An example might be to compute several different terrain models. To illustrate, all existing features may be surveyed and placed into Zone 1 and an as-built survey may be performed in the same area and the data placed into Zone 2. This would allow separate terrain models to be created make a “before construction” and “after construction” comparison.

The Electronic Field Book system supports nine (9) separate zone numbers which are numbered one (1) through nine (9) and if no zone number is entered during data collection, the Electronic Field Book system will enter zone number one (1) as a default. Zones also have no effect on the data processing results.

Descriptions & Comments

Comments and descriptions may also be added to points during the field survey data collection process. These comments and descriptions may be added to better describe the objects which are being located and will be recorded as a ***remark*****.** The previously mentioned axis test results are recorded as remarks.

Survey Chains

A ***Survey Chain*** is a named series of points that have been previously located and the geometry for each point defined. A chain may also be described as the *“ordered connection of points that define the boundary of an object”.* The point names which define a chain must be connected in the proper order to produce the correct image. Proper use of a point’s geometry will also allow the chains to properly create circular arcs, smooth curves, and straight lines.

Chains are simply line work. Note the point information indicates whether the points are on a straight or curved portion of a chain. Chains have no numerical processing needs, but are provided here as defined in EFB. A chain can include:

Chain name - Chain names work under the same prefix/suffix logic as point names. Names are required for each chain.

Attribute - The same ground G, feature F, or user defined U options as existed in point attributes exist here. A G attribute indicates to most graphics/design systems that the chain is a break line in a DTM.

Zone - This has the same meaning as in point information. It is a way to segregate data such as surface models.

Feature code - This has the same meaning as in point feature codes except that they relate to lines.

Comments - This is for more extensive describing of a chain beyond a feature code.

Station - Stationing can be associated with the chain mainly for definition of a baseline.

Point List - This is a sequential list of the point names in the chain. A comma exists between point names. If two commas exist in sequence, this is a location where no line is to be drawn ("pen up"). FDOT allows for "macro" defining of chains such that:

A1-5 is the same as A1, A2, A3, A4, A5.
B12-10,Q12,A6-8,,9-10 is the same as B12, B11, B10, Q12, A6, A7, A8,, A9, A10.

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Chapter Three - Understanding Least Squares

The use of adjustment of survey measurements is obviously something the surveying community wishes could be avoided. Unfortunately we, and the instrumentation we use, are not perfect in our measuring ability, and adjustment is the term that has been associated with the procedures we use in accounting for our inconsistencies. If an adjustment changes a measurement within an acceptable random error limit we should not be concerned. The statistical difference between the adjusted and the measured quantity in this situation is negligible. A four second (4”) adjustment of a horizontal angle measured twice with a six second (6”) least count theodolite is obviously within the expected error range of the angle. A thirty second (30”) adjustment of that angle could be termed intolerable, and a surveyor may not accept the adjustment. The cause of the intolerable adjustment (data entry error, field blunder, etc.) needs to be determined and the measurement corrected. The readjustment based upon the correction then needs to be evaluated for acceptability. One role of this chapter is to explain why adjustment can be a valid procedure, and how to judge when it is not valid.

Most members of the surveying community are familiar with the compass rule as an effective adjustment procedure for a loop traverse adjustment. Unfortunately, this approach is limited in versatility when a traverse network (series of interconnected traverses) is encountered. A least squares approach to adjustment of survey data analyzes any survey network configuration in the same fashion. Least squares analysis is not limited to surveying. It is an accepted procedure in mathematics, statistics, computer science, and a variety of engineering disciplines. In most other disciplines least squares is considered a "data analysis" technique as opposed to an adjustment process. This chapter will illustrate that it is really an analysis technique in surveying, too. Adjustment actually exists in any redundant survey network - misclosures are restricted to a limited number of closing measurements in an "unadjusted" situation. While this unadjusted approach may be a valid procedure in some cases, one would normally desire a more uniform adjustment procedure since we know that this is how random errors occur in our measurements. No matter what technique is used, if redundancy exists, it will be shown that adjustment exists.

The final point to be addressed in this chapter is the accepted lack of understanding of least squares analysis in a large component of the surveying population. This is partially due to the lack of understandable reading material on the subject, and the requirement of a computer for it to be implemented in a production environment. The personal computer revolution is a recent phenomena which has allowed the surveyor access to least squares for survey network analysis, although efficient PC based software is no longer a difficult commodity to locate.

One does not require an in-depth understanding of linear algebra, calculus, statistics, or computer science to become a knowledgeable user of least squares analysis. A computer, dedicated software, and a few hours of hands-on instruction and use, is all that is required. This chapter does not replace hands-on instruction and use, but can serve as a primer for those who are unfamiliar with this “adjustment” technique. This chapter is directed to the user, and not to one who wishes to understand the mathematics which is being utilized in least squares operations.

Is There Really Such a Thing as "Unadjusted" Data?

The answer to this question is obviously "yes", but it pertains only to non-redundant data or the raw measurements themselves. Once redundant information such as a loop traverse is created there is always some form of adjusted information, even if an adjustment procedure such as the compass rule is not applied. A three-sided loop traverse provides a very simple example of this phenomena. Assume all interior angles have been measured along with the three distances, station 1 has fixed coordinates, and the direction from 1 to 2 is known.

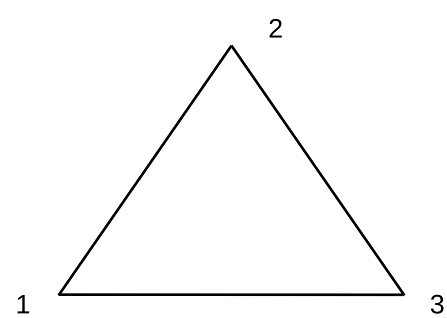

Figure 3-1 = Three Sided Traverse

The assumption of coordinates at 1 and the fixed direction "fixes" the network's position and orientation in a 2-D coordinate system. Let us first consider only angles. It is known that the sum of the interior angles of an n-sided polygon must equal (n-2) x 180 degrees, but, due to random error, it is unlikely that the angles in the example will sum to that. If you treat two of your angles as "unadjusted", by the defined angular geometry [(n-2) x 180] the third angle is automatically adjusted by -1 * the angular closure. If one of the angles was left unmeasured, there would be no redundancy in angles and thus no logical way to adjust angles.

If one assumes a "raw" closure (no angle adjustment prior to linear closure computation) is desired, in an n-sided polygon there are always n possible linear closures that can be computed. In the three sided example a linear error of closure can be computed beginning and ending at station 1 without using the angle at station 1. The same procedure can begin at station 2 and station 3, in each case not using the angles at 2 and 3 respectively. In each case a different linear closure will be realized because the same measurements are not used in all three cases. There are thus three unique compass rule adjustments possible if angles are not adjusted prior to closure computation.

Even if this confusing issue is ignored, a loop traverse with a non-zero linear closure has to have adjustment due to the geometric constraint of sum of latitudes and departures each totaling zero. Simply computing coordinates of 2 and 3 clockwise from station 1 will ignore use of the angles at 1 and 3 and the distance from 2 to 3. This omission actually places all adjustment in these three measurements. As stated before, one should observe if the amounts of angular and distance adjustment are within reasonable random error limits. If this is true, the amounts of adjustment are within the limits of one's measuring abilities. If the amount of adjustment to various measurements is not within acceptable limits the adjustment process is indeed invalid. The source of the unreliable measurements should be determined and corrected. This demonstrates that if redundancy exists adjustment has to exist. If redundancy exists, geometric constraints prevents all measurements from remaining unadjusted.

When does a Compass Rule Approach to Traverse Adjustment become Difficult?

A compass rule adjustment of a loop traverse with reasonable angular and distance closures is a very valid procedure, and will often produce final coordinates which are very close to those produced by a least squares adjustment. Unfortunately a loop traverse is not a highly redundant situation. A loop traverse is also fairly weak geometrically, and can have undetected larger compensating errors in it.

The sum of the interior angles, sum of latitudes, and sum of departures are the only geometric constraints in a loop traverse. It can also be shown by a mathematical technique called error propagation that a traverse's geometry is strongest in the direction it "runs". A section of traverse running north-south will therefore have weaker easting and stronger northing coordinates. Consider the north-south traverse as a guitar string. It bends easier east-west than it can be stretched north-south. Now let us assume another traverse section is surveyed in an east-west direction and it intersects the north-south section. If coordinates have already been computed on the north-south line (and possibly adjusted) the east-west section will be tying into coordinates weak in easting. If you compute coordinates on the east-west section first the north-south section will be intersecting weak northing coordinates. Least squares provides the solution to this problem.

Before we discuss why a least squares approach resolves this problem, let us consider another problem involved in compass rule type adjustment of a complicated traverse network. This problem involves priority of the lines in the adjustment process. Let us assume the following traverse network, with each side of the polygons representing series of angle and distance measurements.

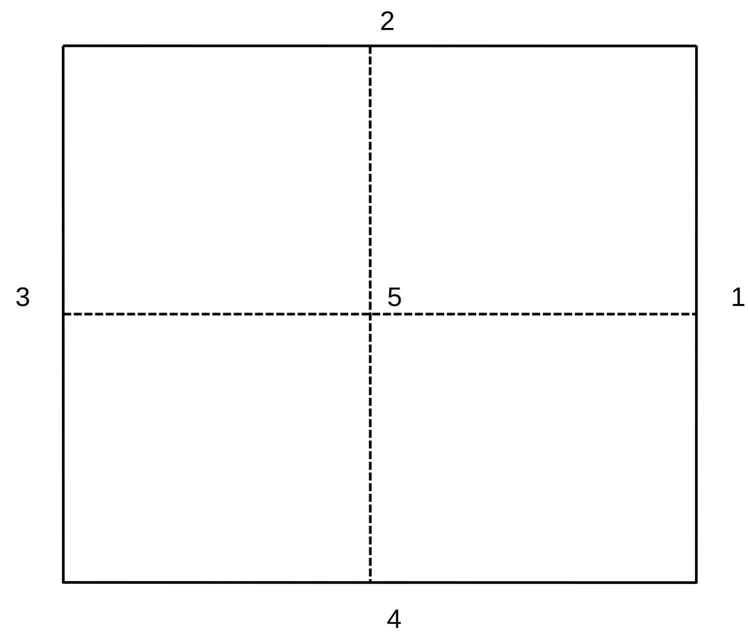

Figure 3-2 = Traverse Network

Which of the following priorities of adjustment should be used :

Case A: (1) outside loop 4-1-2-3
(2) 2-5-4
(3) 3-5
(4) 1-5

Case B: (1) outside loop 4-1-2-3
(2) 3-5-1
(3) 4-5
(4) 2-5

Case C: (1) 3-4-5-3
(2) 4-1-2-3
(3) 2-5
(4) 1-5

Case D: (1) 1-5-4-1
(2) 5-3-4
(3) 5-2-3
(4) 2-1

etc., etc., etc.

There is an incredibly large number of adjustment priority combinations, with little or no ability to judge which priority is "best". Consider how many possibilities exist in a USPLS township where all township (exterior) and section lines have been traversed. A common "rule of thumb" procedure in compass rule approaches to traverse networks is to adjust the exterior of the network as one loop first, then decide on a priority approach of adjusting interior traverses to "fit" the adjusted exterior. This concept is often termed a rigid boundary approach. This technique is the worst possible approach that could be used from an elementary error propagation standpoint. The exterior will generally contain more stations than any other loop in the network, and thus you would expect generally worse closures in it than any smaller loops. You would thus be adjusting the component with the largest expected error, and forcing smaller traverse sections (less propagated error) to fit it.

There is no statistically correct procedure that defines sequential compass rule adjustments of a traverse network. As opposed to a sequential procedure, least squares allows simultaneous adjustment of any traverse network geometry (including any number of control stations). This will initially seem impossible since many surveyors are not familiar with how least squares works, and thus a basic discussion of concepts is now required.

What does one need to know to feel Comfortable about Using Least Squares Analysis?

Whenever we measure something more than once and average the repetitions a least squares solution is being performed. An average minimizes the sum of the squares of the residuals. This is the underlying principle of least squares. A residual is the difference between the measurement and its adjusted quantity (an adjusted quantity being a simple average in this case). The residuals have to be squared because they tend to be both positive and negative, and thus a simple summation produces zero if a simple average is being computed.

Now that one realizes he or she has been using least squares all along in averaging, we now need to define how it applies to survey networks, and where the concept of weighting (or error estimation) of survey measurements becomes important. Horizontal survey networks consist of measured azimuths, angles, and distances in addition to control coordinates. Least squares adjusts all measurement types simultaneously in addition to adjusting all traverse legs simultaneously. This means relating angular quantities (azimuths and angles) to those of linear dimensions (distances and coordinates). To allow this, the least squares condition is expanded to minimizing the sum of the squares of the weighted residuals. A weight is equal to one divided by the measurement's error estimate. Adding the weight into the least squares condition makes all terms in the summation unitless. As an example, a distance, its error estimate, and its residual, all have units in feet. Weight x residual in unit terms is (1/feet) x (feet) where the feet cancel one another out, so the determined quantity is therefore unitless. The unitless quantity can be directly compared to unitless quantities derived from angles and azimuths.

Notice that the least squares condition has no dependency on number of traverse legs, number of traverse connections, number of measured azimuths, number of control points, etc. At this time it is also illustrated that the least squares principle can be applied to any measurement system in any science (not just surveying). It can also be applied to differential leveling, 3-D traversing, GPS vectors, or any combination of survey measurements. One estimates errors in various measurements using knowledge and experience. While repetition of a measurement such as an angle gives a clue to its reliability, the error estimate derived from repeated measurements does not usually take into account instrument and target setup errors, some atmospheric errors, etc.

In other words, the standard error computed from a series of repetitions often tends to be smaller than what a surveyor should estimate since it does not account for other possible error sources. An obvious example is repeated EDM measurements from the same instrument / target setup. Often these values will not differ by more than 0.01 ft. but the combined error in instrument and reflector setups over their respective points can easily be larger than this value. Angle and azimuth error estimates are a function of least count of an instrument, number of repetitions, and stability of instrument setup among other factors. An interesting option of least squares is that control coordinates can be assigned error estimates and allowed to adjust. If control coordinates are not to adjust, they should be given a very small error estimate (such as 0.001 ft.). The control coordinate can therefore be treated as a measurement in the least squares solution.

Least squares has procedures which allow one to verify if one's error estimates are reasonable. The first simple check is a look at all of the measurement residuals (amount of adjustment applied to each measurement) and see if any are much larger in magnitude (absolute value) than the error estimate. If all but a few are acceptable, the unacceptable ones are obviously possible blunders. If a majority are much smaller than your error estimates you have been pessimistic about the quality of your work, or there is very little redundancy in your work. To scan thousands of residuals would be extremely tedious so two "global" error computations can be made. The first is known as a ***root-mean-square (RMS) error***. For a particular measurement type, RMS error is the square root of the sum of the squared residuals, divided by the number of that type of measurement. It could be thought of as an average residual for that particular type of measurement.

The RMS error should be near in magnitude to your average error estimate for a particular type of measurement

A value which is an *indicator* of your error estimating abilities for all types of measurements (the entire survey network) is the standard error of unit weight. To compute this quantity the sum of the squares of the weighted residuals is divided by the number of redundant measurements (termed number of degrees of freedom), and the square root of that computed quantity is taken. Since a residual and its respective error estimate should be near equal in magnitude, a weighted residual tends to be near one in amount.

Of course, random error says some will be larger than one and some smaller than one. If this is true the standard error of unit weight will tend to be near one. A value larger than 2.5 indicates error estimates were optimistic or blunders exist. A value less than 0.7 indicates pessimistic error estimates or simply a lack of redundancy, therefore no adjustment of measurements is possible.

A test can be applied to the standard error of unit weight to statistically validate the quality of your error estimates. A "rule-of-thumb" approach of 0.7 to 2.5 works well, too. A failure of this test could indicate an invalid adjustment due to poor error estimates or blunders. If no blunders can be found, it is generally appropriate to change some or all of your error estimates. Notice that you can use your error estimates to "classify" different qualities of surveys within a network, and adjust all of the network simultaneously.

Least squares still preserves the geometric constraints of sum of interior angles being (n-2) x 180 degrees and sum of latitudes and departures of a loop being zero. Adjusted angles will close perfectly between adjusted azimuth measurements. If the data is azimuths (or bearings) and distances with no angles the sum of the interior angles constraint disappears but the latitude and departure constraints remain. This is no different than information derived from a compass rule approach. A compass rule adjustment actually produces residuals for all measurements, but they are generally not termed residuals. The simultaneous analysis of all data on all traverse legs, with the ability to weight measurements using your error estimates, is the key difference. The simultaneous approach allows the systematic distortions which result from a sequential compass rule approach to be eliminated. You truly obtain the "best fit" coordinates based on a series of measurements and your error estimates.

Additional Information about Least Squares Adjustment of Horizontal Survey Data

A brief discussion of items involved in least squares analysis of horizontal survey data will help users with questions like "Why do I do this?" and "What do these numbers represent?". This will be presented in a question and answer format.

(1) Why does adjustment of large networks take so long to run?

Least squares analysis of survey networks requires solution of a system of equations equal in size to the number of unknowns. Unknowns in horizontal survey networks are the 2-D coordinates of the stations. A 1000 station network has 2000 unknown coordinates (1000 N, 1000 E). This means a system of 2000 equations, 2000 unknowns (called the normal equations) needs to be solved. Even on a fast computer this is not a trivial process. As the size of the network increases, the time required for the solution increases exponentially (i.e., a 1000 station network takes more than twice the time to solve as a 500 station network).

(2) Why does least squares of horizontal networks require an iterative solution?

The equations used in horizontal data are "non-linear" equations. The inverse distance and azimuth equations are examples of non-linear equations because they include items such as square roots, squared terms, and trigonometric functions in them. A leveling network produces linear equations of the form:

Elev. B - Elev. A = measured elevation difference + residual

There are no powers or trigonometric functions in this equation. To solve non-linear equations the equations are so-called "linearized". In doing this one creates a solution which solves for updates to approximations for all unknowns. The updates are added to the approximations, and the solution for the updates occur again (the second iteration). When the updates become "negligibly small" (all less than 0.005 ft. for most surveying applications) the solution has converged on the least squares solution for all coordinates.

Several questions arise:

(a) How are approximations for all coordinates generated, and how close to their final adjusted values do they have to be?

Conventional traverse computations is the most effective approach to approximate coordinate generation. EFBP performs a compass rule adjustment for all traverse routes, outputs closure reports and residuals for all measurements from the compass rule. These serve as excellent approximations unless blunders exist, and are generated automatically from any unordered data set.

(b) How many iterations are usually required?

If no blunders exist the solution will usually terminate in 2 iterations. The first iteration will illustrate the difference between the compass rule and least squares solution, and the second iteration will produce all negligible updates.

If blunders exist a solution will often run more than 2 iterations. There is generally little need to run more than 4 iterations for a data set.

(c) What is a divergent solution?

If approximations are very poor, or substantial blunders exist, it is possible that iteration updates will grow (diverge) instead of decrease (converge). It is important that one looks at pre-adjustment closures and compass rule residuals for obvious blunders, which can be corrected, prior to running the least squares adjustment.

(3) What are the meanings of standard errors of coordinates and error ellipses?

These quantities give the surveyor a feel for the positional reliability of his or her produced coordinates. They are a function of the proximity of the coordinates to control stations in the network (further from control you are less confident of the positional reliability of your coordinates). These error analysis results are very computationally intensive to obtain, and thus should only be generated for large networks if truly necessary.

A short discussion of statistical properties of standard errors is required to understand this component of least squares results. Least squares analysis assumes measurements are drawn from a normal distribution. A normal distribution results in the familiar bell-shaped curve of statistics. Values of data is represented on the x axis and frequency of occurrences on the y axis. The center of the bell shaped curve is the average. Statistics can show that approximately 66.7% of your data falls within the region between the average minus the standard error and the average plus the standard error.

This applies directly to standard errors of survey coordinates. If you performed the same survey over, using the same techniques under the same conditions, you would be 66.7% confident that the new coordinate will fall within "plus or minus" the standard error of the first produced coordinate. The error ellipse produces SU - maximum error, SV - minimum error, and T - angle from north to the direction of the maximum error direction. One will normally find maximum error approximately 90 degrees from the direction of the traverse at that point. Error ellipses provide an effective visual tool for inspecting positional accuracy's of least squares adjusted station positions. All standard errors and error ellipse parameters in the latest version of EFBP are 95 % percent confidence values. The multiplier is a function of the redundancy (degrees of freedom) of your survey.

(4) What is the meaning of the "Band is xx stations" which appears just prior to the adjustment process itself?

The equations which are being solved tend to be "sparse". Sparse means there are lots of zero coefficients. If one can figure out where the zeros are, the station order can be switched until the zeros are ordered in some systematic fashion. One approach to re-ordering equations or stations is bandwidth optimization. It is used by many adjustment programs. The band is the "width" of the equations with the zero terms ordered outside of the non-zero band. A 1000 station network with a band of 20 stations will solve much faster than one with a band of 100 stations. The band is a function of redundancy and the number of traverse leg connections. The total number of terms in a banded solution is a function of band size and the number of stations. Without algorithms which take advantage of sparsity we would be waiting a lot longer for solutions to occur.

Least squares adjustment is a statistically valid approach which can solve any survey network configuration simultaneously. With efficient software, a user can become proficient at using least squares in a short time. Hands-on experience with real data sets is the best learning tool that exists.

One should not abuse the use of least squares adjustment. A user should always examine that amounts of adjustment to measurements are within acceptable limits. Least squares adjustment does not eliminate the need for preservation of our measurement information. It does validate whether or not our measurements appear reliable. EFBP is an integrated data processing with least squares analysis. Hopefully this information will allow hands-on experience to be a more fruitful learning procedure.

Statistical Analyses In Analyzing Data Using EFBP

EFBP includes a variety of statistical analyses which may initially be foreign to many land surveyors, but will become valuable tools with very minimal training.

Specific items which need to be considered in this discussion are :

(1) error estimation,
(2) standard error of unit weight/ chi-squared test,
(3) coordinate standard errors and error ellipses,
(4) validity of use of state plane coordinates in the adjustment process.

Basic Concepts of Error Estimation

While the majority of these concepts can be obtained in the preceding discussion, it doesn't hurt to say it again.

While many initial users are perplexed at the concept of error estimation it is really something one does in any analysis of survey data. One example of this is when looks at a traverse closure and deems it acceptable or not. You are using your "apriori" knowledge of what errors exist in your measurements. Prior to least squares we actually prioritized our sections of traverse in some well-thought out order. The first traverse is totally superior to subsequent ones in this scenario, and the subsequent ones cannot affect the first traverse's coordinates. This is error estimation in an absolute sense - data set A is so superior to data set B that B cannot affect A. This has been used in control coordinate superiority to our measurements.

When estimating distance, angle, and azimuth error the key item to remember is "ESTIMATION". You are not required to absolutely define error in the way error propagation is defined in a textbook.

Instead you are merely giving a logical value based on your knowledge of the type of the survey, instrumentation used, the terrain, etc. The least squares analysis will indicate to you if your error estimates do not seem to fit the quality of the data. The standard error of unit weight and residuals will all help in this analysis. If these indicators tell you something is fitting much better or worse than predicted, and you are confident the data has been input correctly, it is then you must decide whether to refine your error estimates.

The true indicator of the quality of your adjustment are your residuals, which simply tell you how much adjustment had to be applied to the input control coordinate, distance, angle, or azimuth. Note that the residual is associated with the error estimate - you expect a distance with a 0.05 ft. error estimate to adjust more than one with a 0.01 ft. error estimate. Residuals larger than three times their respective error estimate are generally considered as suspect. Statistics says a residual larger than three times its error estimate is suspect at a 95 % confidence limit. This means you are 95% confident it is a blunder.

All residuals should not necessarily be less than its error estimate. Statistics says only 66 % of them should be in a normal distribution. A significant number of residuals greater than its error estimate is an indication of slightly optimistic error estimates.

Standard Error Of Unit Weight

The standard error of unit weight is a unitless quantity (like residual / error estimate)that is an overall indicator of the quality of your error estimates. In EFBP it was generically said that if that number is between 0.7 and 2.5 you are doing a good job of error estimation. If you were perfect at error estimation the number would always be near one. The standard error of unit weight for perfect data would be zero but with crummy data it is open-ended on the large numerical side. This means the standard error of unit weight is not from a normal (bell-shaped) statistical distribution because it is not open-ended on the small end.

The standard error of unit weight can be statistically evaluated using a chi-squared test. This test is based on degrees of freedom (the number of measurements minus the number of unknown coordinates). The concept is that the more data you have the less variability there will be in your overall statistical indicators (outliers have less of an effect) and thus as your degrees of freedom goes up the tightness of your chi-squared test goes down. The chi-squared test thus is a low and high number range for the standard error of unit weight, and its range quits changing when the degrees of freedom exceeds 30. When your data exceeds 30 degrees of freedom your limits at a 95% confidence limit will always be 0.748 to 1.208.

This is also called the 5 % significance level. Meeting this range says your error estimates make sense at a 95% confidence level. If we were testing at the 99 % confidence level the range becomes larger since you want to be sure you are not messing with error estimates that are all right. This may seem backwards (higher confidence - bigger spread) but it has to do with the fact that in statistics you try to keep all data as is unless you have a real good reason to change it. If you fail the test by a little it does not mean you should continue to edit error estimates as it will insignificantly change your final coordinates. This is why in EFBP the stated "limit" of the range was set arbitrarily higher in the documentation. You, as a surveyor, should evaluate if your residuals are too large, and act accordingly.

Why is it hard to pass the chi squared test? Are you 95% confident about anything that is related to measurements? Sometimes a question is the best answer.

Coordinate Standard Errors And Error Ellipses

In all reality this is at best an uncertainty number because it gets bigger as things become more marginal. The only real statistical way to define uncertainty about a position statistically is an error ellipse. An error ellipse is defined by two axis dimensions and the direction from north of the major axis.

In statistics error estimates of derived quantities such as coordinates are produced from t distributions which are a function of degrees of freedom and the desired confidence level. A low number of degrees of freedom results in a large multiplier to reach 95 % confidence as opposed to a large number of degrees of freedom. This makes sense since you cannot feel comfortable with your data until you have some redundancy. Like the chi-squared test, the t distribution multiplier quits changing after reaching 30 degrees of freedom where the multiplier of one sigma errors will be 2.51. The meaning of the produced coordinate error estimates is easy to explain using a cadastral survey scenario. You perform a dependent resurvey using all very permanent points, i.e., your traverse points aren't going to move. You run an adjustment of your data and produce coordinates and error estimates. If you went out and did the survey over under the same conditions, using the same instrumentation, the same techniques, and the same control, you would be 95 % confident that you could recompute all coordinates within the one you initially determined plus or minus its error estimate.

In a field survey sense you can thus think of it as how confident you would be at reproducibility of the coordinates.

Horizontal Datums

EFBP can automatically reduce data to state plane coordinate projections in NAD 27 or NAD 83. All horizontal datum and state plane zone (NGS zone number) information is stored in the control file.

Assumed Horizontal Datum

There are situations where a surveyor chooses to use an assumed coordinate system and apply no geodetic/state plane reductions. This is very useful for checking for blunders in survey measurements, and determining relative distance and bearing changes between stations. Use of state plane coordinates in a control file with no datum or state plane zone designation will produce incorrect state plane coordinates as no scale or elevation factors can be applied. It is thus suggested when using assumed coordinates to make them "look" very different than state plane coordinate values in that general area. If you are using EFBP without a control file, the first setup is assigned horizontal coordinates of 10000,10000 and due north is assumed to the first station sighted at that setup.

North American Datum of 1927 (NAD 27)

This datum is based on the Clarke ellipsoid of 1866. The units for distance and state plane coordinates were defined in U.S. Survey Feet, and thus EFBP will only process in this datum in English units. This datum was created by fixing a latitude/longitude at station Meade's Ranch, Kansas, and fixing a geodetic azimuth to a nearby azimuth mark. The type of measurements which made up the geodetic control network for this datum was primarily triangulation as EDM's had not been invented. The production of coordinates had to occur without the use of computers! All geodetic and state plane coordinate production prior to 1986 was with respect to this datum.

North American Datum of 1983 (NAD 83)

This datum is based on the World Geodetic Reference ellipsoid of 1984. The units for distance and state plane coordinates were defined in meters, with conversion to U.S. survey feet or international feet left up to the user's preference. No fixed control existed. The type of measurements now included traverse, doppler, and the global positioning system (GPS) in addition to triangulation. It resulted in a least squares adjustment of approximately 250000 stations and resulted in new and better coordinates for stations which had coordinates in NAD 83. Not all stations which had NAD 27 coordinates were part of this adjustment, and it is thus often desirable to convert these coordinates to NAD 83. The National Geodetic Survey (NGS) has produced a public domain program called NADCON for this purpose. The Army Corps of Engineers updated NADCON with more options such as NAD 27 state plane to NAD 83 state plane. This public domain program is called CORPSCON.

The exact conversion between meters and U.S. survey feet is 1 meter = 39.37 inches. The exact conversion between meters and international feet is 25.4 millimeters = 1 inch. If performing a survey in English units in NAD 83 the surveyor must know if the particular state he or she is in has passed legislation stating which foot should be used. If the state has not passed legislation one should find which foot is being used by the agency one is doing work for. One should not worry if which foot is used for one's measurements. The difference in a 1000 ft. distance is only 0.002 ft., and thus not within the measuring ability of conventional survey measurements.

Other Datums

Due to the advent of the global positioning system (GPS) several states and regions have found it desirable to create a high precision network of GPS observations and perform a least squares analysis of it for coordinate production. This will use the NAD 83 ellipsoid and NAD 83 state plane zone constants. A station which has coordinates in NAD 83 and the high precision network will not be equal, and differences are usually less than one foot. This makes unlabelled coordinates nearly impossible to detect as NAD 83 or supernetwork. Supernetworks are usually labeled such as NAD 83 (90) which implies the supernetwork coordinates which were published in 1990.

EFBP permits tagging of any two digit year to a horizontal datum in the control file which will be also be placed in the final coordinate file. A year greater than 82 indicates NAD 83 datum and state plane zone constants will be used. A year greater than 83 indicates the coordinates are referenced to a regional supernetwork. No mixing of control coordinates from different datums in one job should ever occur as there are systematic shifts between them.

Vertical Datums

A vertical datum is not significant numerically to EFBP as geodetic reductions such as scale factors, elevation factors, and convergence angles are only applied to 2-D (horizontal) measurements. Nonetheless, it is very important to label control and final elevations with a vertical datum number. A lack of vertical datum number indicates an assumed vertical datum is being used. A vertical datum is designated with a 2 digit number in the control and final coordinate files.

Assumed Vertical Datum

This datum would indicate the benchmarks used are with respect to some arbitrary reference. If you are using EFBP without a control file, the first setup is assigned an arbitrary elevation of 500.00 .

If you have a geodetic horizontal datum and an assumed vertical datum, the elevations should at least be derived from interpolating from a map with reference to a vertical datum. This is because elevation factors in the geodetic reductions are based on the elevations in the control file, and it is assumed these elevations are with respect to a vertical datum.

National Geodetic Vertical Datum of 1929 - NGVD 29

This datum was the only national geodetic vertical reference until approximately 1993. It was the production of elevations from differential leveling which was compiled by NGS at that time. Elevations were published in feet, and a series of benchmarks near the coastline were held fixed to force the datum to be referenced close to mean sea level. All benchmarks and contour maps published prior to 1993 by NGS, the U.S. Geological Survey and other federal and state mapping agencies were with respect to this datum.

North American Vertical Datum of 1988 - NAVD 88

The plethora of leveling observations which succeeded NGVD 27 plus better gravity measurements created the need for a redefinition of the vertical datum in North America. While labeled NAVD 88, the elevations were not published until 1993. All elevations are published in meters, and a user follows the same logic as horizontal coordinates in converting to either U.S. survey or international feet. Only one benchmark (near the mouth of the St. Lawrence River) was held fixed in the least squares adjustment of more than 200,000 benchmarks!

Elevations for the same benchmark in NGVD 29 and NAVD 88 will not be equal. Many benchmarks with NGVD 29 elevations were not included in the NAVD 88 and thus need translation to it. NGS has provided public domain program VERTCON for that purpose.

Local Datum

It is possible in an area to have a local datum which is offset from either NGVD 29 or NAVD 88. This should be labeled in the control and final coordinate files with a vertical number other than 29 or 88.

State Plane Projections

State plane coordinates are based on two types of projection systems - a Lambert Conic Conformal or a Transverse Mercator. States that are elongated north-south tend to use Mercator zones and states elongated east-west tend to use Lambert zones. Florida is an example of a state elongated in portions of the state in different directions, and is thus made up of both Lambert and Mercator zones. All zones have central meridians with defined longitudes which point true north-south except for one Mercator zone in Alaska where the central meridian is offset 45 degrees from true north. This is called an oblique Mercator projection. In NAD 1927 state plane zones the size of state plane zones were limited by the fact that the difference between a grid distance and a ground distance reduced to the ellipsoid would not exceed 1/10000. The difference between these two distances is known as the scale factor. The scale factor varies according to your location in a zone, and deviates furthest from unity at the center and extremes (E-W in Mercator, N-S in Lambert) of the zone. Thus larger states have more zones than smaller states. In NAD 83 some states decided to eliminate some zones which in some cases now makes the difference between grid and ellipsoid distance greater than 1/10000. Some states also changed some zone origins, central meridian longitude, or meridian lines of scale factor of one.

Lambert Conical Projection

The Lambert projection is a cone which intersects the ellipsoid at two defined longitudes where scale factor would be one. The scale factor does not change in an east-west direction.

Transverse Mercator Projection

The Mercator is a cylindrical projection where the centerline of the cylinder is running in an east-west direction. The cylinder intersects the ellipsoid at defined longitudes.

Zone Origin, False Northings And False Eastings

An origin for the zone is defined by latitude and longitude. A false easting is assigned to the central meridian which prevented negative eastings. While sometimes the origin received a false northing, it was more common to set the false northing of the origin to zero as it was far enough south of the location of the zone to prevent creation of negative northings.

NAD 27 vs. NAD 83

To force NAD 83 state plane coordinates to look different than their NAD 27 equivalents two items were instituted. NAD 83 state plane coordinates were published by NGS in meters, while NAD 27 state plane coordinates were published in feet. In addition the false easting (and in some cases also the false northing) were changed so that even if coordinates in NAD 83 were converted to feet they would not match their NAD 27 counterparts. In most cases false eastings in NAD 27 Lambert zones were 2000000 ft. in NAD 27 to and NAD 27 Mercator false eastings were 500000 ft. The false eastings in NAD 83 actually vary from state to state.

Grid Distance vs. Ground Distance

The grid distance between two points is simply the Pythagorean plane of the end point coordinates.

Grid distance is computed from ground (horizontal) distance using the following formula :

Grid distance = Ground distance x scale factor x elevation factor

and thus ground distance is computed from grid distance by the following formula :

Ground distance = Grid distance ÷ (scale factor x elevation factor)

Scale factor for a line is usually computed by averaging the scale factors at the end points of the line. Remember the scale factor is a function of your location in the zone. The elevation factor is derived from the average of the end point elevations (average elevation) and in feet is computed by the following formula :

elevation factor = 20,906,000 ÷ (20,906,000 + average elevation)

where 20,906,000 ft. is a suitable approximation for the radius of the earth. The metric equivalent of 20,906,000 can obviously be computed and then average elevations can be entered in meters. It should be noted that it is theoretically correct to reduce to the ellipsoid, and not the geoid (elevation reference). The difference between the geoid and ellipsoid is approximately 20-30 meters in North America, which causes an error in elevation factor of approximately 1/200000. This makes it smaller than our usual random errors in surveying, and thus using elevation, not ellipsoid height, is valid.

EFBP and State Plane Reductions

The abstracting initial phase of EFBP identifies redundant stations, and generates preliminary coordinates for the least squares analysis by automatic coordinate geometry computations. Even without using state plane reductions, these preliminary coordinates are rarely most than 10 feet from their least squares adjusted values. The second component of EFBP is the 1D least squares analysis and sideshot computations for all 1-D sideshots. This produces elevations for all stations which can be used for elevation factors for any 2-D coordinate computations. The third component of EFBP is the 2D least squares analysis. It uses the preliminary coordinates from the abstracting stage to obtain point scale factors. The end point scale factors of a distance are averaged to obtain a scale factor for that line.

Scale factors change minimally over survey measurement type distances, and thus the preliminary coordinates are as good as the final least squares adjusted values for scale factor generation. Every point has an elevation from the 1D computations and thus an average of the end point elevations for a line can be used to generate elevation factors. If geodetic azimuths exist in the control file, the preliminary coordinates are used to compute a convergence angle for reduction of that azimuth to grid.

Similarly the preliminary coordinates are used to generate T-t corrections for all geodetic azimuths and horizontal angles. Sideshots are generally fairly short lines and thus the scale factor change, elevation factor change, and T-t corrections will be negligible. Thus the horizontal sideshots, which are based on the least squares adjusted coordinates of the redundant stations, utilize the sideshot's occupied station's point scale factor and elevation factor. Thus it has been defined how all measurements reductions to grid are automatically employed. It has also been defined how all sideshot computations are based on the results of the least squares analysis.

Validity Of Use Of State Plane Coordinates In The Adjustment Process

This issue has mainly been a constant source of criticism from certain people who do not understand how things can be performed geodetically sound in state plane coordinates if one applies correct scale, elevation, and convergence factors. This is quite an irony since when one works in assumed coordinates we are actually assuming a flat earth and that meridians do not converge toward the poles. State plane has often not been used because inversing coordinates in a plane mode gives grid (not ground) values. More COGO systems now allow you to obtain ground distances, ground acreage at an average elevation, and geodetic bearings from grid coordinates. To test the validity of using state coordinates, a variety of tests of "perfect" townships, which are of course fictitious in nature, were performed. The data was generated using an external software system.

The data was tested at project datums, multiple elevations, and in the middle and slightly outside the limits of both Lambert and Mercator state plane zones. The least squares, which is operating in state plane, should show inaccuracies in the form of residuals if state plane coordinates could not be used. No problems were detected (all residuals were less than .001 ft. and .1 second) though it should still be determined how far outside a zone one has to go before problems occur.

Chapter Four - The Observation File

The method of entering field survey data or measurements into EFBP is by way of an ASCII based text file. This observation file must have the file name extension of .OBS and is commonly referred to as the ".OBS file". If the field survey data is collected using the Electronic Field Book system, the .OBS file is constructed from previously discussed field data files.

During the data collection process, EFB files will be present on the data collector. When the collection process is completed, the files will need to be exported / downloaded from the data collector to a directory on a personal computer (PC).

Observation File Format

During the course of the field survey, that data which is collected is stored in the *SEGMENT.RAW* file. As stated previously, the *SEGMENT.RAW* file is stored in a binary file format and in that form, it cannot be used for processing. The *TSMTOASC.EXE* command must be used to convert the *SEGMENT.RAW* file into an ACSII text file which will be identified as the segment observation, or .OBS file.
This .OBS file format represents raw, unprocessed data from both angle measuring and elevation measuring surveying instrumentation. The data records in the file are fixed format in that specific data elements must be present in specific columns. Files of this type are referred to as being column specific. Line lengths may not exceed eighty (80) characters in length.

Data Records

Survey data may be represented in multiple lines in the file, meaning that data from one single observation may be contained in one (1) or more lines of data or record.

These data type indicators are given as follows :

H - Header record
C - Calibration record
S - Setup record
O - Observation
R - Remark
F - Unprocessed Chain Records
P - Point/Chain Prefix records

The type of data which is contained in each record is indicated by the first character in each line.

Observation Records

The Electronic Field Book data collection system allows data to be collected in various modes. The mode which was used to collect the data is indicated by a two (2) digit number combination which follows the data type indicator. The nine (9) mode record types for observations are given as follows :

01	**HVD**	**06**	**D**
02	**HD**	**07**	**SOR**
03	**HV**	**08**	**SO**
04	**H**	**09**	**R**
05	**VD**		

Remember, these record types only apply to observation records.

In the .OBS file, the data type indicator and the mode record type are separated by a space. Two (2) additional observation record types will be found in most .OBS files. A double zero (00) record type is used to identify the line which contains point name, reference name, geometry, attribute and feature code of the observed point. A double nine (99) record type is used to indicate a line which contains a comment or remark.

Observation Record Types

The first record in an observation file is a ***Header record***. The header record is immediately followed by a ***Calibration record***. After the header and the initial calibration record, calibration records may be found anywhere in the .OBS file, based on the field surveyors' selection of this option.

A ***Setup record*** will follow a calibration record, unless a calibration is repeated in the field. Once a calibration has been performed, setup records may be found throughout the observation file, indicating the location an instrument setup was made.

Observation records will follow the setup record under the setup which they were observed. Observation records are organized by point name and all measurements made to a point under a given setup are placed in the point record. This assures that all observations made to a particular point from a particular setup are grouped together.

The observation record will contain a ***00*** mode record to identify the point, then multiple ***01*** through ***09*** mode records, depending on how may times the point was observed from a particular setup. A ***99*** record may, or may not, exist for each point observed. Column three is usually blank. If the letter "D" is present in column three, it means that this line has been marked as deleted and processing ignores it. When a line has been marked as deleted, it represents an observation which was deleted by the field survey crew during the data collection process or subsequent processing editing. If the letter "M" is present in column three, it means that the data has been modified. Again this indicates that a change was made to the recorded data by the field survey crew during the data collection process or modified during processing editing. Lines which have been marked as modified are again ignored, as it is the old information which is not desired, and immediately preceding the modified record is the new information which should be utilized. All angular values are in degrees minutes seconds format with a space between the degrees, the minutes, and the seconds.

Chains will be represented in the .OBS file as a chain record with an unprocessed point lists. These unprocessed point lists represent the connectivity of the points in the list.

.OBS File Structure

The .OBS file format is very structured in nature. Editing of the .OBS filet to correct any problems need to be made cautiously as the file is read by EFBP and other systems as "fixed format". This means it is assumed certain columns contain certain types of data. For point names and other alphanumeric files left justification to the proper column is required. For real numbers the column of the decimal point is critical. For integers (degrees and minutes) left justification to the proper column is required. The rule is thus place changes back in their same column locations.

To help one with the placement of data in columns, in this chapter every segment of .OBS file is preceded by the following display :

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890
```

This display is present to assist the user in recognizing the proper columns in .OBS file examples.

Header Record

The header record in an .OBS file using the Electronic Field Book contains the units of measure (feet or meters), the segment name, and optionally remarks about the project. The information contained in the header is not used by EFBP as the units of measure are determined from the data contained in the .CTL control file. The units in the header are used in the field by the Electronic Field Book in that the header information instructs the Electronic Field Book system on how to store the distances which are electronically transmitted from the total station. The header is always at the top of the .OBS file and only one header exists per .OBS file. EFBP will process normally in the absence of a header record.

An example of the header record format is:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

H 00 NNNNNNNNNNNNNNNNNNNNNNN TT:TT:TT MM/DD/YY                    UUUUUUU   V.VV

NN..NN   = Project Name
TT:TT:TT = Time
MM/DD/YY = Date
UU..UU   = Selected Units of Measure
V.VV     = Electronic Field Book Version
```

Figure 4-2 = Header Record Type 00 Format

The ***H 00*** record contains the time and date the project was activated and the selected units of measure. The selected units of measure indicate which unit of measure was used to locate all of the data contained in the .OBS file. The units will be listed as either ENGLISH or METRIC. The entry of remarks are totally optional.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

H 99 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

DD..DD   = Remarks, if any, about the Project
```

Figure 4-3 = Header Record Type 99 Format

The ***H 99*** record is an optional line which contains remarks or comments which pertain to the header.

Remark Record

A remark record in an .OBS file contains information which was entered by the Electronic Field Book operator during data collection. Typically, this information will be in the form of comments or remarks which are pertinent to the observed point. This information may include monument descriptions and sizes, tree types or canopy diameters, etc. Remark records may be placed at any point in the .OBS file, depending upon when they were recorded by the Electronic Field Book operator. Remark records are also used in conjunction with other record types and this usage will be explained later.

An example of a remark record format is:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

R 00 TT:TT:TT MM/DD/YY

TT:TT:TT = Time
MM/DD/YY = Date
```

Figure 4-4 = Comment/Remark Record Type 00 Format

The ***R 00*** record contains the time and date the remark or comment was recorded.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

R 99 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

DD..DD   = Remarks, if any, about the Project
```

Figure 4-5 = Comment/Remark Record Type 99 Format

The ***R 99*** record is an optional line which contains remarks or comments which pertain to a recorded observation.

Calibration Record

The information contained in the calibration record is also not required for successful use of EFBP. The calibration is present only as a requirement of the Electronic Field Book system. Most of the calibration record information is informational in its content and not used by EFBP. This information includes items such as temperature, atmospheric pressure, weather code, observer's initials, notekeeper's initials, rodperson's initials, instrument brand and model, instrument serial number, EDM absolute error, EDM ppm error, stadia constant, level test indicator, axis test indicator and comments indicator.

The Electronic Field Book system calibration allows the operator to perform a peg test on the level or a horizontal and vertical axis test on a total station. The peg test results are not numerically used by EFBP as the user is supposed to adjust the level's cross hair based on the test results. The total station axis test contains an Electronic Field Book system operator-defined number of direct and reverse pointings on the same well defined point. EFBP determines the total station operator's pointing error and the systematic errors present in the vertical and horizontal circles.

The systematic errors are corrected for in all subsequent measurements in the .OBS file. If multiple calibrations exist in an .OBS file, the calibration derived systematic error corrections are applied to all subsequent measurements until the next calibration record is encountered. The new values are then used until the next calibration is encountered and so forth. EFBP will process normally in the absence of any calibration record(s).

An example of the calibration record format is :

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

C*00 HH:MM:SS MM/DD/YY TTT PP.P WWWWWW OPR REC RD1 RD2 RD3

if * = D  =  If present then Calibration marked deleted
HH:MM:SS  =  Time of Calibration
MM/DD/YY  =  Date of Calibration
TTT       =  Temperature (degrees Fahrenheit)
PP.P      =  Pressure (inches of mercury)
WWWWWW    =  Weather code
OPR       =  Instrument operator's initials
REC       =  Field computer operator's initials
RD1       =  Rodman 1 initials
RD2       =  Rodman 2 initials
RD3       =  Rodman 3 initials
```

Figure 4-6 = Calibration record Type 00 Format

The ***C 00*** record contains the time and date the calibration was recorded, the temperature, atmospheric pressure, weather code, observer's initials, notekeeper's initials and rodperson's initials. These data elements are all entered by the Electronic Field Book system operator during the calibration process. If the letter “D” is present in column three, it means that this line has been marked as deleted and processing ignores it. If the letter "M" is present in column three, it means that the data has been modified. Lines which have been marked as modified are again ignored, as it is the old information which is not desired, and immediately preceding the modified record is the new information which should be utilized.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

C*01 MKMKMKMKMK MLMLMLMLML ########## EA PP SSS

if * = D =  If present then observation marked deleted
MK...MK  =  Make of instrument
ML...ML  =  Model of instrument
##...##  =  Serial number (ID) of instrument
EA       =  EDM standard error (millimeters)
PP       =  EDM parts-per-million error
SSS      =  Stadia factor
```

Figure 4-7 = Calibration Record Type 01 Format

The ***C 01*** record contains brand and model of the instrument, EDM constant error in millimeters, EDM ppm error and stadia factor.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

C*03 HH:MM:SS                      O HHH MM SS.S VVV MM SS.S

if * = D =  If present then Calibration marked deleted
HH:MM:SS =  Time of Pointing
O        =  Telescope orientation (D/R)
HHH      =  Horizontal direction degrees
MM       =  Horizontal direction minutes
SS.S     =  Horizontal direction seconds
VVV      =  Vertical direction degrees
MM       =  Vertical direction minutes
SS.S     =  Vertical direction seconds
```

Figure 4-8 = Calibration Record Type 03 Format

The ***C 03*** records are the pointings for a total station calibration and from left to right include time of observation, direct or reverse, horizontal circle reading and vertical circle reading.

If an axis test was performed by the Electronic Field Book system operator in conjunction with the calibration, the results of the axis test are computed and added to the .RAW file as a remark.
An example of the axis test remark record format is :

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

R 00 HH:MM:SS MM/DD/YY
R 99 TTTTTTTTT;   N:  X HD HHH MM SS SD EEE HR HHH MM SS SD EEE VD  DD MM SS SD
R 99 EEE VR VVV MM SS SD EEE COR H  CCCC V  CCCC

HH:MM:SS   =  Time of Axis Test Computation
MM/DD/YY   =  Date of Axis Test Computation
TT..TT     =  Test Format
N:  X      =  Number of Observation (x = number of recorded observation pairs)
HD         =  Average Horizontal Circle Reading (Direct Telescope)
HHH        =  Direction in degrees
MM         =  Direction in minutes
SS         =  Direction in seconds
SD EEE     =  Standard Deviation (EEE =  standard deviation in seconds)
HR         =  Average Horizontal Circle Reading (Reverse Telescope)
VD         =  Average Vertical Circle Reading (Direct Telescope)
VR         =  Average Vertical Circle Reading (Reverse Telescope)
COR H      =  Computed Horizontal Correction (CCCC = correction in seconds)
COR V      =  Computed Vertical Correction (CCCC = correction in seconds)
```

Figure 4-9 = Axis Test Record Format

These remarks are placed in the .OBS file immediately following the calibration record. If no remarks are present, no axis test was performed. The ***R 00*** record contains the time and date the test computation results were recorded. The ***R 99*** records contain the average horizontal and vertical circle readings, their associated standard deviations and the computed horizontal and vertical corrections. If a level or “peg” test was performed prior to using a level, the test data will likewise be recorded in the .RAW file.

An example of the level test record format is :

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

C*13 HH:MM:SS   S1.RA S1.RB S2.RA S2.RB

if * = D  =  If present then Calibration marked deleted
HH:MM:SS  =  Time of reading
S1.RA     =  Rod reading for Setup 1 rod A in Level check
S1.RB     =  Rod reading for Setup 1 rod B in Level check
S2.RA     =  Rod reading for Setup 2 rod A in Level check
S2.RB     =  Rod reading for Setup 2 rod B in Level check
```

Figure 4-10 = Level Test Record Format

The ***C 13*** record contains the time the test data was recorded and the rod readings.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

C*99 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

if * = D  =  If present then Calibration marked deleted
DD..DD    =  Comments about Calibration
```

Figure 4-11 = Calibration Remark/Comment Record Format

The ***C 99*** record is an optional line which contains remarks or comments which pertain to the calibration.

Setup record

The instrument setup record is used by EFBP to obtain occupied station name and height of the instrument. The height of the instrument is irrelevant if only 2-D survey observations are made or if differential leveling is being performed. Other attribute type setup information that can be entered includes the geometry, (point or straight (P) or curve (C)), attribute, zone, comments, feature code and reference name of the setup point. This information is not used in the actual numerical processing which is performed by EFBP but becomes critical when once the data is imported into a graphics system, such as a CAD workstation. Note that the reference name is used to manage the control coordinates in CTL program and is not used directly by EFBP.

An example of a setup record is:

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

S*00 NNNNNNNN CCCCCCCCCCCCCCCC G TZ FFFFFFFFFFFFFFFFFFFFFFFF

if * = D  =  If present then Setup marked deleted
if * = M  =  If present then Setup marked modified
NN...NN   =  Point name the instrument is setup over
CC...CC   =  Reference Name designation
G         =  Geometry of point instrument is over
T         =  Attribute of the point instrument is over
Z         =  Zone of the attribute
FF...FF   =  Feature code
```

Figure 4-12 = Setup Record Type 00 Format

The ***S 00*** record contains the name, reference name, geometry, attribute, zone, and feature code of the setup station. The feature code may have the format of the feature code followed by a dash and then followed by a description, i.e. TREE-24 inch Oak.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

S*01 HH:MM:SS MM/DD/YY XX.XXX

if * = D  =  If present then Setup marked deleted
if * = M  =  If present then Setup marked modified
HH:MM:SS  =  Time of Setup
MM/DD/YY  =  Date of Setup
XX.XXX    =  Height of instrument over mark
```

Figure 4-13 = Setup Record Type 01 Format

The ***S 01*** record contains the time and date the setup was recorded and the measured height of the instrument. The height of the instrument should have been entered by the Electronic Field Book system operator in the current selected units of measure.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

S 99 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

DD.DD    =  Comments about the setup
```

Figure 4-14 = Setup Comment/Remark Record Format

The ***S 99*** record is an optional line which contains remarks or comments which pertain to the setup.

Observation Records

Observation components can be divided into the numerical measurements and user defined values associated with them, and the attribute information associated with the point that has been collected. There is one unique record number for each various type of observation which is available in the Electronic Field Book system.

The ***O 01*** record indicates an observation performed in the HVD mode. Other types of records are ***O 02*** for HD observations, ***O 03*** for HV observations, ***O 04*** for H observations, ***O 05*** for VD observations, ***O 06*** for D observations, ***O 07*** for SOR observations, ***O 08*** for SO observations, and ***O 09*** for R observations.

In HD and D records, the distance can only be horizontal in nature as no zenith angle is associated with that record type. Note for derivatives of HVD observations, the data not actually measured is left blank. If a .OBS file is modified and a ***O 01*** record is changed to a ***O 04*** record, the zenith angle and slope distance will be ignored even if they exist in the modified line.

An example of an observation record is as follows :

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890
O*00 NNNNNNNN CCCCCCCCCCCCCCCC G TZ FFFFFFFFFFFFFFFFFFFFFFFF RRRRRRRR

if * = D =  If present then observation marked for deletion
if * = M =  If present then observation marked for modification
NNNNNNNN =  Point Name
CC...CC  =  Reference name designation
G        =  Geometry type
T        =  Attribute of the point that the target is over
Z        =  Zone of the point
FF...FFF =  Feature code
RRRRRRRR =  Route name if station offset locations are present. The Route
           represents a stationed Chain.
```

Figure 4-15 = Observation Record Type 00 Format

The ***O 00*** record contains the name, reference name, geometry, attribute, zone, and feature code of the observed point. The feature code may have the format of the feature code followed by a dash and then followed by a description, i.e. TREE-24 inch Oak.

Only points which have been located in Station Offset mode will have the route field filled in, as this is a requirement of that particular mode of observation. Total station, or HVD cross sections, will have a route or alignment name, station value, and orientation information about the observed point stored in the Feature code field.

This feature code information indicates a special case of Station Offset location which uses the ***X attribute***. For a complete description of the use of this function, please refer to the EFB User's Guide.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

O*01 HH:MM:SS   HT.HHT ECC.EC E PN O HHH MM SS.S VVV MM SS.S DDDDD.DDD T

if * = D =  If present then observation marked for deletion
if * = M =  If present then observation marked for modification
HH:MM:SS =  Time of observation
HT.HHT   =  Height of target above the mark
ECC.EC   =  Eccentric distance from target to object
E        =  Eccentric orientation of target relative to object (L,R,F or B)
PN       =  Position Set Number
O        =  Telescope orientation (D - Direct or R - Reversed)
HHH      =  Horizontal direction Degrees
MM       =  Horizontal direction Minutes
SS.S     =  Horizontal direction Seconds
VVV      =  Vertical direction Degrees
MM       =  Vertical direction Minutes
SS.S     =  Vertical direction Seconds
DDDD.DDD =  Distance
T        =  Type of distance - Slope (S) or Horizontal (H)
```

Figure 4-16 = Observation Record Type 01 Format

A ***O 01*** record represents an observation which was recorded in HVD mode. This record will contain the time the observation was recorded, the height of the observed target, eccentric distance and direction (if any), the position set number, the telescope orientation (D for direct or R for reverse), the horizontal circle reading (in degrees, minutes and seconds), the vertical circle reading (in degrees, minutes and seconds) the measured distance and the type of distance. In this mode, the distance will be measured as a slope distance, indicated by the letter S.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

O*02 HH:MM:SS   HT.HHT ECC.EC E PN O HHH MM SS.S             DDDDD.DDD T

if * = D =  If present then observation marked for deletion
if * = M =  If present then observation marked for modification
HH:MM:SS =  Time of observation
HT.HHT   =  Height of Target above the mark
ECC.EC   =  Eccentric distance target to object
E        =  Eccentric orientation of target relative to object
PN       =  Position Number
O        =  Telescope orientation
HHH      =  Horizontal direction Degrees
MM       =  Horizontal direction Minutes
SS.S     =  Horizontal direction Seconds
DDDD.DDD =  Distance
T        =  Type of Distance
```

Figure 4-17 = Observation Record Type 02 Format

A ***O 02*** record represents an observation which was recorded in HD mode. This record will contain the time the observation was recorded, the height of the observed target, eccentric distance and direction (if any), the position set number, the telescope orientation (D for direct or R for reverse), the horizontal circle reading (in degrees, minutes and seconds) and the measured distance and the type of distance. In this mode, the distance will be measured as a horizontal distance, indicated by the letter H. Eccentric distances are indicated by F for front, B for back, L for left and R for right.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

O*03 HH:MM:SS   HT.HHT          PN O HHH MM SS.S VVV MM SS.S

if * = D =  If present then observation marked for deletion
if * = M =  If present then observation marked for modification
HH:MM:SS =  Time of observation
HT.HHT   =  Height of Target above the mark
PN       =  Position Number
O        =  Telescope orientation
HHH      =  Horizontal direction Degrees
MM       =  Horizontal direction Minutes
SS.S     =  Horizontal direction Seconds
VVV      =  Vertical direction Degrees
MM       =  Vertical direction Minutes
SS.S     =  Vertical direction Seconds
```

Figure 4-18 = Observation Record Type 03 Format

A ***O 03*** record represents an observation which was recorded in HV mode. This record will contain the time the observation was recorded, the height of the observed target, the position set number, the telescope orientation (D for direct or R for reverse), the horizontal circle reading (in degrees, minutes and seconds) and the vertical circle reading (in degrees, minutes and seconds).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

O*04 HH:MM:SS   HT.HHT          PN O VVV MM SS.S

if * = D =  If present then observation marked for deletion
if * = M =  If present then observation marked for modification
HH:MM:SS =  Time of observation
PN       =  Position set Number
O        =  Telescope orientation (D - Direct or R - Reversed)
HHH      =  Horizontal direction Degrees
MM       =  Horizontal direction Minutes
SS.S     =  Horizontal direction Seconds
```

Figure 4-19 = Observation Record Type 04 Format

A ***O 04*** record represents an observation which was recorded in H mode. This record will contain the time the observation was recorded, the height of the observed target, the position set number, the telescope orientation (D for direct or R for reverse) and the horizontal circle reading (in degrees, minutes and seconds).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

O*05 HH:MM:SS   HT.HHT          PN O             VVV MM SS.S DDDD.DDD T

if * = D =  If present then observation marked for deletion
if * = M =  If present then observation marked for modification
HH:MM:SS =  Time of observation
HT.HHT   =  Height of Target above the mark
PN       =  Position set Number
O        =  Telescope orientation (D - Direct or R - Reversed)
VVV      =  Vertical direction Degrees
MM       =  Vertical direction Minutes
SS.S     =  Vertical direction Seconds
DDDD.DDD =  Distance
T        =  type of Distance (S - Slope or H - Horizontal)
```

Figure 4-20 = Observation Record Type 05 Format

A ***O 05*** record represents an observation which was recorded in VD mode. This record will contain the time the observation was recorded, the height of the observed target, the position set number, the telescope orientation (D for direct or R for reverse), the vertical circle reading (in degrees, minutes and seconds) the measured distance and the type of distance. In this mode, the distance will be measured as a slope distance, indicated by the letter S.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

O*06 HH:MM:SS   HT.HHT          PN T                         DDDDD.DDD T

if * = D =  If present then observation marked for deletion
if * = M =  If present then observation marked for modification
HH:MM:SS =  Time of observation
DDDD.DDD =  Distance
PN       =  Position set Number
T        =  type of Distance (H - Horizontal)
```

Figure 4-21 = Observation Record Type 06 Format

A ***O 06*** record represents an observation which was recorded in D mode. This record will contain the time the observation was recorded, the height of the observed target, the position set number, the telescope orientation (D for direct or R for reverse) and the measured distance and the type of distance. In this mode, the distance will be measured as a horizontal distance, indicated by the letter H.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

O*07 HH:MM:SS   SSSSSS.SS OOOO.OO                          UU.UUU XX.XXX LL.LLL

if * = D =  If present then observation marked for deletion
if * = M =  If present then observation marked for modification
HH:MM:SS =  Time of observation
SSSS.SS  =  Station of object along route
OOOO.OO  =  offset distance from route
UU.UUU   =  upper cross-hair reading
XX.XXX   =  middle cross-hair reading
LL.LLL   =  lower cross-hair reading
```

Figure 4-22 = Observation Record Type 07 Format

A ***O 07*** record represents an observation which was recorded in SOR mode. This record will contain the time the observation was recorded, the station value at which the observation was made, the offset distance from the baseline (a '-' sign indicates left and a '+' sign indicates right), the upper cross-hair reading, the middle cross-hair reading and the lower cross-hair reading.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

O*08 HH:MM:SS   SSSSSS.SS OOOO.OO

if * = D =  If present then observation marked for deletion
if * = M =  If present then observation marked for modification
HH:MM:SS =  Time of observation
SSSS.SS  =  Station of object along route
OOOO.OO  =  Offset distance from route
```

Figure 4-23 = Observation Record Type 08 Format

A ***O 08*** record represents an observation which was recorded in SO mode. This record will contain the time the observation was recorded, the station value at which the observation was made and the offset distance from the baseline (a '-' sign indicates left and a '+' sign indicates right).

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

O*09 HH:MM:SS                                                UU.UUU XX.XXX LL.LLL

if * = D =  If present then observation marked for deletion
if * = M =  If present then observation marked for modification
HH:MM:SS =  Time of observation
UU.UUU   =  upper cross-hair reading
XX.XXX   =  middle cross-hair reading
LL.LLL   =  lower cross-hair reading
```

Figure 4-24 = Observation Record Type 09 Format

A ***O 09*** record represents an observation which was recorded in R mode. This record will contain the time the observation was recorded, the upper cross-hair reading, the middle cross-hair reading and the lower cross-hair reading.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

O 99 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

DD..DD   = Remarks, if any, about the Project
```

Figure 4-25 = Observation Comment/Remark record Format

The ***O 99*** record is an optional line which contains remarks or comments which pertain to an observation. An ***O 99*** record may also be *added* during the editing of the .OBS file to highlight, indicate or explain any modifications which may have been made. The simple averaging process is thus a fairly simple computation which is well documented in statistics texts and surveying textbook sections on statistics as it applies to surveying.

Survey Chain Data

During the creation of the .OBS file from the .RAW file, the survey chain data is read from the .CHN file and added to the .OBS file. This allows for the editing of the survey chain point name lists or for the creation of additional survey chains.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

R 00 00:00:00 12/31/99
R 99 CHAIN DATA STARTS HERE
F 00 NNNNNNNN                    AZ FFFFFFFFFFFFFFF
F 01 PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
F 02 LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
R 00 00:00:00 12/31/99
R 99 CHAIN DATA ENDS HERE

NN..NN   =  Assigned Survey Chain Name
A        =  Attribute
Z        =  Zone
FF..FF   =  Feature Code
PP..PP   =  Chain point name list
LL..LL   =  Expanded chain point name list
```

Figure 4-28 = Survey Chain Record Format

A standard remark record (a ***R 00*** and a ***R 99***) is used to define the beginning of the survey chain data within the .OBS file.

The ***F 00*** record contains the survey chain name, the attribute, the zone and the feature code. The ***F 01*** record contain the chain point name list as it was entered in the field by the Electronic Field Book system operator and is displayed in compressed or "optimized" format. The chain list is stored in the Electronic Field Book in this format in order to occupy the minimum amount of space. The ***F 02*** record contains the expanded chain point list in non-abbreviated form. Any double comma entries (",,") from the ***F 01*** record are replaced in the ***F 02*** record by the word GAP. Both ***F 01*** and ***F 02*** records may occupy more than one line as they are never allowed to extend beyond column seventy-two (72) and a line always ends in a comma between station names in the list.

Another standard remark record (a ***R 00*** and a ***R 99***) is used to define the end of the survey chain data.

<u>Prefix Record</u>

The last record which is present in the .OBS file is the prefix record. A standard remark record (a ***R 00*** and a ***R 99***) is used to define the beginning of the prefix data within the .OBS file.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

R 00 00:00:00 12/31/99
R 99 PREFIX DATA STARTS HERE
P 00
P 01 PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
P 01 PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
P 02 CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
R 00 00:00:00 12/31/99
R 99 PREFIX DATA ENDS HERE

PP..PP   =  Used point prefix information
CC..CC   =  Used chain prefix information
```

Figure 4-29 = Prefix Record Format

The ***P 01*** records contain the point prefixes which have been used followed by the largest numeric suffix which was used for that particular prefix with each separated by a comma. The ***P 02*** records contain the chain prefixes which have been used followed by the largest numeric suffix which has been used for that particular prefix, again with each separated by a comma.

Another standard remark record (a ***R 00*** and a ***R 99***) is used to define the end of the prefix data.

Chapter Five - Control Point Management

The best survey data in the world will yield poor processing results if the control information is not accurate. Every survey, from a lot and block mortgage survey to a ten (10) kilometer topographic and terrain model survey, needs good control information. Having good information still only solves half of the control problem. These control values must be managed somehow.

Control information, in the form of datum information, horizontal coordinates and benchmark elevations are stored in a control file. The control file will have that same name as the EFB data files and has the file extension .CTL. Like the .OBS file, the .CTL file has a very standardized fixed format. If a control file does not exist for the project to be processed, EFBP will assume coordinates of a northing of 10000, a easting of 10000 and an elevation of 500 for the first setup encountered in the .OBS file. An azimuth of N 0° 0’ 0” E will also be applied to the first measurement recorded at that setup.

If your data is not totally connected by field measurements, you will not produce coordinates on all of your points without a .CTL file (i.e., control coordinates are required to generate coordinates for non-connected segments of data). Likewise, if your first setup contains no data and was not deleted, or if your first setup consists of leveling data and HVD data exists later in the .OBS file, coordinate generation may not be possible without a .CTL file. In these cases, EFBP can still be utilized for abstracting and repetition error information only, as that is independent of coordinate generation. This means that even without a control file, a .GEN file can still be created.

EFBP uses field survey names to identify all points, including control points. The Electronic Field Book system allows for the use of reference names to identify control points, but their use is not required. Format Of The Control (.CTL) File

Like the observation, or .OBS file, which was previously discussed, the .CTL file is also a column specific file. That is, when examining a .CTL file, EFBP expects to find certain types of control information in specific locations within the file.

If the data is not entered correctly, EFBP will not be able to read the .CTL file properly, and the processing will more than likely fail.

The .CTL file format is defined as follows :

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

G 00 PPPPPPPPPPPPPPPPPPPPPPP
G 01 NNNNNNNN RRRRRRRRRRRRRRRR                               ZZZZ HHUVV
G 02 XXXXXXXX.XXX YYYYYYYY.YYY ZZZZZZ.ZZZ AAAA.AAA BBBB.BBB CCCC.CCC
G 03 TTTTTTTT RRRRRRRRRRRRRRRR DDD MM SS.S EEEE.EEE K

if * = D = If present then control information marked for deletion
if * = M = If present then control information marked for modification
PP..PP   = Project Name
NN..NN   = Control Point Name
RR..RR   = Reference Name
ZZZZ     = NGS State Plane Zone Code
HH       = Horizontal Datum Year
U        = Units of Measurement
VV       = Vertical Datum Year
XX..XX   = X Coordinate (Easting) Value
YY..YY   = Y Coordinate (Northing) Value
ZZ..ZZ   = Elevation
AA..AA   = Standard Error for X Coordinate
BB..BB   = Standard Error for Y Coordinate
CC..CC   = Standard Error for Elevation
TT..TT   = Point name of azimuth terminus
DDD      = Horizontal direction in degrees
MM       = Horizontal direction in minutes
SS.S     = Horizontal direction in seconds
EE..EE   = Standard error for Horizontal direction in seconds
K        = Type of azimuth (G - Grid or A - Geodetic or Blank - Assumed)
```

Figure 5-4 = Typical .CTL File Format

A ***G 00*** record represents a header record which contains the project name. There should only be one (1) ***G 00*** record in any .CTL file. Each control station will then follow the .CTL file header record. Each control station entry will consist of two (2) lines of information with an optional line for azimuth information.

The ***G 01*** record contains the control station name, the control station's reference name, state plane NGS zone number, horizontal datum, units of measurement and vertical datum. The state plane NGS zone number, horizontal datum and vertical datum entries are optional if assumed coordinates are being used. The units of measurement will be indicated by the letter "M" for metric, the letter "F" for Survey Foot or the letter "I" for International Foot distances.

The ***G 02*** record contains the X coordinate (easting), the Y coordinate (northing), the Z coordinate (elevation), the X coordinate error estimate, the Y coordinate error estimate, and the Z coordinate's error estimate. If a coordinate area is blank, EFBP assumes that it is unknown. If a coordinate error estimate area is blank, EFBP assigns the error estimate defaults to equal fixed, or 0.001.

The azimuth record is a ***G 03*** record and follows the ***G 02*** record for the "from" station of the azimuth. It contains the "to" station name, the azimuth expressed in degrees, minutes and seconds, the error estimate for the decimal seconds, and the azimuth type. The letter "G" indicates a grid azimuth, the letter "A" indicates an astronomic azimuth and no indicator, i.e. a "blank", indicates and assumed azimuth. If the error estimate for the decimal seconds is blank, EFBP assigns the error estimate to equal fixed, or 0.10 seconds.

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012045678901234567890123456789012345678901234567890

G 99 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

DD..DD   = Remarks, if any, about a control point
```

Figure 5-5 = Observation Comment/Remark record Format

The ***G 99*** record is an optional line which contains remarks or comments which pertain to a specific control point. A ***G 99*** record may be *added* during the editing of the .CTL file to highlight, indicate or explain any modifications which may have been made to a control point.

Chapter Six - Introduction to EFB Processing

The use of EFBP to obtain survey coordinates can best be described as a four (4) step process. You can instruct the program to stop at any given step if desired and once started, the program moves between steps with no additional input required input from the user. Obviously one needs to set up the appropriate parameters to accomplish this and the EFBP setup menu allows for the selection of these processing parameters.

- The ***first step*** performed by EFBP is abstracting data, horizontal sideshot identification, and preliminary horizontal traverse closure and coordinate generation.

  This process produces the first report file which carries the .GEN filename extension. Abstracting an .OBS file involves:

  (1) averaging of multiple repetitions and computing of respective error statistics
  (2) reducing raw data to 2-D and 1-D measurement equivalents,
  (3) computing initial error estimates for all values, and
  (4) comparing horizontal distances and elevations on lines measured multiple times and "weighted" averaging their values based on error estimates. Weighted averaging permits the size of the error estimate to be used in the adjustment process so better indicators of quality measurements have more affect in the adjustment process.

  The redundant part of the horizontal data is then identified (non-sideshots). The program then automatically performs traverse closures until every redundant horizontal station has "approximate" coordinates. These coordinates serve as the required estimates for the 2-D least squares adjustment to operate.

- The ***second step*** of processing is generation of all elevation information. This procedure creates the .1D report file. First the redundant portion of the vertical component of the survey network is identified, and a least squares analysis of this data is performed. Sideshot elevation determinations are then computed based on the least squares adjusted elevations.

- The ***third step*** of processing is the 2-D least squares step which produces the .2D report file. All reductions to state plane are performed automatically if a zone and datum are defined. Elevation reduction to grid is possible because these values have been generated in the previous step.

Traverse closures are then computed which compare raw survey measurements (reduced to grid if that is defined) to adjusted coordinates.

- The ***fourth step*** of processing is two distinct operations. The first part computes the horizontal sideshots based on the least squares adjusted coordinates of the redundant survey. Grid reductions are again automatically performed if required. The second portion merges the coordinate information with the attribute information in generation of the final .XYZ file. If SOR, SO, (station offset) or R (differential leveling) data exists a .SOE (station, offset, elevation) report file is generated.

The EFBP Menu

When the EFBP program is executed, a menu will be presented. This menu allows the user to initially set or to change any previously established processing variable. An explanation of the available processing variables follows.

Processing Menu

This is an example menu for the selection of the processing variables.

```
(1) PROJECT NAME IS BRIDGE
(2) USE REPETITION ERRORS PLUS ADD-ONS IN ERROR ESTIMATION
(3) DO NOT COMPUTE COORDINATE STANDARD ERRORS AND ERROR ELLIPSES
(4) CORRECT FOR EARTH CURVATURE AND ATMOSPHERIC REFRACTION
(5) ROBUST ERROR ESTIMATE PROMPT WILL NOT APPEAR
(6) PROCESS TO FINAL COORDINATE .XYZ FILE

FOLLOWING USED AS ADD-ONS TO ERROR FROM REPETITION
DISTANCE   DISTANCE     HORZ.     AZIMUTH   TRIG. LEV.   TRIG. LEV.  DIFF. LEV.
CONSTANT     PPM     ANGLE (SEC)   (SEC)     CONSTANT        PPM      CONSTANT
(7)  .004 (8)  5.00 (9)   4.0   (10)    .1 (11)  .008   (12) 20.00  (13)  .010

FOLLOWING ARE USER DEFINED ERROR ESTIMATES
  DISTANCE   DISTANCE     HORZ.      AZIMUTH    TRIG. LEV.   DIFF. LEV.
  CONSTANT     PPM     ANGLE (SEC)    (SEC)      CONSTANT     CONSTANT
(14)  .006 (15)  5.00   (16)  10.0 (17)    .1   (18)  .020   (19)  .010

(20) SETUP ERROR (ALWAYS USED) =   .005
(21) READ ERROR ESTIMATE ADD-ONS FROM DIFFERENT DEFAULT.CON
(22) READ USER DEFINED ERROR ESTIMATES FROM DIFFERENT DEFAULT.SD
FLAG MAXIMUM SPREADS ABOVE
(23) DISTANCE =   .005 (24) ANGLES =   10.0 (25) ELEV. DIFFERENCES =   .020
ENTER A # TO CHANGE, OR PRESS ENTER TO START PROCESSING
```

Explanations for each processing menu option are presented in the following sections. Please note that the selection of the desired datum and units or measurement (feet vs. meters) is performed via the control program. The control program, referred to as CTL, allows for the modification of the segment control file. This CTL program is explained in a separate chapter.

Processing Options

The processing menu allows the for the selection of the name of the segment to be processed in addition to five (5) processing alternatives.

Option One (1) - Project Name

Option One allows the user to change the name of the project which is being analyzed. In order for a segment to successfully process, the *SEGMENT.OBS* file and a *SEGMENT.CTL* file must be present in the working directory.

A free adjustment may be performed without a *SEGMENT.CTL* file. In this case initial coordinates of 50,000.0000, 50,000.0000 and a north azimuth are used for segment data processing. To change the project name press the **[1]** key and type in the desired segment name. When the desired segment name has been entered, press the **[ENTER]** key. The new segment name will now be displayed.

Option Two (2) - Use Repetition Errors Plus Add-Ons In Error Estimation

Option Two allows for the use of repetition errors plus user defined add-ons for error estimation in the least squares analysis. If this option is not used, processing will take place using user defined error estimates without any influence from repetition error.
Pressing the **[2]** key acts as a toggle, activating or de-activating the use of repetition errors.

Option Three (3) - Do Not Compute Coordinate Standard Errors And Error Ellipses

Option Three allows for the computation of coordinate standard errors and error ellipses. While this information can be of some use, in most cases, they are not required or needed. If this option is not enabled, (turned off so that the program will not compute standard errors), the least squares solution will operate faster as less computations are necessary.

Pressing the **[3]** key acts as a toggle, activating or de-activating the computation of standard errors and error ellipses.

Option Four (4) - Correct For Earth Curvature And Atmospheric Refraction

Option Four allows for the recorded field observations to be corrected for the systematic errors of atmospheric refraction and earth curvature. If for some reason the zenith angles and slope distances which are recorded in the *SEGMENT.OBS* file are already corrected, this option should be turned off.

Pressing the **[4]** key acts as a toggle, activating or de-activating the application of the systematic error corrections.

Option (5) - Robust Error Estimate Prompt Will Not Appear

Option Five allows for the use of robustness, which is a re-weighting technique used in least squares to try to identify blunders. It is simply strategy which uses the residuals (amounts of adjustment) in making weaker data have less effect on the adjustment by giving the weaker data larger error estimates.

As previously stated, the use of robustness should only be used to attempt to identify blunders. Robustness should be turned off prior to generating the final *SEGMENT.XYZ* file.

Pressing the **[5]** key acts as a toggle, activating or de-activating the use of robustness.

Option (6) - Process To Final Coordinate .XYZ File

Option Six allows the user to select which level of processing is performed each time the EFBP program is run. There are currently four (4) levels of processing and these levels are described as follows :

The 1st level which includes the abstracting of repeated measurements and preliminary coordinate generation. This level produces the *SEGMENT.GEN* report.

The 2nd level which includes the first level together with a vertical, or 1D, least squares adjustment. This level produces the *SEGMENT.GEN* and segment .1D reports.

The 3rd level which includes the first and second levels together with a horizontal, or 2D, least squares adjustment. This level produces the *SEGMENT.GEN*, *SEGMENT.1D* and *SEGMENT.2D* reports.

The 4th level which includes the first, second and third levels together with the final coordinate and attribute production. This level produces the *SEGMENT.GEN*, *SEGMENT.1D, SEGMENT.2D* and *SEGMENT.XYZ* files.

Pressing the **[6]** key displays a secondary menu which allows the user to select the processing level which will be used. The selected processing level will remain in effect until an alternate level is selected.

ADD-ONS

The processing menu allows for the direct entry of add-ons to the errors from repetition for least squares data analysis. These values are initially read from the DEFAULT.CON file but may be changed via the menu at any time. If new values are entered via the menu, these new values are also written to the DEFAULT.CON file.

```
FOLLOWING USED AS ADD-ONS TO ERROR FROM REPETITION
DISTANCE   DISTANCE     HORZ.     AZIMUTH   TRIG. LEV.   TRIG. LEV.  DIFF. LEV.
CONSTANT     PPM     ANGLE (SEC)   (SEC)     CONSTANT        PPM      CONSTANT
(7)  .004 (8)  5.00 (9)   4.0   (10)    .1 (11)  .008   (12) 20.00  (13)  .010
```

If use of repetition errors is selected, these values are the add-ons to the errors from repetition for least squares error estimation. For example, a horizontal distance repetition error of .005 meters will have .004 meters added to it. Note since trigonometric elevation differences usually erode in accuracy quicker as a function of distance when compared to the horizontal distance, add-on parts per million (ppm's) are separated into a horizontal distance ppm and a trigonometric leveling constant where the trigonometric leveling constant is usually larger in magnitude.

Option Seven (7) - Distance Constant Add-on

Option Seven allows for the entry of a distance constant add-on. Pressing the **[7]** key and then pressing the **[ENTER]** key displays the prompt *"Enter Horizontal Distance Error Constant Add-on" <.004>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.CON file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option Eight (8) - Distance PPM Add-on

Option Eight allows for the entry of a distance ppm add-on. Pressing the **[8]** key and then pressing the **[ENTER]** key displays the prompt *"Enter Horizontal Distance Error PPM Add-on" <5.00>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.CON file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option Nine (9) - Horizontal Angle Error Add-on

Option Nine allows for the entry of a horizontal angle error add-on. Pressing the **[9]** key and then pressing the **[ENTER]** key displays the prompt *"Enter Horizontal Angle Error Add-on in sec." <4.00>.* This add-on must be entered in seconds. The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.CON file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option Ten (10) - Azimuth Error Add-on

Option Ten allows for the entry of an azimuth error add-on. Entering **[10]** and pressing the **[ENTER]** key displays the prompt *"Enter Azimuth Error Add-on in sec." <.100>.* This add-on must be entered in seconds. The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.CON file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option Eleven (11) - Trigonometric Elevation Difference Error Constant Add-on

Option Eleven allows for the entry of a trigonometric elevation difference error constant add-on. Entering **[11]** and pressing the **[ENTER]** key displays the prompt *"Enter Trig. Elevation Difference Error Constant Add-On" <.008>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.CON file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option Twelve (12) - Trigonometric Elevation Difference Error PPM Add-on

Option Twelve allows for the entry of a trigonometric elevation difference error ppm add-on. Entering **[12]** and pressing the **[ENTER]** key displays the prompt *"Enter Trig. Elevation Difference Error PPM Add-On" <20.00>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.CON file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option Thirteen (13) - Differential Leveling Error Constant Add-on

Option Thirteen allows for the entry of a differential leveling error constant add-on. Entering **[13]** and pressing the **[ENTER]** key displays the prompt *"Enter Diff. Leveling Error Constant Add-On" <.010>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.CON file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

It is important to remember that if changes are made via the processing menu, these new values are written to the DEFAULT.CON file and will remain in effect until changed

User Defined Error Estimates

The processing menu allows for the direct entry of error estimates for least squares data analysis. These values are initially read from the DEFAULT.SD file but may be changed via the menu at any time. If new values are entered via the menu, these new values are also written to the DEFAULT.SD file.

```
FOLLOWING ARE USER DEFINED ERROR ESTIMATES
  DISTANCE   DISTANCE     HORZ.      AZIMUTH    TRIG. LEV.   DIFF. LEV.
  CONSTANT     PPM     ANGLE (SEC)    (SEC)      CONSTANT     CONSTANT
(14)  .006 (15)  5.00   (16)  10.0 (17)    .1   (18)  .020   (19)  .010
```

If error estimation from repetition is not selected, or if a measurement is not repeated and thus no repetition error exists, the user defined error estimates will be utilized.

Option Fourteen (14) - Distance Error Estimate

Option Fourteen allows for the entry of a distance error estimate. Entering **[14]** and then pressing the **[ENTER]** key displays the prompt *"Enter Horizontal Distance Error Constant" <.006>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.SD file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option Fifteen (15) - Distance PPM Error Estimate

Option Fifteen allows for the entry of a distance ppm error estimate. Entering **[15]** and then pressing the **[ENTER]** key displays the prompt *"Enter Horizontal Distance Error PPM" <5.00>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.SD file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option Sixteen (16) - Horizontal Angle Error Estimate

Option Sixteen allows for the entry of a horizontal angle error estimate. Entering **[16]** and then pressing the **[ENTER]** key displays the prompt *"Enter Horizontal Angle Error in seconds" <10.00>.* This error estimate must be entered in seconds. The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.SD file.

Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option Seventeen (17) - Azimuth Error Estimate

Option Seventeen allows for the entry of an azimuth error estimate. Entering **[17]** and pressing the **[ENTER]** key displays the prompt *"Enter Azimuth Error in seconds" <.100>.* This add-on must be entered in seconds. The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.SD file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option Eighteen (18) - Trigonometric Elevation Difference Error Estimate

Option Eighteen allows for the entry of a trigonometric elevation difference error estimate. Entering **[18]** and pressing the **[ENTER]** key displays the prompt *"Enter Trig. Elevation Difference Error Constant" <.020>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.SD file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option Nineteen (19) - Differential Leveling Error Estimate

Option Nineteen allows for the entry of a differential leveling error estimate. Entering **[19]** and pressing the **[ENTER]** key displays the prompt *"Enter Differential Leveling Error Constant" <.010>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.SD file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

It is important to remember that if changes are made via the processing menu, these new values are written to the DEFAULT.SD file and will remain in effect until changed.

<u>Other Entries</u>

In addition to error estimates and error add-ons several other variables may be set by the user from the processing menu.

Option Twenty (20) - Setup Error

Option Twenty allows for the entry of a setup error. Entering **[20]** and pressing the **[ENTER]** key displays the prompt *"Enter Setup Error"<.005>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.CON file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

The setup error allows for compensation of the instrument not being setup exactly over the point or error due to mis-adjustment of the optical plummet. This error is always entered in either feet or meters and is added to all horizontal angle and azimuth measurement error estimates (both from repetition and user defined) and is computed by the tangent inverse of the setup error divided by the length of the line. A zero setup error indicates you do not want this type of value added to your error estimates.

Option (21) - Read Error Estimate Add-Ons From Different DEFAULT.CON

The DEFAULT.CON file is the file where error estimate add-ons are read from. It may be advantageous to use values from an old job, or the user may desire to read in some metric default values instead of the English values from the last segment processed. This option allows these alternate files to be accessed.

Option Twenty-one allows for the use of an alternate DEFAULT.CON file for processing. Entering **[21]** and pressing the **[ENTER]** key displays the prompt *"Enter File Path To The File" <C:\EFB\>.* Enter the full directory path to the location of the desired DEFAULT.CON file and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value. Next, the prompt *"Enter File Name For Error Add-ons" <DEFAULT.CON>* will be displayed. Enter the desired file name and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option (22) - Read User Defined Error Estimates From Different DEFAULT.SD

The DEFAULT.SD file is the file where error estimates are read from. It may be advantageous to use values from an old job, or the user may desire to read in some metric default values instead of the English values from the last segment processed. This option allows these alternate files to be accessed.

Option Twenty-two allows for the use of an alternate DEFAULT.SD file for processing. Entering **[22]** and pressing the **[ENTER]** key displays the prompt *“Enter File Path To The File” <C:\EFB\>.* Enter the full directory path to the location of the desired DEFAULT.SD file and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value. Next, the prompt *“Enter File Name For Error Add-ons” <DEFAULT.SD>* will be displayed. Enter the desired file name and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Segment .GEN File Flags

The *SEGMENT.GEN* report can become very large as all repetition errors from each setup are reported. Since the user really only needs to review the "poor" values, asterisks (* *) may be used to flag maximum spreads above defined tolerances. When reviewing the report in a text editor, the user may use the search feature and scan for only the values which are flagged by the asterisks. A maximum spread is defined as the largest difference of a set of repetitions from the average value.

Option (23) - Distance Flag Limit

Option Twenty-three allows for the entry of a distance error flag. Entering **[23]** and then pressing the **[ENTER]** key displays the prompt *"Enter Distance Match Spread Flag Limit <.050>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.CON file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option (24) - Angles Flag Limit

Option Twenty-four allows for the entry of an angular error flag. Entering **[24]** and then pressing the **[ENTER]** key displays the prompt *"Enter Angle Match Spread Flag Limit (Sec.) <10.0>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.CON file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

Option (25) - Elevation Differences Flag Limit

Option Twenty-five allows for the entry of an elevation difference error flag. Entering **[25]** and then pressing the **[ENTER]** key displays the prompt *"Enter Elevation Difference Match Spread Flag Limit <.020>.* The default entry is displayed in angle brackets following the prompt and this value is read directly from the DEFAULT.CON file. Enter the desired value and press the **[ENTER]** key or just press the **[ENTER]** key to accept the default value.

It is important to remember that if any changes are made via the processing menu, the new values are written to the DEFAULT.CON file and will remain in effect until changed again. These new values remain in effect even if a different segment is selected for processing..

Expanded Discussion Of Some EFBP Options

The following is an expanded discussion of several processing menu features.

Earth Curvature / Atmospheric Refraction Correction

Regarding earth curvature and atmospheric refraction, it is a squared function of the length of the line - a 1000 ft. shot has 4 times (.02 ft) the correction of a 250 ft. shot. (.005 ft.). Thus it is usually smaller than the random error in our trigonometric leveling and this is why not correcting does not create a significant error.

Another reason not to correct it is if someone computes the elevation difference on their calculator without curvature and refraction correction it will not be equal to the value derived from processing with curvature and refraction turned on.

The correction is always positive because of the following:

> Assume a H.I. of zero and a zenith angle of 90°. The further out you go the larger the H.T. will be to keep that "flat" line of sight due to earth curvature. That H.T. which is subtracted must be negated with a positive correction to produce an elevation difference of zero. Note, it is possible with the correction for residuals to get a little worse. This simply shows the random error is bigger than the correction.

Robustness

Robustness is a re-weighting strategy which can be used to find blunders as "the weak get weaker and the strong get stronger." Assume when the 2-D least squares runs two angles have error estimates of 5 seconds and 30 seconds respectively, and the residuals are 45 seconds and 3 seconds respectively. When you robust the new error estimate of the first angle will be (5 + 45) ÷ 2 = 25 seconds and the second angle will be (30 + 3) ÷ 2 = 16.5 seconds. The adjustment process re-runs with the new error estimates.

Robustness should only be used as a tool in blunder detection, not for the production of final coordinates. It will not usually find real huge blunders as caused by station naming. If you have robustness turned on at the end of the least squares portion of LEVEL and LSAQ, you will asked if you want to re-weight.

Answering **[Y]** (yes) to this performs the robustness on all measurements and the least squares re-runs. All measurements are robusted (control, elevation difference, distances, angles, azimuths) though, in an update, EFBP could be allowed to do things like only robust distances.

You can robust as many times as you want. If the standard error of unit weight drops significantly following robusting, this may be taken as a sight that robustness has discovered the error(s) in the data set. The data contained in the .XYZ file will reflect the coordinates from the last robustness but the standard deviations and error ellipses shown will be from the first least squares adjustment. You are probably going to re-process without robusting for your last run anyway.

Different PPM In Error Estimation For Horiz. Distances And Trig. Elevation Differences

We all know longer lines get worse faster in elevation differences than horizontal distances. Assume trig. leveling and horizontal distance ppm's are 30 and 1 respectively. Thus the 30 vs. 1 means a ppm add-on for a 300 ft. and a 3000 ft. line are horizontally (0.0003 ft. vs. .003 ft.) and vertically (.009 ft. vs. .09 ft.). This will allow you to shoot HVD mode (not HD) on long lines as the larger error estimate on the long line elevation differences will make it have less affect on your final coordinates. This is the power of effective error estimation.

Set-up Error

The setup error is applied in such a manner that short lines get a bigger effect - long lines will get essentially no effect. This is again very effective as you do not want small error estimates on 50 ft. backsights or foresights. A .005 ft. setup error amounts to 21 sec. of error in 50 ft., 2 sec. in 500 ft., and 0.2 sec. in 5000 ft. (tangent inverse function). The setup error is always applied so if you do not like it make it zero. One way to think of setup error is in terms of your ability to set up over a point with your tripod, tribrach, and optical plummet.

Chapter Seven - The .GEN File Format

During the various data processing stages, EFBP generates reports which indicate the results of each processing level. The first report presented during the processing of an .OBS file is the .GEN file. The .GEN file details the abstracting results and the preliminary coordinates computed during the first processing step. These preliminary coordinates will be used during the least squares adjustment processing step. The size of the .GEN file will vary with the size of the .OBS file.

A 1726 station topographic route job is used as an example for the following processing reports. Note, this example project is a metric job so all numerical values which reference coordinates, elevations, elevation differences, distances, etc. are in meters. The definition of metric units made in the control (.CTL) file, is reported in the horizontal least squares (.2d) report, and final coordinates are labeled as metric in the final coordinate (.XYZ) and station-offset-elevation (.SOE) files. The first report (.GEN) details abstracting and preliminary coordinate generation. For a job this large the .GEN report is lengthy so only key items are shown here as they represent all the types of information generally shown in this report.

The format of the .GEN file is as follows :

```
PROJECT EXAMP    PARAMETERS
USE REPETITION ERRORS PLUS ADD-ONS IN ERROR ESTIMATION
COMPUTE COORDINATE STANDARD ERRORS AND ERROR ELLIPSES
CORRECT FOR EARTH CURVATURE AND ATMOSPHERIC REFRACTION
ROBUST ERROR ESTIMATE PROMPT WILL NOT APPEAR
PROCESS TO FINAL COORDINATE .XYZ FILE

FOLLOWING USED AS ADD-ONS TO ERROR FROM REPETITION
DISTANCE   DISTANCE     HORZ.     AZIMUTH   TRIG. LEV.   TRIG. LEV.  DIFF. LEV
CONSTANT     PPM     ANGLE (SEC)   (SEC)     CONSTANT        PPM      CONSTANT
     .005      5.00       6.0         10.0       .010        50.00        .010

FOLLOWING ARE USER DEFINED ERROR ESTIMATES
  DISTANCE   DISTANCE     HORZ.      AZIMUTH    TRIG. LEV.   DIFF. LEV.
  CONSTANT     PPM     ANGLE (SEC)    (SEC)      CONSTANT     CONSTANT
      .007       5.00         12.0       10.0         .030         .010

SETUP ERROR (ALWAYS USED) =   .002
FLAG MAXIMUM SPREADS ABOVE
(23) DISTANCE =   .020 (24) ANGLES =   20.0 (25) ELEV. DIFFERENCES =   .030
HORZ. COLLIMATION CORRECTION =     -4.7 SECONDS
VERT. COLLIMATION CORRECTION =     -3.8 SECONDS
HORIZONTAL POINTING STANDARD ERROR  (DIRECT) =       5.0  SECONDS
  VERTICAL POINTING STANDARD ERROR  (DIRECT) =       2.1  SECONDS
HORIZONTAL POINTING STANDARD ERROR (REVERSE) =       5.0  SECONDS
  VERTICAL POINTING STANDARD ERROR (REVERSE) =       3.8  SECONDS
```

```
PROCESSING SETUP #   1 AT STATION A1
REPETITION ERROR ON MULTIPLE POINTING TO STATION A2       IS       1.0  SEC.
REPETITION ERROR ON MULTIPLE POINTING TO STATION A2       IS        .0  SEC.
REPETITION STANDARD ERRORS
SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.          COMPARE
STATION      SD     SD     MAX        SD    SD      MAX      HORZ.     ELEV.
                  (MEAN)  SPREAD         (MEAN)   SPREAD     DIST.     DIFF.
A2          .001    .000    .001     .008   .004     .010
REPETITION STANDARD ERRORS FOR ANGLES
BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
WARNING - CALIBRATION RECORD WITHOUT DATA

PROCESSING SETUP #   2 AT STATION A1
REPETITION ERROR ON MULTIPLE POINTING TO STATION A2       IS        .0  SEC.
REPETITION ERROR ON MULTIPLE POINTING TO STATION A2       IS       1.0  SEC.
REPETITION STANDARD ERRORS
SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.          COMPARE
STATION      SD     SD     MAX        SD    SD      MAX      HORZ.     ELEV.
                  (MEAN)  SPREAD         (MEAN)   SPREAD     DIST.     DIFF.
A2          .001    .000    .001     .005   .002     .007     -.004      .005
REPETITION STANDARD ERRORS FOR ANGLES
BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD

PROCESSING SETUP #   3 AT STATION A1
REPETITION ERROR ON MULTIPLE POINTING TO STATION A2       IS       4.0  SEC.
REPETITION ERROR ON MULTIPLE POINTING TO STATION A2       IS       8.0  SEC.
REPETITION STANDARD ERRORS
SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.          COMPARE
STATION      SD     SD     MAX        SD    SD      MAX      HORZ.     ELEV.
                  (MEAN)  SPREAD         (MEAN)   SPREAD     DIST.     DIFF.
A2          .000    .000    .001     .005   .002     .007     -.002      .012
REPETITION STANDARD ERRORS FOR ANGLES
BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD

PROCESSING SETUP #   1 AT STATION A2
REPETITION ERROR ON MULTIPLE POINTING TO STATION A1       IS       4.0  SEC.
REPETITION ERROR ON MULTIPLE POINTING TO STATION A1       IS       1.0  SEC.
REPETITION ERROR ON MULTIPLE POINTING TO STATION BM1      IS       7.0  SEC.
REPETITION ERROR ON MULTIPLE POINTING TO STATION BM1      IS       4.0  SEC.
REPETITION STANDARD ERRORS
SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.          COMPARE
STATION      SD     SD     MAX        SD    SD      MAX      HORZ.     ELEV.
                  (MEAN)  SPREAD         (MEAN)   SPREAD     DIST.     DIFF.
A1          .001    .001    .002     .005   .003     .008      .000  *  -.042*
BM1         .000    .000    .000     .001   .000     .001
REPETITION STANDARD ERRORS FOR ANGLES
BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
A1             BM1             2.        1.          1.
```

```
1714 OF  1726 STATIONS ARE HORIZONTAL SIDESHOTS
TRAVERSE CLOSURE REPORT
LINEAR ERROR OF CLOSURE IS         .048 FT.

PRECISION IS 1/       17355.


STATION                    X COOR.         Y COOR.

A2                      495149.598      128318.648
TRAV1                   495281.157      128298.531
A3                      495980.147      128287.811

TRAVERSE CLOSURE REPORT
LINEAR ERROR OF CLOSURE IS         .051 FT.

PRECISION IS 1/       16398.


STATION                    X COOR.         Y COOR.

A2                      495149.598      128318.648
TRAV2                   495631.118      128293.637
A3                      495980.147      128287.811


STATION  BM1      HAS COORDINATES GENERATED BY ANGLE AND DISTANCE
FROM KNOWN BACKSIGHT
X=   495201.372 Y=   128318.744


STATION  BM7      HAS COORDINATES GENERATED BY ANGLE AND DISTANCE
FROM KNOWN BACKSIGHT
X=   496993.652 Y=   128259.200
```

FINAL GENERATED COORDINATES

STATION	X COOR.	Y COOR.
A1	494886.316	128284.789
A2	495149.598	128318.648
A3	495980.147	128287.811
A4	496811.525	128276.865
A5	497318.565	128280.773
BM1	495201.372	128318.744
TRAV1	495281.157	128298.531
TRAV2	495631.118	128293.637
TRAV3	496404.186	128282.819
BM7	496993.652	128259.200
TRAV4	497080.913	128272.918
TRAV5	497330.332	128286.047

DISTANCE RESIDUALS

DISTANCE		RESIDUAL
A1	- A2	.016
A2	- BM1	.000
A2	- TRAV1	.008
TRAV1	- A3	.040
TRAV1	- BM1	.004
A3	- A2	.046
A3	- TRAV2	.021
TRAV2	- A2	.029
A3	- A4	.042
A3	- TRAV3	.024
TRAV3	- A4	.023
A4	- A5	.030
A4	- BM7	.000
A4	- TRAV4	.016
TRAV4	- A5	.014
TRAV4	- BM7	.013
TRAV4	- TRAV5	.017
TRAV5	- A4	.029
TRAV5	- A5	.001

ANGLE RESIDUALS

ANGLE			RESIDUAL (SEC)
A1	- A2	- BM1	.0
A1	- A2	- TRAV1	-3.1
A2	- TRAV1	- A3	.0
A2	- TRAV1	- BM1	-4.7
A2	- A3	- TRAV2	-1.8
A2	- TRAV2	- A3	.0
A4	- A3	- TRAV2	2.0
A4	- A3	- TRAV3	2.1
A3	- TRAV3	- A4	.0
TRAV3	- A4	- A5	-1.4
TRAV3	- A4	- BM7	.0
TRAV3	- A4	- TRAV4	-8.9
A4	- TRAV4	- A5	.0
A4	- TRAV4	- BM7	-15.0
A4	- TRAV4	- TRAV5	5.4
A4	- TRAV5	- A5	.0

Individual components of this .GEN file will be described in the following sections.

EFBP Setup Parameters

This first section always exists at the start of a .GEN file. It echoes the default parameters which were established in the initial menu of EFBP. This information is critical in the exact reproducibility of final coordinates.

This information includes the project name, processing options, selected add-ons to errors from repetition, user defined error estimates and maximum spread flags. Any maximum spread which exceeds the indicated value will be flagged in the .GEN file with asterisks. This flagging makes detecting errors easier. This information will only be displayed once in the .GEN file and will it always be the first information displayed.

```
PROJECT EXAMP    PARAMETERS
USE REPETITION ERRORS PLUS ADD-ONS IN ERROR ESTIMATION
COMPUTE COORDINATE STANDARD ERRORS AND ERROR ELLIPSES
CORRECT FOR EARTH CURVATURE AND ATMOSPHERIC REFRACTION
ROBUST ERROR ESTIMATE PROMPT WILL NOT APPEAR
PROCESS TO FINAL COORDINATE .XYZ FILE

FOLLOWING USED AS ADD-ONS TO ERROR FROM REPETITION
DISTANCE   DISTANCE     HORZ.     AZIMUTH   TRIG. LEV.   TRIG. LEV.  DIFF. LEV
CONSTANT     PPM     ANGLE (SEC)   (SEC)     CONSTANT       PPM      CONSTANT
     .005      5.00       6.0         10.0       .010        50.00        .010

FOLLOWING ARE USER DEFINED ERROR ESTIMATES
  DISTANCE   DISTANCE     HORZ.      AZIMUTH    TRIG. LEV.   DIFF. LEV.
  CONSTANT     PPM     ANGLE (SEC)    (SEC)      CONSTANT     CONSTANT
      .007       5.00         12.0       10.0         .030         .010

SETUP ERROR (ALWAYS USED) =   .002
FLAG MAXIMUM SPREADS ABOVE
(23) DISTANCE =   .020 (24) ANGLES =   20.0 (25) ELEV. DIFFERENCES =   .030
```

Instrument Calibration

The next section details a typical instrument calibration data entry. The axis test data which is contained in the .OBS file will be reduced and any errors detected will be displayed. The axis test involves sighting a easily identifiable point with the total station at least once with the telescope in the direct mode and once with the telescope in the reverse mode. Ideally, multiple observations of the same target are preferred over single observations.

The Florida Department of Transportation requires at least three (3) observations, consisting of three (3) direct and three (3) reverse observations, be made. Multiple pointings ensure the quality of the calibration data and provides an estimate of the observer's pointing ability. The pointing errors represent the standard deviations of multiple pointings and would be flagged with asterisks if they were above the user defined tolerances in the EFBP default settings.

```
HORZ. COLLIMATION CORRECTION =     -4.7 SECONDS
VERT. COLLIMATION CORRECTION =     -3.8 SECONDS
HORIZONTAL POINTING STANDARD ERROR  (DIRECT) =       5.0  SECONDS
  VERTICAL POINTING STANDARD ERROR  (DIRECT) =       2.1  SECONDS
HORIZONTAL POINTING STANDARD ERROR (REVERSE) =       5.0  SECONDS
  VERTICAL POINTING STANDARD ERROR (REVERSE) =       3.8  SECONDS
```

If the instrument was in perfect calibration and the instrument operator was perfect in pointing at the selected target, the sum of the zenith circle readings in direct and reverse would be 360° 0' 0". Similarly, the direct and reverse horizontal circle readings would differ by exactly 180° 0' 0". Normally, there will be some small error present no matter how perfect the instrument operator attempts to be.
EFBP reduces individual horizontal circle readings to horizontal angles uniquely for each position number and face (direct or reverse) before averaging. This process cancels the effects of horizontal collimation error. The calibration corrections in the vertical direction are much more critical due to our inability to level trigonometrically as precisely as we measure horizontally.
The displayed corrections are computed by taking one-half of the difference between the average of the direct observations and the average reverse observations. Corrections are computed for both the observed horizontal and vertical angles. Consistent high corrections would indicate a total station in need of service and adjustment or an instrument operator in need of service and adjustment.

The computed corrections are applied to each observation which follows the axis test in the .OBS file until the next calibration and axis test is encountered. At that point, the computed corrections from the next axis test are held until the next axis test is encountered and so forth. If only one axis test is encountered, it's computed corrections will be applied to all observations within the file.

If a calibration without an axis test is encountered, is will be indicated in the .GEN file in the following manner :

```
WARNING - CALIBRATION RECORD WITHOUT DATA
```

This message only serves as a warning and will not have any effect on the continuation of the processing.

Observation Data Reduction

The next section details a typical setup and it's associated observations. Each setup will be identified by its point name and will be further identified as the setup number for that station name. The setup number feature is very useful in reviewing the .GEN file as it allows specific setups to be identified quickly and easily. As an example, consider a situation where a problem exists in the third setup at station A15. Using the search features found in most text editors, one could quickly move past the first two setups at A15 in the .OBS file to reach the problem third setup at A15.

```
PROCESSING SETUP #   1 AT STATION A2
REPETITION ERROR ON MULTIPLE POINTING TO STATION A1       IS       4.0  SEC.
REPETITION ERROR ON MULTIPLE POINTING TO STATION A1       IS       1.0  SEC.
REPETITION ERROR ON MULTIPLE POINTING TO STATION BM1      IS       7.0  SEC.
REPETITION ERROR ON MULTIPLE POINTING TO STATION BM1      IS       4.0  SEC.
REPETITION STANDARD ERRORS
SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.          COMPARE
STATION      SD      SD      MAX        SD    SD       MAX      HORZ.     ELEV.
                 (MEAN)  SPREAD          (MEAN)   SPREAD     DIST.     DIFF.
A1          .001    .001    .002     .005   .003     .008      .000  *  -.042*
BM1         .000    .000    .000     .001   .000     .001
REPETITION STANDARD ERRORS FOR ANGLES
BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
A1             BM1             2.        1.          1.
```

Immediately following the setup record, repetition error on multiple pointing information will be found, provided multiple pointings to any one point occurred at the given setup. These repetition errors represent the difference in horizontal circle reading between two pointings with the same position set number with the same telescope orientation. In the above example, this setup was occupied for a long time while collecting a significant amount of topographic detail. As a check, the instrument operator routinely re-observed the backsight to assure that the horizontal circle or instrument setup has not been disturbed. In this case, the instrument operator was using point A1 as a horizontal backsight and BM1 for a vertical backsight. The displayed multiple pointing spreads would be asterisked if they were found to be above user defined tolerances. It is important to note that this multiple pointing error is with respect to horizontal circle readings, *not* horizontal angles.

Following the repetition errors on multiple pointings results in the setup report are repetition errors which resulted from multiple observations where the observation values are reduced to horizontal distances, elevation differences (mark to mark elevation difference), and horizontal angles. During this reduction process, EFBP selects as the backsight station, the point which has been observed the highest number of times, from that setup. If different points were observed the same number of times, the point name which appears first in the list of observed points for that setup is selected as the backsight as that generally is the first station sighted in chronological order.

Repetition errors are computed by way of a simple averaging process. Given to the ability to correct observations for instrument systematic errors based upon a calibration and axis test, direct and reverse readings are treated as individual observations. This is done since they are corrected for instrument systematic errors. Older averaging procedures used to average common direct and reverse readings, and then average those values, because instrument calibration values were not automatically being corrected. While standard errors are important, the maximum spread, or max. spread, is more useful in blunder detection as it reports the largest deviation of any single observation of a point from the average of all of the observation the point. This value would also be asterisked if it were above user defined tolerance level.

Number Of Horizontal Sideshots

Once all of the observation data has been reduced, EFBP will determine how many of the observations were sideshots. This message is an important indicator of the validity of the survey data. Normally, the surveyor is generally able to estimate how many traverse stations exist in the .OBS file. If this indicator appears to be incorrect, a station naming problem usually exists. Station naming problems often causes stations to be "connected" to stations in the .OBS file which cannot be possible, based on your knowledge of the field survey.

```
  1714 OF  1726 STATIONS ARE HORIZONTAL SIDESHOTS
```

A horizontal sideshot is defined as a point without horizontal control coordinates that is attached to only one other point by means of one angle and one distance measurement. A spur traverse (a series of setups ending in a sideshot) is recognized as all sideshots because the processing algorithm "peels" sideshots in an iterative fashion until no sideshots remain.

Traverse Closure Report

The next section details a typical traverse closure report. Once all of the sideshots have been removed, EFBP is required to identify how to generate coordinates on all of the remaining points. This is necessary as the horizontal least squares adjustment needs preliminary or approximate coordinates for all of the unknown stations. The processing algorithm generates preliminary coordinates independent of the order in which the data was collected and can handle any combination of any type of loop traverse, link traverse, intersection, or resection. The preliminary coordinate generator tries to find closure routes as an aid to the user in blunder detection..

```
TRAVERSE CLOSURE REPORT
LINEAR ERROR OF CLOSURE IS         .048 M.

PRECISION IS 1/       17355.


STATION                    X COOR.         Y COOR.

A2                       495149.598      128318.648
TRAV1                    495281.157      128298.531
A3                       495980.147      128287.811

TRAVERSE CLOSURE REPORT
LINEAR ERROR OF CLOSURE IS         .051 M.

PRECISION IS 1/       16398.


STATION                    X COOR.         Y COOR.

A2                       495149.598      128318.648
TRAV2                    495631.118      128293.637
A3                       495980.147      128287.811


STATION  BM1      HAS COORDINATES GENERATED BY ANGLE AND DISTANCE
FROM KNOWN BACKSIGHT
X=   495201.372 Y=   128318.744


STATION  BM7      HAS COORDINATES GENERATED BY ANGLE AND DISTANCE
FROM KNOWN BACKSIGHT
X=   496993.652 Y=   128259.200
```

Note in the above example two closure routes were found. Points BM1 and BM7 were not traversed through and thus are not on a closure route but they were observed from more than one setup and are therefore redundant in nature. In that situation, preliminary coordinates are generated for that station from one of the setups on which it was sighted

A poor misclosure on one traverse can generate poor closures on subsequent traverses even though all of the subsequent traverses have good data. One should always look for a problem on the first poor traverse and correct that problem. Once the problem has been identified and corrected, it will be necessary to re-process the data before evaluating those subsequent traverses. The reason for this is best explained by example. A traverse through the points A1-A2-A3-A4-A5, where A1 and A5 are control points or have existing preliminary coordinates, reports a poor closure. The coordinates on a link traverse, which are always subjected to a compass rule adjustment at this stage and will result in poor coordinates due to the poor closure.

A subsequent traverse through the points A2-B1-B2-A3 could have good measurements but an apparent poor closure due to the end point's coordinates being generated from a bad traverse. The identification and correction of the problem in the first traverse link, followed by re-processing, will provide suitable coordinates for A2 and A3 from the first traverse, and thus suitable closures on the subsequent traverse.

Compass Rule Residuals

When coordinate generation for every redundant station is complete, all redundant measurements are compared to the preliminary coordinates in generating pre-least squares residuals (the difference between what you measured and the value as derived from the coordinates. On measurements that existed on traverses the residual is due to the compass rule adjustment. In the case of unique solutions such as the angle-distance combinations for BM1 and BM7, the measurements used to compute that point's coordinates will have zero residuals as they were used in unique determination of those coordinates. The other measurements to BM1 and BM7 will contain pre-adjustment residuals as they were not used in the coordinate computation. If those measurements have large residuals, the problem could be in either the measurements used to determine the coordinates or in the ones that were not used.

DISTANCE RESIDUALS

DISTANCE		RESIDUAL
A1	- A2	.016
A2	- BM1	.000
A2	- TRAV1	.008
TRAV1	- A3	.040
TRAV1	- BM1	.004
A3	- A2	.046
A3	- TRAV2	.021
TRAV2	- A2	.029
A3	- A4	.042
A3	- TRAV3	.024
TRAV3	- A4	.023
A4	- A5	.030
A4	- BM7	.000
A4	- TRAV4	.016
TRAV4	- A5	.014
TRAV4	- BM7	.013
TRAV4	- TRAV5	.017
TRAV5	- A4	.029
TRAV5	- A5	.001

ANGLE RESIDUALS

ANGLE			RESIDUAL (SEC)
A1	- A2	- BM1	.0
A1	- A2	- TRAV1	-3.1
A2	- TRAV1	- A3	.0
A2	- TRAV1	- BM1	-4.7
A2	- A3	- TRAV2	-1.8
A2	- TRAV2	- A3	.0
A4	- A3	- TRAV2	2.0
A4	- A3	- TRAV3	2.1
A3	- TRAV3	- A4	.0
TRAV3	- A4	- A5	-1.4
TRAV3	- A4	- BM7	.0
TRAV3	- A4	- TRAV4	-8.9
A4	- TRAV4	- A5	.0
A4	- TRAV4	- BM7	-15.0
A4	- TRAV4	- TRAV5	5.4
A4	- TRAV5	- A5	.0

Pre-adjustment residuals should be used with some care as their magnitude can be misleading. A series of traverse closures in a compass rule adjustment lead to error accumulation in the coordinates that compounds, so later traverses and their measurements will appear of less quality than they possibly are. The simultaneous least squares adjustment, where there is no "hierarchy" of traverse routes, will allow this apparent error accumulation to be removed.

Chapter Eight - The .1D File Format

The next report presented during the processing of an .OBS file is the .1D file. The .1D file details the results of the vertical least squares adjustment. The size of the .1D file will vary with the number of setups used and the number of observations of benchmarks or vertical control points.

The following .1D file was produced by processing the one thousand seven hundred and twenty-six (1,726) point topographic survey using the EFBP processors. Note, this is derived from a different data set that the previous .GEN file. This .1D file also contain results based upon a *metric* job. The key sections of the .1D file will be discussed here. These key sections generally represent all of the types of information one might encounter while reviewing a .1D file.

The format of the .1D file is as follows :

```
MISCLOSURE OF MULTIPLE ELEV. DIFFERENCE MEASUREMENTS
  STATIONS           MISCLOSURE
A1       - A2              .005
A1       - A2              .010
A1       - A2              .008
A3       - TRAV2           .010
A3       - TRAV2           .000
A3       - TRAV2           .001
A3       - TRAV2           .008
A3       - TRAV2           .004
A3       - TRAV2           .008
TRAV3    - A4              .005
A3       - TRAV3           .026
A4       - TRAV4           .003
A4       - TRAV4           .005
A4       - TRAV4           .018
A4       - TRAV4           .012
A3       - TRAV3           .006
A3       - TRAV3           .002
END OF MISCLOSURE REPORT

 1708 OF  1726 STATIONS IDENTIFIED AS VERTICAL SIDESHOTS
BAND IS  10 STATIONS
LEVEL NETWORK ADJUSTMENT

NUMBER OF BENCHMARKS =     9
NUMBER OF STATIONS =    18
NUMBER OF MEASUREMENTS =    25
NUMBER OF REQUIRED TERMS FOR NORMAL EQUATIONS =      188
```

RESULTS OF ADJUSTMENT

BENCHMARK ELEVATION RESIDUALS

STATION	INPUT ELEV.	ADJUSTED ELEV.	ERROR EST.	RESIDUAL
A1	9.211	9.211	.001	.000 (.0)
BM1	10.101	10.101	.001	.000 (.0)
BM2	7.448	7.448	.001	.000 (.0)
BM3	9.114	9.114	.001	.000 (.0)
BM4	8.996	8.996	.001	.000 (.0)
BM5	8.898	8.898	.001	.000 (.0)
BM6	9.715	9.715	.001	.000 (.0)
BM7	9.717	9.717	.001	.000 (.0)
BM8	8.252	8.252	.001	.000 (.0)

BENCHMARK RMS ERROR = .000 SNOOP RMS = .0
MAX. BENCHMARK RESIDUAL AT STATION BM1 OF .000

RESIDUALS

FROM	TO	MEASURED	RESIDUAL	EST. ERROR
A1	A2	.918	.003 (.2)	.013
A2	BM1	-.034	.003 (.2)	.013
A2	TRAV1	-.707	.005 (.4)	.012
TRAV1	A3	-.539	.043 (.9)	.049
TRAV1	BM1	.669	.002 (.2)	.015
A3	A2	1.172	.028 (.5)	.058
A3	TRAV2	-.115	.007 (.6)	.013
TRAV2	A2	1.274	.033 (.9)	.039
TRAV2	BM2	-1.374	-.003 (.1)	.019
TRAV2	BM3	.289	.000 (.0)	.019
A3	A4	.914	.068 (1.2)	.059
A3	TRAV3	-.002	-.016 (.9)	.017
TRAV3	A4	1.008	-.007 (.3)	.021
TRAV3	BM4	.090	-.008 (.3)	.030
TRAV3	BM5	-.012	-.005 (.4)	.013
A4	A5	-1.455	.038 (.8)	.049
A4	BM6	-.201	.000 (.0)	.018
A4	BM7	-.202	.003 (.1)	.022
A4	TRAV4	-1.044	.001 (.1)	.013
TRAV4	A5	-.374	.000 (.0)	.025
TRAV4	BM7	.846	-.001 (.1)	.015
TRAV4	TRAV5	-.516	.006 (.2)	.026
TRAV5	A4	1.507	.046 (1.1)	.043
TRAV5	A5	.138	-.002 (.2)	.011
TRAV2	BM8	-.584	.012 (.6)	.020

ELEV. DIFF. RMS ERROR = .022 SNOOP RMS = .5
MAX. ELEV. DIFF. RESIDUAL A3 - A4 OF .068

```
95% CONFIDENCE F STATISTIC STANDARD ERROR MULTIPLIER FOR   16 D.F. IS  2.71

   STATION        ADJUSTED ELEV.     STANDARD ERROR

   A1                      9.211               .002
   A2                     10.132               .014
   BM1                    10.101               .002
   TRAV1                   9.429               .019
   A3                      8.933               .022
   TRAV2                   8.825               .018
   A4                      9.915               .018
   TRAV3                   8.914               .018
   BM2                     7.448               .002
   BM3                     9.114               .002
   BM8                     8.252               .002
   A5                      8.498               .035
   BM6                     9.715               .002
   BM7                     9.717               .002
   TRAV4                   8.872               .021
   TRAV5                   8.362               .035
   BM4                     8.996               .002
   BM5                     8.898               .002

    STANDARD ERROR OF UNIT WEIGHT IS       .666
     WITH   16 DEGREES OF FREEDOM

CHI SQUARED TEST ON ANALYSIS
  .657 <   .666 <  1.282
  (LOW)             (HIGH)
PASSES AT THE 5 % SIGNIFICANCE LEVEL
```

Individual components of this .1D file will be described in the following sections.

Compare Same Line On Different Setups

While elevation differences in the .GEN report are compared to the first setup's values for that line, in this report the comparisons in this report are made to the existing weighted average for that elevation difference.

```
MISCLOSURE OF MULTIPLE ELEV. DIFFERENCE MEASUREMENTS
  STATIONS           MISCLOSURE
A1       - A2              .005
A1       - A2              .010
A1       - A2              .008
A3       - TRAV2           .010
A3       - TRAV2           .000
A3       - TRAV2           .001
A3       - TRAV2           .008
A3       - TRAV2           .004
A3       - TRAV2           .008
TRAV3    - A4              .005
A3       - TRAV3           .026
A4       - TRAV4           .003
A4       - TRAV4           .005
A4       - TRAV4           .018
A4       - TRAV4           .012
A3       - TRAV2     *     .051*
A3       - TRAV3           .006
A3       - TRAV3           .002
END OF MISCLOSURE REPORT
```

Note that the tolerance was set at 0.03 m. for asterisks on elevation difference comparisons, and one appears larger than that. In this case, this was not cause for alarm as it is on a long line (407 meters) which was being used as a horizontal backsight, and the long line relates to a larger error estimate in the least squares analysis. Thus the long lines have fairly minimal weight in the least squares analysis. Some lines were measured many times as they served as backsights for several setups on the same point for large amounts of topographic data collection.

Number Of Sideshots, Bandwidth, And Adjustment Network Size

Sideshots are non-benchmarks which are connected to only one other station. Spurs are removed by eliminating the legs of the spur(s) in an iterative fashion until all non-benchmarks are connected to at least two other stations. The surveyor is usually aware of approximately how many redundant elevations points should exist. Station misnaming is usually the problem when this number is incorrect. Note the number of horizontal sideshots may not equal the number of vertical sideshots as the location and number of horizontal vs. vertical control points could vary, and thus the redundant portion of the survey can contain different stations.

```
 1708 OF  1726 STATIONS IDENTIFIED AS VERTICAL SIDESHOTS
BAND IS  10 STATIONS
LEVEL NETWORK ADJUSTMENT

NUMBER OF BENCHMARKS =     9
NUMBER OF STATIONS =    18
NUMBER OF MEASUREMENTS =    25
NUMBER OF REQUIRED TERMS FOR NORMAL EQUATIONS =      188
```

The band is an indicator of the size of the equations required for the vertical least squares analysis, and is thus an indicator to a user how long the solution will take to be resolved. The normal equations are the equations that are solved in least squares, and its number of terms is a function of the bandwidth and the number of stations. The time required for the solution to resolve is also a function of the number of stations and the processing speed of your computer. The remaining information is simply some numeric information regarding the size of the survey. The number of measurements is reflected after weighted averaging has created one elevation difference for every line in the survey network.

Benchmark Adjustment Information

This portion reflects the benchmarks. Note through the use of error estimates in the .CTL file for benchmarks it is possible to allow them to be treated as a measurement in the adjustment instead of an absolutely fixed value. This would allow the benchmark elevations to adjust based on the least squares, and thus a residual (amount of adjustment) will appear.

BENCHMARK ELEVATION RESIDUALS

STATION	INPUT ELEV.	ADJUSTED ELEV.	ERROR EST.	RESIDUAL
A1	9.211	9.211	.001	.000 (.0)
BM1	10.101	10.101	.001	.000 (.0)
BM2	7.448	7.448	.001	.000 (.0)
BM3	9.114	9.114	.001	.000 (.0)
BM4	8.996	8.996	.001	.000 (.0)
BM5	8.898	8.898	.001	.000 (.0)
BM6	9.715	9.715	.001	.000 (.0)
BM7	9.717	9.717	.001	.000 (.0)
BM8	8.252	8.252	.001	.000 (.0)

The 0.001 m error estimate reflects the benchmarks are to be held fixed (because 0.001 m is a very low error estimate compared to the error estimates on the elevation differences). The number in the parenthesis is the *snoop number*, which is the absolute value of the residual divided by the error estimate. Snoop numbers larger than 3.0 are asterisked as that reflects a high level of certainty that something is wrong with the data as the residual is more than three times larger than its error estimate.

Snoop Number

Looking at a large number of residuals and error estimates is difficult as one has to mentally make the association of magnitude of the two quantities. To simplify this in both the .1D and .2D least squares reports snoop numbers are associated with all measurements. A ***snoop number*** is the absolute value of the residual divided by the error estimate. If the residual is larger than the error estimate the snoop number is greater than one, and a residual which is smaller than the error estimate produces a snoop number less than one. Snoop numbers greater than three are flagged with asterisks to highlight a potential problem. Usually a series of flagged residuals can be traced to a single problem, and the asterisks go away once the problem is resolved and reprocessing occurs.

The best part of the snoop number concept is how it relates to measurements of the same type which have different error estimates. Let us revisit the example consider two angle residuals of 10 and 60 seconds respectively. At first it looks like the second is much worse than the first and is indicative of a blunder. But the 10 second residual is associated with a 4 second error estimate because of long sight distances, while the 60 second residual has a 12 ft. backsight distance and a 14 ft. foresight distance which created an error estimate (mostly due to setup error) of 80 seconds. The 10 second residual would produce a snoop number of 2.5, and the 60 second residual would produce a snoop number of 0.75. The snoop number shows the 10 second residual indicates a worse observation than the 60 second residual. The 2.5 snoop number is usually regarded as acceptable, but is nearing the concern magnitude and thus may warrant some investigation.

Note a large blunder can often create several other measurements to be asterisked. The definitions of snoop number, residual, and error estimate are consistent for all types of measurements in the .1D and .2D reports

Benchmark RMS Errors and Maximum Benchmark Residual

RMS is an abbreviation for root-mean-square. RMS error is the square root of the sum of the squares of the residuals divided by the number of measurements for that particular type of measurement. It can thus simply be described as a form of average residual. The snoop RMS is the equivalent computation for the snoop numbers for that type of measurement.

```
BENCHMARK RMS ERROR =       .000 SNOOP RMS =   .0
MAX. BENCHMARK RESIDUAL AT STATION         BM1      OF       .000
```

The maximum residual is the largest residual in an absolute sense (independent of error estimates and sign).

Definitions of RMS error and maximum residual are consistent for all types of measurements in the .1D and .2D reports

Elevation Difference Information

The elevation difference station names, measurements (weighted average for lines observed multiple times), elevation difference, residual, snoop number, and error estimate are presented. Everything is self-explanatory except for possibly error estimates. The general concept of error estimation is explained elsewhere in this user's guide.

RESIDUALS

FROM	TO	MEASURED	RESIDUAL		EST. ERROR
A1	A2	.918	.003	(.2)	.013
A2	BM1	-.034	.003	(.2)	.013
A2	TRAV1	-.707	.005	(.4)	.012
TRAV1	A3	-.539	.043	(.9)	.049
TRAV1	BM1	.669	.002	(.2)	.015
A3	A2	1.172	.028	(.5)	.058
A3	TRAV2	-.115	.007	(.6)	.013
TRAV2	A2	1.274	.033	(.9)	.039
TRAV2	BM2	-1.374	-.003	(.1)	.019
TRAV2	BM3	.289	.000	(.0)	.019
A3	A4	.914	.068	(1.2)	.059
A3	TRAV3	-.002	-.016	(.9)	.017
TRAV3	A4	1.008	-.007	(.3)	.021
TRAV3	BM4	.090	-.008	(.3)	.030
TRAV3	BM5	-.012	-.005	(.4)	.013
A4	A5	-1.455	.038	(.8)	.049
A4	BM6	-.201	.000	(.0)	.018
A4	BM7	-.202	.003	(.1)	.022
A4	TRAV4	-1.044	.001	(.1)	.013
TRAV4	A5	-.374	.000	(.0)	.025
TRAV4	BM7	.846	-.001	(.1)	.015
TRAV4	TRAV5	-.516	.006	(.2)	.026
TRAV5	A4	1.507	.046	(1.1)	.043
TRAV5	A5	.138	-.002	(.2)	.011
TRAV2	BM8	-.584	.012	(.6)	.020

For elevation differences, the error estimate is generally derived from the repetition error (if measured more than once from the same setup), number of distinct measurements which have been averaged in a weighted procedure, and user defined constant and ppm (parts per million) error estimates. The ppm places larger error estimates on longer lines which is very logical in trigonometric leveling as vertical error increases on longer lines.

Of specific interest is that the magnitude of the asterisked values in the multiple elevation difference measurement comparison is not reflected as predominately in the least squares residuals. The weighted averaging process, especially when lines are measured in both directions, eliminates a major portion of this apparent misclosure.

Elevation Difference and Maximum Elevation Difference

These parameters are the same in nature for elevation differences as they were for benchmark elevations.

```
ELEV. DIFF.  RMS ERROR =       .022 SNOOP RMS =   .5
MAX. ELEV. DIFF. RESIDUAL         A3       -         A4       OF       .068
```

Note the elevation difference (or any other) measurement RMS error does not reflect the difference in error estimates of measurements of that type. The snoop RMS is thus a better indicator of the overall relation of residuals to error estimates for that particular measurement type.

F Multiplier, Adjusted Elevations, and Elevation Standard Errors

The F-statistic multiplier is applied to all one sigma standard errors of final elevations in achieving 95% confidence elevation standard errors. As the redundancy (number of degrees of freedom) grows this multiplier decreases because added redundancy provides more confidence in your results. The adjustment's standard error of unit weight is also a multiplier in obtaining final elevation standard errors.

95% CONFIDENCE F STATISTIC STANDARD ERROR MULTIPLIER FOR 16 D.F. IS 2.71

STATION	ADJUSTED ELEV.	STANDARD ERROR
A1	9.211	.002
A2	10.132	.014
BM1	10.101	.002
TRAV1	9.429	.019
A3	8.933	.022
TRAV2	8.825	.018
A4	9.915	.018
TRAV3	8.914	.018
BM2	7.448	.002
BM3	9.114	.002
BM8	8.252	.002
A5	8.498	.035
BM6	9.715	.002
BM7	9.717	.002
TRAV4	8.872	.021
TRAV5	8.362	.035
BM4	8.996	.002
BM5	8.898	.002

Final adjusted elevations and 95 % confidence standard errors (if this option is activated) follow. The meaning of the standard errors is that if you went and performed the same survey again, under the same conditions, you would be 95% confident you would be within the standard error of the adjusted elevation.

Standard Error Of Unit Weight and Degrees Of Freedom

The standard error of unit weight is the square root of the sum of the snoop numbers squared divided by the number of degrees of freedom. If error estimation is being performed reasonably with regards to the quality of the measurements, and no blunders exist, the standard error of unit weight will be near one. Less than one indicates the measurements tend to be of better quality than the error estimates, and greater than one indicates the measurements are of less quality than the error estimates, or blunders exist. It is up to the surveyor to deem if the adjustment is valid through examination of standard error of unit weight, residuals, snoop numbers, and RMS errors.

```
STANDARD ERROR OF UNIT WEIGHT IS       .666
 WITH   16 DEGREES OF FREEDOM
```

The number of degrees of freedom is number of benchmarks plus number of elevation differences minus number of elevations. In our example those numbers are 9, 25, and 18 respectively, so the number of degrees of freedom is 9 + 25 - 18 = 16.

Chi Squared Test

The chi squared test is a test of the validity of the least squares analysis, i.e., do the residuals reflect the quality of the error estimate based on the resultant standard error of unit weight. It is performed at the 5 % significance level which is 95% confidence.

```
CHI SQUARED TEST ON ANALYSIS
  .657 <   .666 <  1.282
  (LOW)             (HIGH)
PASSES AT THE 5 % SIGNIFICANCE LEVEL
```

The high and low values of the range which defines passing the test shrinks as the number of degrees of freedom grows. This is because more redundancy should ensure more consistency in resultant data. Passing anything at 95% confidence is not easy, and thus one should not regard failure of the test as a need to reprocess the data. Use survey judgment in evaluation of residuals, snoop numbers, rms errors, and standard error of unit weight in verifying the suitability of the adjustment.

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Chapter Nine - The .2D File Format

The next report presented during the processing of an .OBS file is the .2D file. The .2D file details the results of the horizontal least squares adjustment. The size of the .2D file will vary with the number of setups used and the number of observations of horizontal control points.

The .2D Least Squares Input Files

The .2d report is generated from two files - the .LSA (measurements) file and the .2SD (error estimates) file. These files are generated by the abstracting and preliminary coordinate generation process of EFBP. The first four components of .LSA and .2SD complement one another. These sections (in order) are control coordinates, horizontal distances, horizontal angles, and azimuths. A line of data ends with a 0 or a 1. A 0 means more of that data type follows, while a 1 designates the end of that data type.

The control coordinate format is station X Y in .LSA, while in .2SD the X,Y error estimates replace the coordinates. The distances are from station, to station, distance (error estimate in .2SD). The angles are backsight station, occupied station, foresight station, degrees, minutes, and seconds. Angle error in seconds replaces the measurement in .2SD. Azimuths are from station, to station, degrees, minutes, and seconds. Azimuth error in seconds replaces the measurement in .2SD. All measurements are not yet reduced to grid if a datum has been selected. The fifth section of .LSA are the horizontal approximate coordinates required for the 2-d least squares to operate. The format is station name, X coordinate, and Y coordinate followed by a 0 or 1 as defined before.

The .LSA file for the presented .2d file follows. Note, no azimuths exist in this job so the station names are zeroes.

```
A1             494886.316       128284.789    0
A2             495149.598       128318.648    0
A3             495980.147       128287.811    0
A4             496811.525       128276.865    0
A5             497318.565       128280.773    1
A1                A2                     265.467    0
A2                BM1                     51.774    0
A2                TRAV1                  133.096    0
TRAV1             A3                     699.112    0
TRAV1             BM1                     82.310    0
A3                A2                     831.167    0
A3                TRAV2                  349.099    0
TRAV2             A2                     482.199    0
A3                A4                     831.492    0
A3                TRAV3                  424.092    0
TRAV3             A4                     407.406    0
A4                A5                     507.085    0
A4                BM7                    182.982    0
A4                TRAV4                  269.433    0
TRAV4             A5                     237.796    0
TRAV4             BM7                     88.345    0
TRAV4             TRAV5                  249.781    0
TRAV5             A4                     518.918    0
TRAV5             A5                      12.896    1
A1         A2          BM1         187 13 18.50 0
A1         A2          TRAV1       196  1 17.25 0
A2         TRAV1       A3          172 11  4.25 0
A2         TRAV1       BM1           5 31 17.00 0
A2         A3          TRAV2       358 49 46.25 0
A2         TRAV2       A3          177 58 58.75 0
A4         A3          TRAV2       180 12  9.25 0
A4         A3          TRAV3       359 55 14.50 0
A3         TRAV3       A4          180  9 47.03 0
TRAV3      A4          A5          178 43 13.88 0
TRAV3      A4          BM7         184 42  8.38 0
TRAV3      A4          TRAV4       179 59 58.13 0
A4         TRAV4       A5          177 16  2.87 0
A4         TRAV4       BM7         350 13 20.88 0
A4         TRAV4       TRAV5       176  8 55.88 0
A4         TRAV5       A5          336 52 17.12 1
0                 0                    0  0    .00   1
BM1                  495201.372            128318.744    0
TRAV1                495281.157            128298.531    0
TRAV2                495631.118            128293.637    0
TRAV3                496404.186            128282.819    0
BM7                  496993.652            128259.200    0
TRAV4                497080.913            128272.918    0
TRAV5                497330.332            128286.047    1
```

The .2SD file follows. Note, the setup error for angles and azimuths is not yet applied to these values which explains why the error estimates in .2d are larger than the error estimates in this file. Also note that the shorter lines receive larger setup error contributions than longer lines.

```
A1             .001       .001    0
A2             .001       .001    0
A3             .001       .001    0
A4             .001       .001    0
A5             .001       .001    1
A1              A2                          .003    0
A2              BM1                         .005    0
A2              TRAV1                       .004    0
TRAV1           A3                          .009    0
TRAV1           BM1                         .006    0
A3              A2                          .010    0
A3              TRAV2                       .003    0
TRAV2           A2                          .007    0
A3              A4                          .010    0
A3              TRAV3                       .004    0
TRAV3           A4                          .004    0
A4              A5                          .008    0
A4              BM7                         .006    0
A4              TRAV4                       .003    0
TRAV4           A5                          .006    0
TRAV4           BM7                         .006    0
TRAV4           TRAV5                       .007    0
TRAV5           A4                          .008    0
TRAV5           A5                          .005    1
A1         A2         BM1          7.17 0
A1         A2         TRAV1        9.25 0
A2         TRAV1      A3           6.25 0
A2         TRAV1      BM1          8.00 0
A2         A3         TRAV2        7.25 0
A2         TRAV2      A3           7.25 0
A4         A3         TRAV2       10.75 0
A4         A3         TRAV3        7.50 0
A3         TRAV3      A4          18.47 0
TRAV3      A4         A5          10.75 0
TRAV3      A4         BM7          9.25 0
TRAV3      A4         TRAV4       11.50 0
A4         TRAV4      A5          10.87 0
A4         TRAV4      BM7          9.87 0
A4         TRAV4      TRAV5        9.88 0
A4         TRAV5      A5           7.13 1
```

The .2D File

The following .2D file was produced by processing the one thousand seven hundred and twenty-six (1,726) point topographic survey using the EFBP processors. The key sections of the .2D file will be discussed here. These key sections generally represent all of the types of information one might encounter while reviewing a .2D file.

The format of the .2D file is as follows :

```
      PARAMETRIC HORIZONTAL LEAST SQUARES ADJUSTMENT

  ALL MEASUREMENTS ARE REDUCED TO THE NAD 90
  0903 FLORIDA NORTH LAMBERT

  COORDINATE AND DISTANCE UNITS ARE METERS
  BAND IS   5 STATIONS
  NUMBER OF TERMS REQUIRED IN NORMAL EQUATIONS =     277

  95% CONFIDENCE F STATISTIC STANDARD ERROR MULTIPLIER FOR   21 D.F. IS  2.64

                        RESULTS OF ADJUSTMENT

                                              STANDARD ERRORS  ERROR ELLIPSE INFO.
  STATION            ADJUSTED X   ADJUSTED Y   IN X    IN Y      SU      SV     T

  A1                 494886.316   128284.789   .001   .001    .001   .001   -7.3
  A2                 495149.598   128318.648   .001   .001    .001   .001   -4.6
  BM1                495201.370   128318.744   .005   .003    .005   .003  -86.5
  TRAV1              495281.157   128298.531   .004   .004    .004   .004  -84.0
  A3                 495980.147   128287.811   .001   .001    .001   .001    1.4
  TRAV2              495631.116   128293.637   .003   .007    .007   .003    1.2
  A4                 496811.525   128276.865   .001   .001    .001   .001     .1
  TRAV3              496404.186   128282.823   .003   .010    .010   .003     .7
  A5                 497318.565   128280.773   .001   .001    .001   .001    -.4
  BM7                496993.644   128259.196   .005   .006    .006   .005   19.0
  TRAV4              497080.913   128272.921   .003   .005    .005   .003     .8
  TRAV5              497330.333   128286.048   .004   .003    .004   .003   59.9

                        RESIDUALS IN THE OBSERVATIONS

                          CONTROL POINT COORDINATES

   STATION           X RESIDUAL  X EST. ERROR  Y RESIDUAL  Y EST. ERROR

   A1                  .000  ( .2)    .001       .000  ( .0)    .001
   A2                  .000  ( .0)    .001       .000  ( .0)    .001
   A3                  .000  ( .1)    .001       .000  ( .0)    .001
   A4                  .000  ( .1)    .001       .000  ( .0)    .001
   A5                  .000  ( .1)    .001       .000  ( .0)    .001

  EASTING CONTROL RMS =      .000 SNOOP RMS =   .1
  MAX. EASTING RESIDUAL AT A1       OF      .000
  NORTHING CONTROL RMS =      .000 SNOOP RMS =   .0
  MAX. NORTHING RESIDUAL AT A4       OF      .000
```

DISTANCES

OCCUPIED STATION	SIGHTED STATION	DISTANCE	RESIDUAL		EST. ERROR
A1	A2	265.453	.002	(.6)	.003
A2	BM1	51.771	-.001	(.2)	.005
A2	TRAV1	133.089	.001	(.3)	.004
TRAV1	A3	699.075	.003	(.3)	.009
TRAV1	BM1	82.305	-.001	(.3)	.006
A3	A2	831.123	.002	(.2)	.010
A3	TRAV2	349.080	.001	(.3)	.003
TRAV2	A2	482.173	.006	(.8)	.007
A3	A4	831.448	-.002	(.2)	.010
A3	TRAV3	424.069	.001	(.3)	.004
TRAV3	A4	407.384	.001	(.4)	.004
A4	A5	507.058	.002	(.3)	.008
A4	BM7	182.972	-.002	(.3)	.006
A4	TRAV4	269.418	.002	(.5)	.003
TRAV4	A5	237.784	.002	(.3)	.006
TRAV4	BM7	88.340	-.002	(.3)	.006
TRAV4	TRAV5	249.768	.002	(.3)	.007
TRAV5	A4	518.890	.000	(.0)	.008
TRAV5	A5	12.895	-.001	(.3)	.005

DISTANCE RMS ERROR = .002 SNOOP RMS = .4
MAX. DISTANCE RESIDUAL TRAV2 - A2 OF .006

ANGLES

BACKSIGHT STATION	OCCUPIED STATION	FORESIGHT STATION	ANGLE	RESIDUAL (SECONDS)		EST. ERROR (SECONDS)
A1	A2	BM1	187-13-18.5	-1.8	(.2)	10.8
A1	A2	TRAV1	196- 1-17.2	-1.9	(.2)	9.9
A2	TRAV1	A3	172-11- 4.2	-1.3	(.2)	7.0
A2	TRAV1	BM1	5-31-17.0	-2.0	(.2)	9.9
A2	A3	TRAV2	358-49-46.2	-1.5	(.2)	7.4
A2	TRAV2	A3	177-58-58.7	.5	(.1)	7.4
A4	A3	TRAV2	180-12- 9.3	2.3	(.2)	10.8
A4	A3	TRAV3	359-55-14.5	3.7	(.5)	7.6
A3	TRAV3	A4	180- 9-47.0	-3.1	(.2)	18.5
TRAV3	A4	A5	178-43-13.9	.2	(.0)	10.8
TRAV3	A4	BM7	184-42- 8.4	-4.1	(.4)	9.6
TRAV3	A4	TRAV4	179-59-58.1	-4.9	(.4)	11.6
A4	TRAV4	A5	177-16- 2.9	-5.1	(.5)	11.1
A4	TRAV4	BM7	350-13-20.9	-3.3	(.3)	11.0
A4	TRAV4	TRAV5	176- 8-55.9	.8	(.1)	10.1
A4	TRAV5	A5	336-52-17.1	-1.8	(.1)	32.8

ANGLE RMS ERROR = 2.8 SECONDS SNOOP RMS = .3
MAXIMUM ANGLE RESIDUAL A4 - TRAV4 - A5
OF 5.1 SEC.

STANDARD ERROR OF UNIT WEIGHT IS .420
WITH 21 DEGREES OF FREEDOM
CHI SQUARED TEST ON ANALYSIS
.700 < .420 < 1.247
(LOW) (HIGH)
DOES NOT PASS AT THE 5 % SIGNIFICANCE LEVEL

TRAVERSE CLOSURE REPORT
SUM OF DISTANCES ALONG TRAVERSE IS 832.164
CLOSURE IN X = -.004 CLOSURE IN Y = -.004
ANGULAR CLOSURE = 1.3 SECONDS
LINEAR ERROR OF CLOSURE (AFTER ROTATION) IS .004
BEFORE ROTATION PRECISION IS 1/ 142855.
AFTER ROTATION PRECISION IS 1/ 216536.

STATION	BEARING	DISTANCE	X	Y
A2			495149.598	128318.648
TRAV1	S81-18-22.4E	133.088	495281.157	128298.531
A3	S89- 7-16.8E	699.073	495980.147	128287.811

```
TRAVERSE CLOSURE REPORT
SUM OF DISTANCES ALONG TRAVERSE IS        831.253
CLOSURE IN X =    -.007 CLOSURE IN Y =     .001
ANGULAR CLOSURE =     -.5 SECONDS
LINEAR ERROR OF CLOSURE (AFTER ROTATION) IS         .007
BEFORE ROTATION PRECISION IS 1/      125075.
AFTER  ROTATION PRECISION IS 1/      126100.

STATION         BEARING       DISTANCE        X            Y

A2                                       495149.598   128318.648
TRAV2        S87- 1-35.8E      482.168   495631.116   128293.637
A3           S89- 2-37.5E      349.079   495980.147   128287.811

---------------------------------------------------
TRAVERSE CLOSURE REPORT
SUM OF DISTANCES ALONG TRAVERSE IS        831.453
CLOSURE IN X =    -.003 CLOSURE IN Y =    -.006
ANGULAR CLOSURE =     3.1 SECONDS
LINEAR ERROR OF CLOSURE (AFTER ROTATION) IS         .003
BEFORE ROTATION PRECISION IS 1/      124017.
AFTER  ROTATION PRECISION IS 1/      323735.

STATION         BEARING       DISTANCE        X            Y

A3                                       495980.147   128287.811
TRAV3        S89-19-33.6E      424.068   496404.186   128282.823
A4           S89- 9-43.4E      407.382   496811.525   128276.865

---------------------------------------------------
TRAVERSE CLOSURE REPORT
SUM OF DISTANCES ALONG TRAVERSE IS        507.202
CLOSURE IN X =    -.003 CLOSURE IN Y =    -.006
ANGULAR CLOSURE =     5.1 SECONDS
LINEAR ERROR OF CLOSURE (AFTER ROTATION) IS         .003
BEFORE ROTATION PRECISION IS 1/       74806.
AFTER  ROTATION PRECISION IS 1/      153355.

STATION         BEARING       DISTANCE        X            Y

A4                                       496811.525   128276.865
TRAV4        S89- 9-40.5E      269.417   497080.913   128272.921
A5           N88- 6-27.5E      237.782   497318.565   128280.773

---------------------------------------------------
TRAVERSE CLOSURE REPORT
SUM OF DISTANCES ALONG TRAVERSE IS        531.785
CLOSURE IN X =    -.002 CLOSURE IN Y =     .000
ANGULAR CLOSURE =     1.8 SECONDS
LINEAR ERROR OF CLOSURE (AFTER ROTATION) IS         .002
BEFORE ROTATION PRECISION IS 1/      324257.
AFTER  ROTATION PRECISION IS 1/      335623.

STATION         BEARING       DISTANCE        X            Y

A4                                       496811.525   128276.865
TRAV5        N88-59- 9.6E      518.890   497330.333   128286.048
A5           S65-51-28.5W       12.896   497318.565   128280.773
```

```
TOTAL LENGTH OF EVALUATED TRAVERSE DISTANCE =      3.534 KM.

PRECISION BASED ON LATITUDE AND DEPARTURE CLOSURES = 1 /    128057.

PRECISION AFTER ORIENTATION CORRECTION = 1 /    197475.
```

The individual components of this .2D file will be described in the following sections.

Datum Parameters

This information is only output if a datum and zone are defined in the .CTL file using the program CTL. EFBP only utilizes NAD 27 or NAD 83, but you are able to replace those numbers with a different year of adjustment. As an example, in Florida the High Accuracy Regional Network (HARN) was established/adjusted in 1990 and is known as NAD 83 (90).

```
ALL MEASUREMENTS ARE REDUCED TO THE NAD 90
0903 FLORIDA NORTH LAMBERT

COORDINATE AND DISTANCE UNITS ARE METERS
```

This survey utilized those coordinates and thus 90 was entered instead of 83. It is the same ellipsoid and state plane zone constants, but the 90 indicates to a reviewer which adjustment is referenced. A number larger than 82 tells EFBP to use NAD 83 constants, and a number less than 83 indicates to the program to use NAD 27 constants. The state plane zone which is attributed in the .CTL, file is output along with the units defined in the .CTL file. In NAD 83 meters, survey foot, and international foot are the possible selections. In NAD 27 only the survey foot is allowed. In assumed coordinates no units selection is output as no geodetic reductions are required.

The .OBS file header record is not used to defined units, the data contained in the .CTL file is used for this purpose

The input files to the horizontal least squares are the .LSA (horizontal measurements) and .2SD (horizontal measurement error estimates) files.

Bandwidth, Adjustment Size, and F Statistic

The F-statistic multiplier is applied to all one sigma standard errors of final coordinates in achieving 95% confidence coordinate standard errors. As the redundancy (number of degrees of freedom) grows this multiplier decreases because added redundancy provides more confidence in your results. The adjustment's standard error of unit weight is also a multiplier in obtaining final coordinate standard errors.

```
 BAND IS   5 STATIONS
  NUMBER OF TERMS REQUIRED IN NORMAL EQUATIONS =     277

  95% CONFIDENCE F STATISTIC STANDARD ERROR MULTIPLIER FOR   21 D.F. IS  2.64
```

The band is an indicator of the size of the equations required for the horizontal least squares analysis, and is thus an indicator to a user how long the solution will take to be resolved. The normal equations are the equations that are solved in least squares, and its number of terms is a function of the bandwidth and the number of stations. The time required for the solution to resolve is also a function of the number of stations and the processing speed of your computer. The remaining information is simply some numeric information regarding the size of the survey. The number of measurements is reflected after weighted averaging has created one elevation difference for every line in the survey network.

Adjusted Coordinates, Standard Errors and Error Ellipses

Station name, adjusted X (easting), and adjusted Y (northing) are always listed. The remaining items are 95% confidence error statistics, if that option is turned on in the options menu of EFBP. Standard errors in X and Y mean if you did the same survey over under the same conditions you are 95% confident about the repeatability of that coordinate within that range.

RESULTS OF ADJUSTMENT

			STANDARD ERRORS		ERROR ELLIPSE INFO.		
STATION	ADJUSTED X	ADJUSTED Y	IN X	IN Y	SU	SV	T
A1	494886.316	128284.789	.001	.001	.001	.001	-7.3
A2	495149.598	128318.648	.001	.001	.001	.001	-4.6
BM1	495201.370	128318.744	.005	.003	.005	.003	-86.5
TRAV1	495281.157	128298.531	.004	.004	.004	.004	-84.0
A3	495980.147	128287.811	.001	.001	.001	.001	1.4
TRAV2	495631.116	128293.637	.003	.007	.007	.003	1.2
A4	496811.525	128276.865	.001	.001	.001	.001	.1
TRAV3	496404.186	128282.823	.003	.010	.010	.003	.7
A5	497318.565	128280.773	.001	.001	.001	.001	-.4
BM7	496993.644	128259.196	.005	.006	.006	.005	19.0
TRAV4	497080.913	128272.921	.003	.005	.005	.003	.8
TRAV5	497330.333	128286.048	.004	.003	.004	.003	59.9

The size of these values grow the further a point is from control. An error ellipse indicates the same type of repeatability in a point's 2-D position. SU is the semi-major axis, SV is the semi-minor axis and T is the angle from north (clockwise positive) of the semi-major axis.

Note, a semi-distance is from the center of the ellipse to its exterior. An error ellipse follows the same logic as coordinate standard errors as size is the relative distance from control.

Control Point Residual Information

As in the .1D file, residuals indicate how much of a correction had to be applied to the data. RMS error is the square root of the sum of the squares of the residuals divided by the number of measurements for that particular type of measurement. It can thus simply be described as a form of average residual. The snoop RMS is the equivalent computation for the snoop numbers for that type of measurement.

Control error estimates, residuals, snoop numbers, and RMS errors work the same as with benchmarks in the .1D report.

```
 RESIDUALS IN THE OBSERVATIONS

                           CONTROL POINT COORDINATES

   STATION           X RESIDUAL  X EST. ERROR  Y RESIDUAL  Y EST. ERROR

   A1                 .000  ( .2)    .001        .000  ( .0)    .001
   A2                 .000  ( .0)    .001        .000  ( .0)    .001
   A3                 .000  ( .1)    .001        .000  ( .0)    .001
   A4                 .000  ( .1)    .001        .000  ( .0)    .001
   A5                 .000  ( .1)    .001        .000  ( .0)    .001

  EASTING CONTROL RMS =      .000 SNOOP RMS =   .1
  MAX. EASTING RESIDUAL AT A1       OF      .000
  NORTHING CONTROL RMS =      .000 SNOOP RMS =   .0
  MAX. NORTHING RESIDUAL AT A4       OF      .000
```

Note, northings and eastings are treated as separate measurements, and thus a northing control error estimate may not equal its easting partner. A traverse generally produces better coordinates in the cardinal direction in which the traverse runs.

Horizontal Distance Residual Information

Distance measurement least squares residuals and related values operate the same as elevation differences in the .1D report. A very important additional point to note is that the distance reported is the measured value reduced to grid for the designated state plane zone (or the measured value if an assumed coordinate system is designated).

```
                              DISTANCES

     OCCUPIED            SIGHTED          DISTANCE    RESIDUAL    EST. ERROR
     STATION             STATION

     A1                  A2                265.453     .002  ( .6)    .003
     A2                  BM1                51.771    -.001  ( .2)    .005
     A2                  TRAV1             133.089     .001  ( .3)    .004
     TRAV1               A3                699.075     .003  ( .3)    .009
     TRAV1               BM1                82.305    -.001  ( .3)    .006
     A3                  A2                831.123     .002  ( .2)    .010
     A3                  TRAV2             349.080     .001  ( .3)    .003
     TRAV2               A2                482.173     .006  ( .8)    .007
     A3                  A4                831.448    -.002  ( .2)    .010
     A3                  TRAV3             424.069     .001  ( .3)    .004
     TRAV3               A4                407.384     .001  ( .4)    .004
     A4                  A5                507.058     .002  ( .3)    .008
     A4                  BM7               182.972    -.002  ( .3)    .006
     A4                  TRAV4             269.418     .002  ( .5)    .003
     TRAV4               A5                237.784     .002  ( .3)    .006
     TRAV4               BM7                88.340    -.002  ( .3)    .006
     TRAV4               TRAV5             249.768     .002  ( .3)    .007
     TRAV5               A4                518.890     .000  ( .0)    .008
     TRAV5               A5                 12.895    -.001  ( .3)    .005

  DISTANCE RMS ERROR =       .002 SNOOP RMS =   .4
  MAX. DISTANCE RESIDUAL         TRAV2    -         A2       OF       .006
```

Only one distance (weighted mean) appears for each measured line no matter how many times it was measured in the .OBS file. In the .1D file measured elevation differences (not adjusted values) were listed. This theme of listed measured, not adjusted, values is consistent for all measurement types in the .1D and .2D reports. Residuals, snoop numbers, error estimates, and RMS errors are similar to previous definition.

Horizontal Angle Residual Information

Angle residuals are again the difference between what is measured and the adjusted value. The measured value is the mean at a setup, thus another setup which measured that same angle would also appear.

ANGLES

BACKSIGHT STATION	OCCUPIED STATION	FORESIGHT STATION	ANGLE	RESIDUAL (SECONDS)	EST. ERROR (SECONDS)
A1	A2	BM1	187-13-18.5	-1.8 (.2)	10.8
A1	A2	TRAV1	196- 1-17.2	-1.9 (.2)	9.9
A2	TRAV1	A3	172-11- 4.2	-1.3 (.2)	7.0
A2	TRAV1	BM1	5-31-17.0	-2.0 (.2)	9.9
A2	A3	TRAV2	358-49-46.2	-1.5 (.2)	7.4
A2	TRAV2	A3	177-58-58.7	.5 (.1)	7.4
A4	A3	TRAV2	180-12- 9.3	2.3 (.2)	10.8
A4	A3	TRAV3	359-55-14.5	3.7 (.5)	7.6
A3	TRAV3	A4	180- 9-47.0	-3.1 (.2)	18.5
TRAV3	A4	A5	178-43-13.9	.2 (.0)	10.8
TRAV3	A4	BM7	184-42- 8.4	-4.1 (.4)	9.6
TRAV3	A4	TRAV4	179-59-58.1	-4.9 (.4)	11.6
A4	TRAV4	A5	177-16- 2.9	-5.1 (.5)	11.1
A4	TRAV4	BM7	350-13-20.9	-3.3 (.3)	11.0
A4	TRAV4	TRAV5	176- 8-55.9	.8 (.1)	10.1
A4	TRAV5	A5	336-52-17.1	-1.8 (.1)	32.8

```
ANGLE RMS ERROR =        2.8 SECONDS  SNOOP RMS =   .3
MAXIMUM ANGLE RESIDUAL         A4      -        TRAV4    -         A5
OF     5.1 SEC.
```

If a state plane zone was selected a small (usually less than 0.1 seconds) called the T-t correction is applied to all horizontal angles and would be reflected in the measured values. Note the lines usually have to be longer than 0.5 miles for the T-t correction to exceed 0.1 seconds. All residuals, error estimates, and RMS errors are provided in seconds.

If azimuths were in a job, they would follow the angles and have a similar format. Note azimuths do not exist in the .OBS file but, instead are in the control (.CTL) file. Astronomic azimuths in .CTL are reduced to grid and output in .2D as grid values. Error estimates are assigned to the azimuths during creation of the .CTL file.

Standard Error Of Unit Weight

The standard error of unit weight and the chi squared test on it are similar to its definition in the .1D report.

In the .2D report, the degrees of freedom is equal to 2 x the number of control coordinates + number of distances + number of angles + number of azimuths - 2 x total number of stations. This is more simply defined as number of measurements minus number of unknowns.

```
    STANDARD ERROR OF UNIT WEIGHT IS       .420
    WITH   21 DEGREES OF FREEDOM
CHI SQUARED TEST ON ANALYSIS
  .700 <   .420 <  1.247
  (LOW)            (HIGH)
DOES NOT PASS AT THE 5 % SIGNIFICANCE LEVEL
```

Note the chi squared test "failed" on the good end - the residuals were smaller than the error estimates. While this concept of failure is statistically correct, as a surveyor, one should simply be happy that this occurred and accept these results.

Traverse Closure Report

Traverse closures are performed after the least squares adjustment process is completed. Which traverse closures are performed, in no way affects the least squares adjustment.

```
TRAVERSE CLOSURE REPORT
SUM OF DISTANCES ALONG TRAVERSE IS        507.202
CLOSURE IN X =    -.003 CLOSURE IN Y =    -.006
ANGULAR CLOSURE =     5.1 SECONDS
LINEAR ERROR OF CLOSURE (AFTER ROTATION) IS         .003
BEFORE ROTATION PRECISION IS 1/       74806.
AFTER  ROTATION PRECISION IS 1/      153355.

STATION         BEARING       DISTANCE        X            Y

A4                                       496811.525   128276.865
TRAV4        S89- 9-40.5E      269.417   497080.913   128272.921
A5           N88- 6-27.5E      237.782   497318.565   128280.773
```

Only one traverse closure is shown as an example. EFBP tries to place every unknown redundant station on at least one traverse closure. Once an unknown point is on a closure route EFBP may chose to use its least squares adjusted coordinates as an end point of a link traverse. If you desire additional closure information one should run the program CHK. Link traverses are computed between the adjusted coordinates of the traverse closure end points. The initial bearing is derived from the inverse of the adjusted coordinates of the first and second stations on the traverse. Measured distances and angles (reduced to grid if a datum is defined) are used in traversing to the end point. The closing bearing is based on these computations, is compared to the inversed bearing between the end point and its connected station's least squares adjusted coordinates to obtain the angular closure on the link traverse.

Closure in easting (X) and northing (Y) is made by comparing the traverse based end coordinates to the least squares adjusted values. The linear error of closure after rotation is the comparison of the traverse based distance between end points compared to the distance based on adjusted coordinates. This distance comparison eliminates the rotation error due to the initial bearing assumption on the first line of the traverse.

The traverse length is the sum of the distances along the traverse. Both precisions use that sum of the distances in the denominator. The before rotation precision uses the closures in x and y in calculating the numerator misclosure. The after rotation precision uses the linear error of closure after rotation in the numerator.

Which is the "correct" precision? The after rotation precision is more indicative of the quality of your measurements as it is not based on the quality of the initial assumption of direction. A small error in initial direction will create a large error in northing and easting over a long distance simply due to how a few seconds of error propagates over a few miles.

Total Evaluated Traverse Network

The length of total evaluated traverse distance is provided along with overall precisions computed from sums of linear error of closures and traverse distances.

```
TOTAL LENGTH OF EVALUATED TRAVERSE DISTANCE =      3.534 KM.
PRECISION BASED ON LATITUDE AND DEPARTURE CLOSURES = 1 /    128057.
PRECISION AFTER ORIENTATION CORRECTION = 1 /    197475.
```

2D Least Squares Other Output Files - .COR and .GEO

In addition to the .2D report, the horizontal least squares outputs two (2) adjusted coordinate files. The first file is the .COR file which contains state plane coordinates. A line in the .COR file is made up of station name, easting, northing, scale factor, and convergence angle order.

If an assumed datum was used for processing, no scale factor or convergence angle values will be displayed. The .COR file computed from the preceding data is as follows :

STATION	X COOR.	Y COOR.	SCALE FACTOR	CONVERGENCE
A1	494886.316	128284.789	.99994846	- 0-32- 54.0
A2	495149.598	128318.648	.99994846	- 0-32- 49.1
A3	495980.147	128287.811	.99994846	- 0-32- 33.5
A4	496811.525	128276.865	.99994846	- 0-32- 17.9
A5	497318.565	128280.773	.99994846	- 0-32- 8.3
BM1	495201.370	128318.744	.99994846	- 0-32- 48.1
BM7	496993.644	128259.196	.99994846	- 0-32- 14.4
TRAV1	495281.157	128298.531	.99994846	- 0-32- 46.6
TRAV2	495631.116	128293.637	.99994846	- 0-32- 40.0
TRAV3	496404.186	128282.823	.99994846	- 0-32- 25.5
TRAV4	497080.913	128272.921	.99994846	- 0-32- 12.8
TRAV5	497330.333	128286.048	.99994846	- 0-32- 8.1

The other produced adjusted coordinate file is the .GEO file, which displays the control point name, control point latitude, and control point longitude. If an assumed datum was used for processing, this file will be empty. The .COR and .GEO files only contain information on control and traverse station points which were present in the 2-D least squares adjustment. No sideshots will be present. The .GEO file computed from the preceding data is as follows :

STATION	LATITUDE	LONGITUDE
A1	30- 9- 9.98215	85-35- 28.18986
A2	30- 9- 11.16345	85-35- 18.36345
A3	30- 9- 10.41849	85-34- 47.31596
A4	30- 9- 10.31770	85-34- 16.24461
A5	30- 9- 10.59894	85-33- 57.29854
BM1	30- 9- 11.18260	85-35- 16.42883
BM7	30- 9- 9.79942	85-34- 9.43286
TRAV1	30- 9- 10.55092	85-35- 13.44011
TRAV2	30- 9- 10.50015	85-35- .36084
TRAV3	30- 9- 10.38664	85-34- 31.46843
TRAV4	30- 9- 10.27171	85-34- 6.17655
TRAV5	30- 9- 10.77380	85-33- 56.86062

Chapter Ten - Final Coordinates

After the 2-D least squares adjustment has been completed, EFBP computes coordinates for all *horizontal* sideshots contained in the .OBS file. The vertical sideshots were computed immediately after completion of the 1-D least squares adjustment. If a state plane zone and datum have been used for processing, sideshots are also reduced to grid by appropriate elevation and scale factors.

The coordinate data is merged with the attribute information contained in the .OBS file to form a final .XYZ file. If any station-offset or rod reading (SOR, SO, or R) records exist in the .OBS file, a .SOE file will also be generated. If any comments, O 99 records, are present in the .OBS file, these lines are transferred by EFBP to the .XYZ and .SOE files. In the following example, observation data which contained some comments existed in the .OBS file and were thus translated to the .XYZ file.

The .XYZ file is column specific for point names (left justified), attribute information, coordinates (decimal point column location), and coordinate standard errors (decimal point column location). As this sample .OBS file was rather large, to conserve space, only a part of the generated .XYZ file is shown.

```
G 00 EXAMP.XYZ
G 01 A1       46-93-GPS2       P F1 10-6"_ROUND_FDOT         0903 90M88
G 02   494886.316   128284.789      9.211     .001     .001      .002
G 01 A2       46-93-E05        P G1 11-4"X4"_FDOT_CONC       0903 90M88
G 02   495149.598   128318.648     10.132     .001     .001      .014
G 01 A3       46-93-E06        P F1 11-4"x4"FDOT_CONC        0903 90M88
G 02   495980.147   128287.811      8.933     .001     .001      .022
G 01 A4       46-93-E07H       P F1 12-5/8COP.COT.ROD        0903 90M88
G 02   496811.525   128276.865      9.915     .001     .001      .018
G 01 A5       46-93-E08H       P F1 13-10_SPIKE_NAIL         0903 90M88
G 02   497318.565   128280.773      8.498     .001     .001      .035
G 01 AP1                       P G1                          0903 90M88
G 02   494951.660   128332.445      9.822
G 01 AP10                      P G1                          0903 90M88
G 02   494986.242   128320.241      9.830
G 01 BC13                      P G1                          0903 90M88
G 02   494986.122   128320.215      9.830
G 01 BC2                       C G1                          0903 90M88
G 02   494901.537   128335.450      9.166
G 01 BC3                       C G1                          0903 90M88
G 02   494904.200   128327.247      9.112
G 01 BC4                       C G1                          0903 90M88
G 02   494908.390   128323.249      9.097
G 01 BC5                       C G1                          0903 90M88
G 02   494915.627   128321.088      9.084
G 01 BC6                       P G1                          0903 90M88
G 02   494931.979   128320.866      9.195
G 01 MH1                       P G1 59-0.61M_                0903 90M88
G 02   494918.576   128322.199      9.151
```

```
G 01 MH2                       P G1 59-.61_SEWER            0903 90M88
G 02   494902.200   128322.399      8.991
G 01 MH3                       C G1 59-.61                  0903 90M88
G 02   494971.282   128321.497      9.720
G 01 SIGN1                     P G1 26-US98_E&W             0903 90M88
G 02   494915.723   128322.343      9.168
G 01 SIGN2                     P G1 26                      0903 90M88
G 99 COOK WHITEHEAD USED CARS .244 SQUARE METAL POLE
G 02   494908.246   128327.600      9.456
G 01 SIGN3                     P G1 26-US98                 0903 90M88
G 02   494903.155   128340.749      9.297
G 01 SIGN14                    P G1 26                      0903 90M88
G 99 SLIPPERY WHEN WET
G 02   495029.606   128299.221     10.067
G 01 SIGN15                    P G1 26                      0903 90M88
G 99 DIVIDED HIWAY ENDS
G 02   495107.892   128297.774     10.099
G 01 SIGN16                    P G1 26-2_LANE_HIWAY         0903 90M88
G 02   495277.446   128295.986      9.324
G 01 SIGN17                    C G1 26-SPEED_LIMIT_45       0903 90M88
G 02   495150.807   128316.440     10.133
G 01 TREE2                     P G1 50-.244_PALM            0903 90M88
G 02   495843.061   128276.975      9.026
G 01 TREE3                     P G1 50-.3048_PALM           0903 90M88
G 02   495846.543   128279.170      9.174
```

A lack of state plane zone or datum/adjustment year indicates assumed coordinates. What fields must absolutely be filled is a function of the software to which this information will be loaded and has no affect on EFBP except for the facts that EFBP is station name based and a zone and datum/adjustment year are required for geodetic processing. This example was in zone 0903 - Florida North Lambert adjustment year 1990, so the ellipsoid being used is from 1983. The coordinates are metric, and the elevation datum is North American Vertical Datum (NAVD) of 1988.

The ***G 00*** record represents the header of the file and really only serves to ensure the validity of the project name and file purpose. Each coordinate record will always consists of a ***G 01*** and a ***G 02*** record. The ***G 01*** record contains the point name, reference name (if any), the geometry, the attribute, the zone and the feature code of the named point. If a state plane zone and datum have been used for processing, the NGS zone number, the horizontal datum adjustment year, the units of measure and the vertical datum adjustment year will also be displayed.

The ***G 02*** record contains the Y coordinate, the X coordinate and the elevation (if any) of the named point. In the case of a traverse station or control point, the standard deviations of the 95 % confidence values from the .1D and .2D files will also be displayed. These values are not determined for sideshots, and are only determined if that computational option is enabled in the EFBP menu.

If comments are attached to any points, the comments will be indicated as a ***G 99*** record and will be placed between the ***G 01*** and ***G 02*** records. In this job, one can see the message on road signs were entered as comments records. Some sign messages which were short were entered as short descriptions attached to the feature with the "-" option. If a station only has horizontal (X and Y) coordinates, the vertical coordinate (elevation) area will be blank. Likewise, the X and Y coordinate areas are blank if a station has elevation only, as in the case of a benchmark.

SOE Data

This example .OBS file did not contain SOR (station, offset, rod reading/leveling) type data records so an .SOE (station, offset, elevation) file was not created. A portion of a SOE file is shown to demonstrate its content. Note that elevations from differential leveling will also appear in an .XYZ file, but no horizontal coordinates are calculated by EFBP. The horizontal coordinates will be computed later and will be based on a calculated alignment which does not usually exist at the time the field survey data is processed.

The file demonstrates station-offset-elevation, station-offset only, or elevation only (differential leveling) information.

```
G 00 KOGER.SOE
G 01 B6       LEO-115-FLDNR    P G1 17-ELEV.203.67FT
G 04                                                 203.670     .002
G 01 B7       TP1              P G1
G 04                                                 213.691     .044
G 01 B21      LEO-76-FLDNR     P G1 17-ELEV.169.94FT
G 04                                                 169.940     .002
G 01 D1                        P G1 50                         XS1
G 04              1025.00   75.50
G 01 D10                       P G1 50                         XS1
G 04              1100.00  175.50
G 01 D11                       P G1 50                         XS1
G 04              1110.00  201.50
G 01 D12                       P G1 50                         XS1
G 04              1110.00 -140.60
G 01 D13                       P G1 50                         XS1
G 04              1120.00  -50.00
G 01 D14                       P G1 50                         XS1
G 04              1150.00   51.50
G 01 D15                       P G1 50                         XS1
G 04              1165.00 -321.60
G 01 D16                       P G1 50                         XS1
G 04              1170.23   23.25
G 01 D17                       P G1 23                         XS1
G 04              1023.00   51.00                    211.684
G 01 D18                       P G1 24                         XS1
G 04              1046.20  -61.29                    212.634
G 01 D19                       P G1 25                         XS1
G 04              1046.20  -51.00                    211.584
G 01 D2                        P G1 50                         XS1
G 04              1035.00  -25.00
G 01 D20                       P G1 26                         XS1
G 04              1126.00  -15.00                    212.084
G 01 D3                        P G1 50                         XS1
G 04              1040.00  -35.50
G 01 D23                       P G1 26                         XS1
G 04              1150.00  199.50                    215.634
```

The ***G 00*** entry is simply a header record which defines the nature of the file. For each point a ***G 01*** and ***G 04*** record always exists, and ***G 99*** records will be between these lines if comments exist for some points in the .OBS file. The ***G 01*** record consists of station name, reference name (optional), geometry, attribute, zone number, feature code, feature code description, and alignment geometry chain name. Which fields are optional is a function of the software reading this file, and not EFBP which produces it. The feature code description is optional and requires a dash after the feature code. No alignment name is required for stations with only elevations as there is no way to horizontally position them without station-offset or horizontal coordinates.

The ***G 04*** record consists of station, offset, elevation, and elevation standard deviation. The standard deviations are the 95 % confidence values from the .1D file. These are not determined for sideshots, and are only determined if that computational option is turned on in the EFBP initial options. Fields are left blank if that information was not obtained. Note that point B7 only has elevation data, while point D4 has only station offset data. Stationing and offsets are in units of feet or meters, and a negative offset indicates a left offset while facing the positive direction of stationing.

Chapter Eleven - Processing Error Messages

The following chapter makes an attempt to explain the various types of error messages that might be presented by EFBP during a typical data processing session. Before starting your processing, make sure the following files are in the directory that contains your data:

DEFAULT.SD
DEFAULT.CON

The DEFAULT.SD and DEFAULT.CON files are used for error estimate definition in the least squares processing and other various items. If the DEFAULT files do not exist reasonable error estimates will be automatically defined by EFBP. In any case, when you run EFBP you will be presented the menu which will allow you to change the name of the *SEGMENT.OBS* file to be processed or any of the items currently present in the DEFAULT files.

Understanding Error Messages

The key to success in processing data using EFBP is correctly interpreting the messages and reports which are generated during processing. It is important to note that errors in the actual readings transmitted from the total station, the measured angles and distances, are rather uncommon. If communication problems do exist, typically an improperly configured cable is at fault.

The mistakes or blunders that occur are typically due to human error, incorrect data input or misinterpretation and may include any of the following :

(1) station misnaming - observing point A23 but entering A22 as the point name
(2) missing setup - failing to record a new instrument setup
(3) accidentally turning the lower motion
(4) accidentally zeroing the horizontal circle
(5) accidentally toggling the position number
(6) forgetting to toggle the position number
(7) entering an incorrect height of instrument
(8) entering an incorrect height of target
(9) entering an incorrect control station reference name
(10) entering incorrect control coordinates

The error message may be given in the form of a large repetition error or an ignored set of data. This information will help you debug your blunders.

EFBP Error Estimation Generation Messages

The following error messages are typically generated during the EFBP “pre-processing” stage.

COMPUTED STANDARD ERRORS WILL BE USED

This message is intended to inform the user of the type of error estimates will be used during processing.

Processing has two options for generating error estimates for the least squares analysis. The first option is to elect to use computed error estimates, With this option, the standard error of the mean is used plus a user defined "add-on". This accounts for the fact that repetition error does not model random errors such as an error in the setup or the instrument or target.

The second option is to use error estimate which are determined solely by the user. If a point is not observed multiple times, the error estimates defined by the user (not add ons) are used. If a user chooses not to use error estimates computed from repetition the error estimates defined by the user are used for all measurements.

EFBP Control Input Messages

The following error messages are typically generated during a review of the available control information by EFBP prior to processing.

CONTROL INFORMATION FOUND WITHOUT STATION NAME

This error message will be displayed if coordinates are found in the control database, namely the *SEGMENT.CTL* file, without a corresponding control point name. A valid control point must contain a point name and coordinates. The coordinates may take the form of a northing and easting (a horizontal control point), an elevation (a bench mark) or a northing, easting and elevation (a HVD control point). Reference names are optional and only serve to identify control points to the individual performing the processing.

COORDINATE INFO. NOT FOUND AFTER CONTROL STATION NAME

This error message will be displayed if a control point name is found in the control point database without accompanying control point coordinates.

CONTROL POINT IN CONTROL FILE TWICE

This error message is displayed if a control point is present in the control point database twice. The name of the offending control point will be displayed in the error message as in “STATION B21 IN CONTROL FILE TWICE”.

EFBP Abstracting Messages

The following error messages are typically generated during the EFBP data abstraction step. The term abstracting means the meaning of any measurements which have been repeated. This step typically precedes the creation of the *SEGMENT.GEN* file.

To better explain some of the error messages, data from an example *SEGMENT.OBS* file will be shown to help illustrate a potential problem and it's solution.

FOLLOWING OBSERVATIONS DETECTED W/O SETUP - DELETED

Measurements existed which are not attached to a setup record. This should only be possible at the start of a measurement file.

NORMAL ABSTRACTING RESULTS

The following display indicates typical pointing errors if no station naming problems exist. If some of these values are large, it probably indicates a station naming problem, an incorrect position set number, or a missing setup.

```
PROCESSING SETUP #   1 AT STATION SP1
REPETITION STANDARD ERRORS
 SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.           COMPARE
 STATION      SD      SD      MAX        SD     SD       MAX      HORZ.     ELEV.
                    (MEAN)  SPREAD            (MEAN)   SPREAD     DIST.     DIFF.
 BM1        .006    .003    .005      .006   .003      .008
 FCI1       .001    .001    .001      .089   .063      .063
 NP1        .005    .002    .007      .021   .010      .022       .007     -.047
 TOM1       .005    .003    .008      .009   .005      .010
 REPETITION STANDARD ERRORS FOR ANGLES
 BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
 BM1            FCI1           35.       25.         25.
 BM1            NP1            19.        9.         25.
 BM1            TOM1           16.        8.         20.
```

The maximum spread or "*max spread*" value is the defined as the largest deviation of a single observation from the mean of all of the observations. The *"compare horz. dist.* and *elev. diff."* value is shown if a line has been shot previously from a different setup record. This may occur at the same setup or a setup at the sighted station. If all repetition errors are small but the *"compare horizontal distance"* value is large, look for a station naming problem at this setup or a previous setup which measured the line in question. A good *"compare horz. dist."* value but a poor *"elev. diff."* value indicates a problem with a recorded height of instrument (HI) or height of target (HT) at this setup or a previous setup on which the line was measured. If all of the displayed angle errors are large, a backsight station problem is possible. Check for an incorrect point name, reference name or position set number. If only one point name displays a large angle error problem, look for the same type of problems, only concentrate on the shots to that point name. All distance and elevation error values are displayed in the same units or measure that was used to observe the data. All angle repetition error information is in seconds.

These repetition results were derived from the following sample observed data:

```
S 00 SP1                        P G1
S 01 16:21:59 11/23/88  3.680
O 00 BM1      55-84-A09         P G1
O 01 16:32:52    5.000            1 R 354 45 13.0 269 59 39     184.640 S
O 01 16:33:53    5.000            1 D 174 45 46.0  90  0 28     184.640 S
O 01 16:42:43    5.000            2 R  88 24 41.0 269 59 46     184.630 S
O 01 16:41:28    5.000            2 D 268 24 17.0  90  0 27     184.630 S
O 00 FCI1     55-72-A16         P G1
O 01 16:24:15    5.850            1 R   0  0  1.0 270 53 49    3692.450 S
O 01 16:38:03    5.850            1 D 179 59 44.0  89  6  4    3692.450 S
O 00 NP1      55-84-19A         P G1
O 01 16:35:39    5.140            1 D 359 49 31.0  90 32 39     511.230 S
O 01 16:25:39    5.140            1 R 179 49 24.0 269 27 38     511.220 S
O 01 16:44:59    5.140            2 R 273 28 55.0 269 27 36     511.230 S
O 01 16:40:04    5.140            2 D  93 28 48.0  90 32 35     511.230 S
O 00 TOM1                       P G1
O 01 16:34:51    5.360            1 D  38 19  6.0  93 37  5     505.650 S
O 01 16:28:43    5.360            1 R 218 18 59.0 266 23  0     505.650 S
O 01 16:40:40    5.360            2 D 131 58 14.0  93 37  6     505.640 S
O 01 16:43:37    5.360            2 R 311 58 16.0 266 23  2     505.650 S
```

The first two lines from this *SEGMENT.OBS* file represent a setup at SP1 with a recorded instrument height (H.I.) of 3.680 feet. Four measurements were then made to BM1 in HVD mode. This mode is indicated by the 01 record in columns 3-4. The first measurement to BM1 was made using position set one (1) with the telescope in reverse orientation with horizontal circle, zenith circle, and slope distance of 354° 45’ 13.0”, 269° 59’ 39”, and 184.640’ respectively. An observation was then made with the telescope in direct orientation. The third and fourth measurements to BM1 were made in using position set two (2).

The collimation errors are assumed to be zero for this example. Since EFB processing allows each shot to be corrected for systematic error derived from horizontal and vertical collimation, each shot is treated individually. One direct observation and one reverse observation has been conventionally averaged then repetition error computed since collimation error has not been measured. In contrast to this, four (4) direct and four (4) reverse shots are treated as eight (8) measurements in computing standard errors in EFB processing since collimation errors can be corrected using calibration.

The compare horizontal distance and elevation difference was derived from a setup at NP1 from which the following shots were made to SP1:

```
S 00 NP1      55-84-19A        P G1
S 01 14:18:00 11/23/88  5.400
O 00 SP1                       P G1
O 01 14:26:55    3.430           1 D 359 50 52.0  89 31 30     511.230 S
O 01 14:36:18    3.430           1 R 179 50 36.0 270 28 55     511.230 S
O 01 14:51:38    3.430           4 D 162 41 51.0  89 31 18     511.230 S
O 01 14:57:58    3.430           4 R 342 41 42.0 270 28 57     511.230 S
O 01 15:01:30    3.430           5 R 250 45 28.0 270 28 49     511.230 S
O 01 15:08:29    3.430           5 D  70 45 34.0  89 31 21     511.230 S
```

Now consider in the example setup at SP1 that TOM1 and NP1 were misnamed for each other as shown:

```
S 00 SP1                       P G1
S 01 16:21:59 11/23/88  3.680
O 00 BM1      55-84-A09        P G1
O 01 16:32:52    5.000           1 R 354 45 13.0 269 59 39     184.640 S
O 01 16:33:53    5.000           1 D 174 45 46.0  90  0 28     184.640 S
O 01 16:42:43    5.000           2 R  88 24 41.0 269 59 46     184.630 S
O 01 16:41:28    5.000           2 D 268 24 17.0  90  0 27     184.630 S
O 00 FCI1     55-72-A16        P G1
O 01 16:24:15    5.850           1 R   0  0  1.0 270 53 49    3692.450 S
O 01 16:38:03    5.850           1 D 179 59 44.0  89  6  4    3692.450 S
O 00 TOM1                      P G1
O 01 16:35:39    5.140           1 D 359 49 31.0  90 32 39     511.230 S
O 01 16:25:39    5.140           1 R 179 49 24.0 269 27 38     511.220 S
O 01 16:44:59    5.140           2 R 273 28 55.0 269 27 36     511.230 S
O 01 16:40:04    5.140           2 D  93 28 48.0  90 32 35     511.230 S
O 00 NP1      55-84-19A        P G1
O 01 16:34:51    5.360           1 D  38 19  6.0  93 37  5     505.650 S
O 01 16:28:43    5.360           1 R 218 18 59.0 266 23  0     505.650 S
O 01 16:40:40    5.360           2 D 131 58 14.0  93 37  6     505.640 S
O 01 16:43:37    5.360           2 R 311 58 16.0 266 23  2     505.650 S
```

The repetition errors based on this data would be reported as :

```
PROCESSING SETUP #   1 AT STATION SP1
REPETITION STANDARD ERRORS
SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.          COMPARE
STATION      SD     SD     MAX        SD     SD      MAX      HORZ.     ELEV.
                  (MEAN)  SPREAD         (MEAN)   SPREAD     DIST.     DIFF.
BM1        .006    .003    .005     .006   .003     .008
FCI1       .001    .001    .001     .089   .063     .063
TOM1       .005    .002    .007     .021   .010     .022
NP1        .005    .003    .008     .009   .005     .010  *  6.572* *-27.336*
REPETITION STANDARD ERRORS FOR ANGLES
BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
BM1            FCI1           35.       25.        25.
BM1            TOM1           19.        9.        25.
BM1            NP1            16.        8.        20.
```

Notice the repetition errors are fine as the station misnaming was very consistent. The *compare horiz. dist.* and *elev. diff.* caught the problem. It is important to note that when comparing two horizontal distances between any two (2) points, the second measurement, not the first, may be the correct one!

Asterisks (*) appear around max. spread or compare values when they are above user defined values. This indicates a potential problem

The next example is where station names of NP1 and TOM1 were only reversed on the first position in reverse:

```
S 00 SP1                       P G1
S 01 16:21:59 11/23/88  3.680
O 00 BM1      55-84-A09        P G1
O 01 16:32:52    5.000           1 R 354 45 13.0 269 59 39     184.640 S
O 01 16:33:53    5.000           1 D 174 45 46.0  90  0 28     184.640 S
O 01 16:42:43    5.000           2 R  88 24 41.0 269 59 46     184.630 S
O 01 16:41:28    5.000           2 D 268 24 17.0  90  0 27     184.630 S
O 00 FCI1     55-72-A16        P G1
O 01 16:24:15    5.850           1 R   0  0  1.0 270 53 49    3692.450 S
O 01 16:38:03    5.850           1 D 179 59 44.0  89  6  4    3692.450 S
O 00 NP1      55-84-19A        P G1
O 01 16:34:51    5.360           1 D  38 19  6.0  93 37  5     505.650 S
O 01 16:25:39    5.140           1 R 179 49 24.0 269 27 38     511.220 S
O 01 16:44:59    5.140           2 R 273 28 55.0 269 27 36     511.230 S
O 01 16:40:04    5.140           2 D  93 28 48.0  90 32 35     511.230 S
O 00 TOM1                      P G1
O 01 16:35:39    5.140           1 D 359 49 31.0  90 32 39     511.230 S
O 01 16:28:43    5.360           1 R 218 18 59.0 266 23  0     505.650 S
O 01 16:40:40    5.360           2 D 131 58 14.0  93 37  6     505.640 S
O 01 16:43:37    5.360           2 R 311 58 16.0 266 23  2     505.650 S
```

Note how the error appears consistent between the two stations. The asterisks under *"max. spread"* for angles is not for good work.

```
PROCESSING SETUP #   1 AT STATION SP1
REPETITION STANDARD ERRORS
SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.          COMPARE
STATION      SD      SD      MAX        SD     SD       MAX      HORZ.     ELEV.
                   (MEAN)  SPREAD          (MEAN)   SPREAD     DIST.     DIFF.
BM1        .006    .003    .005     .006   .003      .008
FCI1       .001    .001    .001     .089   .063      .063
NP1       3.281   1.640 * 4.921*  13.652  6.826 * 20.478* *  1.649* * -6.865*
TOM1      3.284   1.642 * 4.926*  13.632  6.816 * 20.448*
REPETITION STANDARD ERRORS FOR ANGLES
BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
BM1            FCI1           35.       25.         25.
BM1            NP1         69271.    34635.     ********
BM1            TOM1        69301.    34650.     ********
```

This type of display simply indicates that the error value is so large, there is not enough room to display it in the reserved five places to the right of the decimal point! It is very important to remember similar "poor" repetition errors to two stations often indicates station misnaming between the two.

A four minute (4') pointing blunder is now introduced in the observation to point BM1 which was recorded in position set number two :

```
S 00 SP1                       P G1
S 01 16:21:59 11/23/88  3.680
O 00 BM1      55-84-A09        P G1
O 01 16:32:52    5.000           1 R 354 45 13.0 269 59 39     184.640 S
O 01 16:33:53    5.000           1 D 174 45 46.0  90  0 28     184.640 S
O 01 16:42:43    5.000           2 R  88 24 41.0 269 59 46     184.630 S
O 01 16:41:28    5.000           2 D 268 28 17.0  90  0 27     184.630 S
O 00 FCI1     55-72-A16        P G1
O 01 16:24:15    5.850           1 R   0  0  1.0 270 53 49    3692.450 S
O 01 16:38:03    5.850           1 D 179 59 44.0  89  6  4    3692.450 S
O 00 NP1      55-84-19A        P G1
O 01 16:35:39    5.140           1 D 359 49 31.0  90 32 39     511.230 S
O 01 16:25:39    5.140           1 R 179 49 24.0 269 27 38     511.220 S
O 01 16:44:59    5.140           2 R 273 28 55.0 269 27 36     511.230 S
O 01 16:40:04    5.140           2 D  93 28 48.0  90 32 35     511.230 S
O 00 TOM1                      P G1
O 01 16:34:51    5.360           1 D  38 19  6.0  93 37  5     505.650 S
O 01 16:28:43    5.360           1 R 218 18 59.0 266 23  0     505.650 S
O 01 16:40:40    5.360           2 D 131 58 14.0  93 37  6     505.640 S
O 01 16:43:37    5.360           2 R 311 58 16.0 266 23  2     505.650 S
```

The repetition errors based on this data would be reported as :

```
PROCESSING SETUP #   1 AT STATION SP1
REPETITION STANDARD ERRORS
SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.          COMPARE
STATION      SD      SD      MAX        SD     SD       MAX      HORZ.     ELEV.
                   (MEAN)  SPREAD            (MEAN)   SPREAD     DIST.     DIFF.
BM1         .006    .003    .005     .006   .003      .008
FCI1        .001    .001    .001     .089   .063      .063
NP1         .005    .002    .007     .021   .010      .022      .007      -.047
TOM1        .005    .003    .008     .009   .005      .010
REPETITION STANDARD ERRORS FOR ANGLES
BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
BM1            FCI1           35.       25.         25.
BM1            NP1           107.       53.     *  159.*
BM1            TOM1          109.       54.     *  162.*
```

Note that in this case, the four minute (4') blunder gets slightly hidden by the averaging which takes place. The recorded observations to FC1 were unaffected since it was observed in reverse telescope orientation using position set number two. The repetition errors are consistent to both NP1 and TOM1 indicating an error in the backsight station.

Now lets place the four minute (4’) blunder in TOM1's position set number 2 reverse :

```
S 00 SP1                          P G1
S 01 16:21:59 11/23/88  3.680
O 00 BM1      55-84-A09           P G1
O 01 16:32:52    5.000              1 R 354 45 13.0 269 59 39      184.640 S
O 01 16:33:53    5.000              1 D 174 45 46.0  90  0 28      184.640 S
O 01 16:42:43    5.000              2 R  88 24 41.0 269 59 46      184.630 S
O 01 16:41:28    5.000              2 D 268 24 17.0  90  0 27      184.630 S
O 00 FCI1     55-72-A16           P G1
O 01 16:24:15    5.850              1 R   0  0  1.0 270 53 49     3692.450 S
O 01 16:38:03    5.850              1 D 179 59 44.0  89  6  4     3692.450 S
O 00 NP1      55-84-19A           P G1
O 01 16:35:39    5.140              1 D 359 49 31.0  90 32 39      511.230 S
O 01 16:25:39    5.140              1 R 179 49 24.0 269 27 38      511.220 S
O 01 16:44:59    5.140              2 R 273 28 55.0 269 27 36      511.230 S
O 01 16:40:04    5.140              2 D  93 28 48.0  90 32 35      511.230 S
O 00 TOM1                         P G1
O 01 16:34:51    5.360              1 D  38 19  6.0  93 37  5      505.650 S
O 01 16:28:43    5.360              1 R 218 18 59.0 266 23  0      505.650 S
O 01 16:40:40    5.360              2 D 131 58 14.0  93 37  6      505.640 S
O 01 16:43:37    5.360              2 R 311 54 16.0 266 23  2      505.650 S
```

The repetition errors based on this data would be reported as :

```
PROCESSING SETUP #   1 AT STATION SP1
 REPETITION STANDARD ERRORS
 SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.          COMPARE
 STATION      SD      SD      MAX        SD     SD       MAX      HORZ.      ELEV.
                    (MEAN)  SPREAD             (MEAN)   SPREAD    DIST.      DIFF.
 BM1        .006    .003    .005      .006   .003      .008
 FCI1       .001    .001    .001      .089   .063      .063
 NP1        .005    .002    .007      .021   .010      .022       .007     -.047
 TOM1       .005    .003    .008      .009   .005      .010
 REPETITION STANDARD ERRORS FOR ANGLES
 BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
 BM1            FCI1           35.       25.         25.
 BM1            NP1            19.        9.         25.
 BM1            TOM1          124.       62.     *  185.*
```

Note the four minute (4’) blunder is again slightly masked but it is concentrated on the angle to TOM1.

ERROR WHEN BACKSIGHT RESHOT IS 0.004

In differential leveling, if the backsight is reshot this message displays the difference between the initial and final readings.

REPETITION ERROR ON MULTIPLE POINTING TO STATION FCI1 IS 8.0 SEC.

This type of message is standard when numerous observation of the backsight are recorded while recording a lot of foresight observations. If you did not record numerous observations to the backsight and this message appears, you have a station naming problem or a missing setup.

What this message indicates is that the instrument operator has measured to the same station more than once with the same position number and in the same D/R mode. If this number is very large, a station naming problem or a position set number problem exists, a setup record is missing, the lower motion was used inadvertently, or the instrument was zeroed inadvertently.

In the following *SEGMENT.OBS* information the first position reverse value of FCI1 was incorrectly called BM1. You can usually find this problem by observing two similar position set numbers and direct and reverse readings and noting different circle readings and slope distances.

```
S 00 SP1                      P G1
S 01 16:21:59 11/23/88  3.680
O 00 BM1      55-84-A09       P G1
O 01 16:24:15    5.850          1 R   0  0  1.0 270 53 49    3692.450 S
O 01 16:32:52    5.000          1 R 354 45 13.0 269 59 39     184.640 S
O 01 16:33:53    5.000          1 D 174 45 46.0  90  0 28     184.640 S
O 01 16:42:43    5.000          2 R  88 24 41.0 269 59 46     184.630 S
O 01 16:41:28    5.000          2 D 268 24 17.0  90  0 27     184.630 S
O 00 FCI1     55-72-A16       P G1
O 01 16:38:03    5.850          1 D 179 59 44.0  89  6  4    3692.450 S
O 00 NP1      55-84-19A       P G1
O 01 16:35:39    5.140          1 D 359 49 31.0  90 32 39     511.230 S
O 01 16:25:39    5.140          1 R 179 49 24.0 269 27 38     511.220 S
O 01 16:44:59    5.140          2 R 273 28 55.0 269 27 36     511.230 S
O 01 16:40:04    5.140          2 D  93 28 48.0  90 32 35     511.230 S
O 00 TOM1                     P G1
O 01 16:34:51    5.360          1 D  38 19  6.0  93 37  5     505.650 S
O 01 16:28:43    5.360          1 R 218 18 59.0 266 23  0     505.650 S
O 01 16:40:40    5.360          2 D 131 58 14.0  93 37  6     505.640 S
O 01 16:43:37    5.360          2 R 311 58 16.0 266 23  2     505.650 S
```

The repetition errors based on this data would be reported as :

```
PROCESSING SETUP #   1 AT STATION SP1
REPETITION ERROR ON MULTIPLE POINTING TO STATION BM1 IS * 18888.0* SEC.
REPETITION STANDARD ERRORS
SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.          COMPARE
STATION      SD      SD      MAX       SD     SD      MAX     HORZ.     ELEV.
                  (MEAN)  SPREAD           (MEAN)   SPREAD    DIST.     DIFF.
BM1     ******* 701.473 ********  25.479 11.394 * 45.577*
NP1        .005    .002    .007     .021   .010     .022      .007     -.047
TOM1       .005    .003    .008     .009   .005     .010
REPETITION STANDARD ERRORS FOR ANGLES
BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
BM1            NP1           4722.     2361.     * 7082.*
BM1            TOM1          4718.     2359.     * 7076.*
```

It is obvious by this display that some data shot to BM1 is incorrect. The easiest process for finding this kind of problem is realizing that if the instrument is not horizontally re-zeroed the reverse horizontal circle should be 180 degrees different from the direct horizontal circle reading. If you knew no stations had been reshot on the same position number with the same telescope orientations, one would immediately realize a station naming problem had occurred.

NOT ALL ANGLES HAVE A COMMON BACKSIGHT

This error message indicates that stations observed with a specific position set number and unique telescope orientation (direct or reverse mode) are not connected to any other stations on other position set numbers and unique telescope orientations. This is not allowed in processing. If you really intended to do this it must be a separate setup. In the following data the last shot by time tag was to NP1 and the position number was accidentally changed from 2 to 3.

```
S 00 SP1                          P G1
S 01 16:21:59 11/23/88  3.680
O 00 BM1      55-84-A09           P G1
O 01 16:32:52    5.000              1 R 354 45 13.0 269 59 39     184.640 S
O 01 16:33:53    5.000              1 D 174 45 46.0  90  0 28     184.640 S
O 01 16:42:43    5.000              2 R  88 24 41.0 269 59 46     184.630 S
O 01 16:41:28    5.000              2 D 268 24 17.0  90  0 27     184.630 S
O 00 FCI1     55-72-A16           P G1
O 01 16:24:15    5.850              1 R   0  0  1.0 270 53 49    3692.450 S
O 01 16:38:03    5.850              1 D 179 59 44.0  89  6  4    3692.450 S
O 00 NP1      55-84-19A           P G1
O 01 16:35:39    5.140              1 D 359 49 31.0  90 32 39     511.230 S
O 01 16:25:39    5.140              1 R 179 49 24.0 269 27 38     511.220 S
O 01 16:44:59    5.140              3 R 273 28 55.0 269 27 36     511.230 S
O 01 16:40:04    5.140              2 D  93 28 48.0  90 32 35     511.230 S
O 00 TOM1                         P G1
O 01 16:34:51    5.360              1 D  38 19  6.0  93 37  5     505.650 S
O 01 16:28:43    5.360              1 R 218 18 59.0 266 23  0     505.650 S
O 01 16:40:40    5.360              2 D 131 58 14.0  93 37  6     505.640 S
O 01 16:43:37    5.360              2 R 311 58 16.0 266 23  2     505.650 S
```

The repetition errors based on this data would be reported as :

```
PROCESSING SETUP #   1 AT STATION SP1
REPETITION STANDARD ERRORS
SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.          COMPARE
STATION      SD      SD      MAX        SD     SD      MAX      HORZ.     ELEV.
                  (MEAN)  SPREAD          (MEAN)   SPREAD     DIST.     DIFF.
BM1        .006    .003    .005     .006   .003     .008
FCI1       .001    .001    .001     .089   .063     .063
NP1        .005    .002    .007     .021   .010     .022      .007     -.047
TOM1       .005    .003    .008     .009   .005     .010
REPETITION STANDARD ERRORS FOR ANGLES
BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
NOT ALL ANGLES HAVE A COMMON BACKSIGHT
BM1            FCI1           35.       25.         25.
BM1            NP1            23.       13.         24.
BM1            TOM1           16.        8.         20.
SOME DATA AT STATION SP1      NOT CONNECTED TO OTHER
POINTINGS SO IGNORED
```

The processed data would simply not use the horizontal circle reading which was incorrectly recorded as the 3rd position. The distance and elevation information would be used.

SOME DATA AT STATION A23 NOT CONNECTED TO OTHER POINTINGS SO IGNORED

This means stations on a position set number with unique telescope orientations are not connected to any other stations on other position set numbers and unique telescope orientations, or matching observations from specific positions set numbers and telescope orientations have not been found.

This is not allowed in processing. If you really intended to do this it must be a separate setup. There are two ways EFBP searches for this problem and thus the two error messages exist for what appears to be the same problem. Notice this message also appeared in the previous example.

IGNORED CALIBRATION - # OF DIRECT READINGS DOES NOT EQUAL NUMBER OF REVERSE READINGS

If the pointings in specific telescope orientations are not equal in number, the calibration is ignored and the previous calibration values are retained. An axis test cannot contain four observation id direct mode and five observations in reverse mode.

WARNING - CALIBRATION RECORD WITHOUT DATA

A calibration record is stored even when you do not perform the vertical and horizontal collimation checking process. If you did not intend to perform this test, this warning may be ignored. In this case, the previous calibration values are used until a new set of data is encountered.

```
HORZ. COLLIMATION CORRECTION =    3.6 SECONDS
VERT. COLLIMATION CORRECTION =  -18.3 SECONDS
```

These values represent the computed corrections based upon the recorded axis test data. These values should remain fairly consistent for a particular instrument. If they do not, something in the instrument or setup is very unstable. If these values are unusually large, the instrument operator did not perform this test properly or instrument is very out of adjustment. A very different calibration correction compared to others should probably be deleted as something was wrong regarding the instrument (stuck collimator) or the setup.

```
HORIZONTAL POINTING STANDARD ERROR  (DIRECT) = 3.2 SECONDS
VERTICAL POINTING STANDARD ERROR  (DIRECT) =  5.1 SECONDS
HORIZONTAL POINTING STANDARD ERROR (REVERSE) = 1.1 SECONDS
VERTICAL POINTING STANDARD ERROR (REVERSE) = 7.8 SECONDS
```

These values represent the pointing standard errors based on the recorded axis test data. If these values are large, the instrument operator did a poor job of pointing. Horizontally, the instrument operator may have inadvertently zeroed the instrument or used the lower motion. Delete the calibration if unusually large pointing errors exist. An example of a poor calibration is as follows :

```
C 00 11:49:48 09/06/90  80 30.0 00120  DWH HEC RLB
C 01 TOPCON     GTS-4      W60092      5  3
C 03 12:39:26                     D 274 58  9.0  86 44 24.0
C 03 12:39:50                     D 274 58 11.0  86 44 26.0
C 03 12:39:26                     D 274 58  8.0  86 43 11.0
C 03 12:39:50                     D 274 58  7.0  86 44 21.0
C 03 12:42:00                     R  94 58 32.0 273 15 15.0
C 03 12:42:00                     R  94 58 36.0 273 15 10.0
C 03 12:42:00                     R  94 58 38.0 273 15 12.0
C 03 12:42:18                     R  94 58 30.0 273 15 13.0
```

The axis test results based on this data would be reported as :

```
HORZ. COLLIMATION CORRECTION =     12.6 SECONDS
VERT. COLLIMATION CORRECTION =     21.0 SECONDS
HORIZONTAL POINTING STANDARD ERROR  (DIRECT) =      1.7 SECONDS
VERTICAL POINTING STANDARD ERROR  (DIRECT) =     36.4 SECONDS
HORIZONTAL POINTING STANDARD ERROR (REVERSE) =      3.7  SECONDS
VERTICAL POINTING STANDARD ERROR (REVERSE) =      2.1 SECONDS
```

While thirty-six point four seconds (36.4") may not be considered large, it is many magnitudes larger than the other pointing errors. Typically, the Florida Department of Transportation desires errors of less that fifteen seconds (15.0). Examining the data, it is obvious the third pointing in direct was performed improperly vertically. To delete the offending observation and retain a valid axis test, you must also delete one reverse pointing to obtain equal number of telescope orientations pointings.

EFBP Sideshot Identification Messages

The following error messages are typically generated during the resolution of all sideshots.

This message indicates the number of recorded sideshots.

112 OF 122 STATIONS ARE HORIZONTAL SIDESHOTS

Typically, EFB processing does not require the user to define which observations are sideshots and which observations are part of the traverse data. Processing resolves this automatically. Only traverse (redundant) data is analyzed by least squares. Sideshots are computed after the least squares analysis is completed.

ERROR - ANGLE AT A SETUP AT STATION A23
NOT CONNECTED TO ANY SIGHTED STATIONS AT PREVIOUS SETUPS
PROCESSING CONTINUES BUT THIS PROBLEM NEEDS TO BE CHECKED

An example of this type of problem is an angle with the backsight at point B22, the instrument located at point A23 and a foresight taken to point B23 where none of the three stations are identified as control points and points B22 and B23 have never been occupied or observed previously from other stations. There is little chance that coordinates can be solved in this situation and thus it is probably a station misnaming situation.

CANNOT REALIGN ANGLES AT STATION A23 DUE TO LACK OF ANGLE INFORMATION
PROCESSING CONTINUES BUT THIS PROBLEM NEEDS TO BE CHECKED

This type of problem occurs during sideshot elimination. If a sideshot was originally selected by processing as a backsight, it must be changed to a foresight and a different backsight station selected. If during this process a suitable backsight, which is common to all foresights, cannot be found this warning is displayed. The most common occurrence of this message is when a setup on A23 occurs multiple times and one unique backsight cannot be found common to all setups.

While this may be computationally solvable processing does not allow it. The solution to this problem is to use the same backsight on all setups of the same station. If this practice is not possible on a new setup, observe a previous foresight and processing can resolve this situation.

EFBP Coordinate Generation Messages

The following error messages are typically generated as EFBP attempts to generate coordinates during processing.

NO AZIMUTH FOUND AND ONLY ONE CONTROL POINT
COORDINATE GENERATION IS INCOMPLETE

This message indicates that the recorded horizontal data ties to only one control point and thus without an azimuth coordinates cannot be generated. You may have forgot to enter the azimuth or a second control station. Incorrect station naming may also create this problem as the survey network has been misidentified.

NO DISTANCE TO CONTROL POINT. STOP

This indicates that a distance to a control point was not recorded. This would be possible if the control point was observed in H or V mode. Only in a triangulation or bearing-bearing intersection situation can you produce coordinates if no distances are connected to control stations.

NETWORK CONNECTIVITY IS INCOMPLETE

This message indicates that station naming problems or missing setups have created a situation where the survey data does not permit coordinate generation. This is referred to as a lack of connectivity. An example would be a missing setup in a traverse between two control points.

ROTATION NOT POSSIBLE - MISSING DATA

Coordinate generation did not succeed in connecting two control points, or an azimuth is not on the data which has unrotated coordinates. Data is missing or station misnaming has caused this problem.

****** COORDINATES UNDETERMINED FOR STATION A23***

This message indicates that coordinates for point A23 could not be generated. If station A23 is part of your horizontal survey data, this message indicates a problem due to missing data or station misnaming. If station A23 is part of a differential leveling survey this message can be ignored as you did not intend to have coordinates generated for it.

STATION A23 IS NOT ON A DISTANCE IN INPUT FILE

This message indicates that the distance to point A23 is not present in the observed data. If station A23 is part of your horizontal survey data this may be a problem due to missing data or station misnaming. If station A23 is part of a differential leveling survey this message can be ignored as you did not intend to have coordinates generated for it. If station A23 was intended to be resolved by bearing-bearing intersection or resection this message can again be ignored.

STATION A23 IS NOT ON AN ANGLE IN INPUT FILE

This message indicate that an angle to point A23 is not present in the observed data. If station A23 is part of your horizontal survey data this may be a problem due to missing data or station misnaming. If station A23 is part of a differential leveling survey this message can be ignored as you did not intend to have coordinates generated for it. If station A23 was intended to be resolved by distance-distance intersection this message can again be ignored.

NO COORDINATES FOR STATION A23 WRITTEN TO FILE

This message that no coordinates for point A23 were written to the *SEGMENT.XYZ* file. If station A23 is part of your horizontal survey data this is a problem due to missing data or station misnaming. If station A23 is part of a differential leveling survey this message can be ignored as you did not intend to have coordinates generated for it.

STATION A4 POSITIONED BY ANGLE-ANGLE INTERSECTION FROM STATIONS A1 AND A2

This message indicates that coordinates for point A4 were created by way of a bearing-bearing intersection. Unless this point was intentionally located this way, you may have missing distances.

STATION A5 POSITIONED BY RESECTION FROM STATIONS A3A1, A2 AND A1A2

This message indicates that coordinates for point A5 were created by way of a three point resection. Unless this point was intentionally located this way, you may have missing distances.

STATION A66 POSITIONED BY DISTANCE-DISTANCE INTERSECTION FROM STATIONS A3 AND A2

This message indicates that coordinates for point A66 were created by way of a distance-distance intersection. Unless this point was intentionally located this way, you may have missing angles. This required user input to resolve a multiple solution.

STATION A6 POSITIONED BY THREE DISTANCE INTERSECTION FROM STATIONS A1, A3, AND A2

This message indicates that coordinates for point A6 were created by way of intersection three measured distances. Unless this point was intentionally located this way, you may have missing angles. If the three distances exist in the *SEGMENT.OBS* file, the multiple solution can be automatically resolved.

STATION A18 POSITIONED BY ANGLE-DISTANCE INTERSECTION FROM STATIONS A3 AND A4

This message indicate that coordinates for point A18 were created by way of a bearing-distance intersection. Unless this point was intentionally located this way, you may have missing angles or distances. This possibly required user input to resolve a multiple solution.

TRAVERSE CLOSURE REPORT
LINEAR ERROR OF CLOSURE IS .033 FT.

PRECISION IS 1/ 50739.

STATION	X COOR.	Y COOR.
B6	623323.994	158173.434
B25	623420.673	157621.313
B5	623433.784	157474.263
B1	623547.043	157322.610
B2	623668.589	157386.943
B24	623777.710	157511.384
B23	623904.038	157974.433

This message illustrates a typical traverse closure report. Once all of the sideshots have been removed, the processor begins coordinate generation by attempting to traverse between control points or points with previously computed coordinates. The processor does not compute traverse loops. It only computes traverse links between existing coordinates. Processing is performed in this manner because the end point coordinates are necessary to define the proper rotation of the traverse link. A loop traverse requires a known bearing for rotation and this is not searched for by the processor. A compass rule adjustment of the link traverse is performed. If all abstracting messages show no problems, one should look at the traverse closures in sequential order. The first closure which illustrates a blunder indicates highly that a problem with that traverse link's data. This could be due to incorrect control coordinates or incorrect station names, and is probably not due to the values of the measurements as they have come directly from the total station in most cases.

Poor closures after the first bad closure should usually be ignored until the problem with the first traverse link is resolved.

This is because later traverse links may start or end on coordinates generated from the first "bad" traverse. As an example, if the above traverse closed 1/80 and a later computed traverse started at B25 and ended at B24 it would close poorly due to the poor coordinates of B25 and B24, and not necessarily due to the measurements of the later traverse link.

Closures tend to get slightly worse as later links are identified as you are closing between coordinates generated from series of compass rule adjustments. This problem is resolved by the least squares analysis. If processing shows an angle-distance computation when you were expecting a traverse link closure computation make sure a missing setup or similar problem does not exist on that link traverse. Please be aware that an angle-distance computation is often necessary to get the link traverse closure computation functioning.

If a sideshot is measured to more than once and error estimates from repetition is selected, that data will be included in the redundant (traverse) data and not in the sideshot information. Since this station is not on a link traverse it will require an angle distance combination.

DISTANCE RESIDUALS

DISTANCE		RESIDUAL
A25	- B22	.000
A25	- B23	.000
B23	- B24	-.026
B23	- B6	.000
B24	- B2	-.009
B2	- B1	-.007
B1	- B5	-.010
B5	- B25	-.008
B25	- B6	-.030
GRASS2	- B2	-.078
GRASS2	- B1	-.160
GRASS2	- B5	-.088
GRASS2	- C1	.000
GRASS2	- XS1	.000

ANGLE RESIDUALS

ANGLE			RESIDUAL (SEC)
B22	- A25	- B23	.0
A25	- B23	- B24	-1.8
A25	- B23	- B6	.0
B2	- B24	- B23	.0
B1	- B2	- B24	.0
B2	- B1	- B5	.0
B1	- B5	- B25	.0
B5	- B25	- B6	.0
B23	- B6	- B25	-13.4
B2	- GRASS2	- B1	190.6
B2	- GRASS2	- B5	.0
B2	- GRASS2	- C1	.0
B2	- GRASS2	- XS1	.0

AZIMUTH RESIDUALS

AZIMUTH		RESIDUAL (SEC)
A25	- B22	.0

These residuals show the amounts of adjustment to your data based on the initial compass rule generation of coordinates. Data which has not been used to generate coordinates will contain the largest adjustments and you can sometimes detect a blunder if all of the traverse closures are good but a large residual is found in a measurement that was not used in coordinate generation.

Be a little careful in over-interpretation of the .GEN file residual values as the least squares will provide you with a more realistic evaluation of the adjustment that needed to be applied to your measurements. If a datum is selected, the data is also not yet reduced to grid which could contribute to slightly large misclosures.

.1D Least Squares Messages

The following error messages are typically generated during the vertical (.1D) least squares adjustment stage.

NO BENCHMARKS FOUND - THUS NO LEVELING ANALYSIS

This message indicates that no vertical control is present in the *SEGMENT.CTL* file, i.e. no control point has an elevation associated with it. You need a starting elevation to generate other elevations. This message could be due to a station naming problem of a benchmark.

NO ELEVATION FOR STATION A23 GENERATED

This message indicates that no elevation was generated for the named point. Missing data or station naming problems may create data which is not connected to the rest of your survey. This could prevent determination of elevations. If you did not want an elevation on this station the message can be ignored.

```
MISCLOSURE OF MULTIPLE ELEV. DIFFERENCE MEASUREMENTS
  STATIONS           MISCLOSURE
NP1      - SP1             .047
SP1      - FCI1            .081
SP1      - TOM1            .010
NP1      - TOM1            .017
SP1      - TOM1            .048
SP1      - BM1             .575
NP1      - SP1            2.406
NP1      - SP1            1.124
NP1      - SP1            1.336
SP1      - TOM1            .943
END OF MISCLOSURE REPORT
```

In the *SEGMENT.1D* file, the least squares adjustment report for elevations, any line that is shot multiple times is compared in this report. This includes lines shot in opposite directions or the same line shot on a reoccupation of a setup. It is very useful in looking for height of instrument or height of reflector errors.

In this example, lines from NP1 to SP1 an from SP1 to TOM1 are short lines and thus are indicating a problem. If the line from NP1 to SP1 was a 6000 foot long line, you would probably not be concerned. This report compares to the existing averaged elevation change, while the elevation differences displayed in the *SEGMENT.GEN* file compares to the first measurement of that line.

BENCHMARK ELEVATION RESIDUALS

STATION	*INPUT ELEV.*	*ADJUSTED ELEV.*	*ERROR EST.*	*RESIDUAL*
B22	*211.240*	*211.240*	*.001*	*.000*
B6	*203.670*	*203.670*	*.001*	*.000*
B21	*169.940*	*169.940*	*.001*	*.000*

This message displays the name and elevation of all found vertical control points. You should make sure that all of your benchmarks appear in this message or something wrong occurred during their data entry.

If a benchmark is to remain fixed, or not to adjust, it's residual, the amount of adjustment, should be zero.

This is accomplished by assigning them very small error estimates such as 0.001 ft. If you did want benchmark elevations to adjust based on a reasonable error estimate ensure that the residual is of similar or smaller magnitude than its assigned error estimate. If the residual is dramatically larger than its error estimate (three times bigger is often used) it is important to check its assigned elevation for correctness.

```
RESIDUALS

  FROM          TO            MEASURED      RESIDUAL      EST. ERROR

  NP1           BM1              4.918          .011  ( .3)    .037
  NP1           BM2              6.170          .011  ( .4)    .027
  NP1           FCI1            62.304         -.197  (1.3)    .147
  NP1           SP1              6.270         -.015  ( .8)    .021
  NP1           TOM1           -27.312          .004  ( .3)    .014
  SP1           BM1             -1.325         -.001  ( .1)    .014
  SP1           FCI1            55.729          .123  (1.1)    .116
  SP1           TOM1           -33.557         -.005  ( .3)    .015
  SP1           BM2              -.056         -.019  ( .5)    .035

ELEV. DIFF.  RMS ERROR =       .078 SNOOP RMS =   .7
MAX. ELEV. DIFF. RESIDUAL         NP1      -         FCI1     OF       .197
```

This listing shows how much adjustment (residual) had to be applied to the measured elevation differences. The residual should be of similar or smaller magnitude compared to the error estimate. If not, one should check the measurements which resulted in the elevation difference for correctness (incorrect station name, height of instrument, and height of reflector are common field data entry problems). One should also make sure the error estimates are of reasonable magnitude, and if not change default settings regarding error estimation and reprocess your data. See the beginning of this chapter if one has questions on assigning error estimates.

The number in parenthesis next to the residual is the ***snoop number*** which is equal to the absolute value of the residual divided by the error estimate. A snoop number larger than 3.0 is flagged with asterisks because it is indicative of a problem - the residual is more than three times its error estimate. Note that 33% of your data, from a normal distribution/ bell shaped curve, will have snoop numbers greater than one so do not use a snoop number of greater than one as indicative of a problem. A snoop number of 3.0 is more standard and implies 95 % confidence.

The distance from SP1 to FCI1 is over 4000 ft. which is why it has a large error estimate for its trigonometric leveling derived elevation change.

The maximum residual is highlighted at the end of the residual report. Also highlighted is the root-mean-square (average) residual and snoop number.

.2D Least Squares Messages

The following error messages are typically generated during the horizontal (.2D) least squares adjustment stage.

****** MAXIMUM NUMBER OF ITERATIONS REACHED ******

Least squares analysis of horizontal data requires the use of preliminary coordinates. These preliminary coordinates are generated by the abstracting stage, the first processing program. A least squares adjustment is then performed updating the coordinates.

The solution iterates in updating the coordinates to their least squares values meaning a least squares adjustment is then performed on the updated coordinates. The solution usually quits iterations when the updates are less than 0.005 feet meaning the adjustment is performed over and over again until the changes to the coordinates are less than 0.005 feet.

****** SOLUTION DIVERGING - ITERATION HALTS ******

This message indicates the least squares adjustment did not complete the adjustment process. If blunders exist, the updates to the coordinates in the horizontal least squares analysis can get bigger instead of smaller.

This is called a divergence, and means something is drastically wrong with your data. Always review results from the first processing program before continuing.

ALL MEASUREMENTS ARE REDUCED TO THE NAD 83 0903 FLORIDA NORTH LAMBERT
COORDINATE AND DISTANCE UNITS ARE U.S. SURVEY FEET

This message indicates that all coordinates have been reduce to the specified datum. If you have selected a datum make sure it is correct. In NAD 27 only the U.S. Survey Foot is allowed as a distance unit. In NAD 83 you are allowed meters, U.S. Survey Foot, or the International Foot. Control coordinates, distances, and elevation differences must be in the same units.

Make sure in NAD 83 the correct distance and coordinate units exist.

95% CONFIDENCE F STATISTIC STANDARD ERROR MULTIPLIER FOR 6 D.F. IS 3.21

To obtain standard deviations of final coordinates and error ellipses at 95% confidence a multiplier is applied which is a function of your degrees of freedom (level of redundancy). A more redundant survey results in a lower multiplier because the greater number of checks enables you to be more comfortable with your final results.

			STANDARD ERRORS		ERROR ELLIPSE INFO.		
STATION	*ADJUSTED X*	*ADJUSTED Y*	*IN X*	*IN Y*	*SU*	*SV*	*T*
B22	*626264.633*	*158284.560*	*.146*	*.066*	*.149*	*.059*	*78.2*
A25	*624980.787*	*158016.019*	*.011*	*.013*	*.013*	*.011*	*.0*

The coordinate standard errors here indicate if you performed the survey again, under the same conditions, you would be 95% confident of being within that amount of the least squares adjusted coordinate. The error ellipse defines an area centered about the adjusted coordinates where you would be 95% confident that performing the survey over under the same conditions would produce a coordinate within that area. SU and SV are the semi-major and semi-minor axes of the ellipse respectively, and T is the angle in decimal degrees (positive clockwise) from north of the semi-major axis.

DISTANCES

OCCUPIED STATION	*SIGHTED STATION*	*DISTANCE*	*RESIDUAL*		*EST. ERROR*
NP1	*BM1*	*695.330*	*.014*	*(.6)*	*.023*
NP1	*BM2*	*236.275*	*.079*	*(1.3)*	*.062*
NP1	*FCI1*	*4203.195*	*.000*	*(.0)*	*.035*
NP1	*SP1*	*511.210*	*.005*	*(.6)*	*.008*
NP1	*TOM1*	*334.897*	*-.001*	*(.1)*	*.007*
SP1	*BM1*	*184.639*	*-.002*	*(.2)*	*.011*
SP1	*FCI1*	*3691.994*	*.002*	*(.1)*	*.019*
SP1	*TOM1*	*504.641*	*-.005*	*(.7)*	*.006*
SP1	*BM2*	*281.005*	*.014*	*(.6)*	*.022*

DISTANCE RMS ERROR = .027 SNOOP RMS = .6
MAX. DISTANCE RESIDUAL NP1 - BM2 OF .079

A similar output exists for control coordinates, horizontal angles, and azimuths. Output measurement values are displayed in their grid equivalents if a datum and state plane zone has been selected. This listing shows how much adjustment (residual) had to be applied to the measured distances. The initial error estimates are also given and snoop numbers are displayed in parenthesis. The residual should be of similar or smaller magnitude when compared to the error estimate (snoop number less than 3.0). If not, one should check the raw measurements which resulted in this abstracted (averaged) measurement, especially for hand entry items such as station name. One should also make sure the error estimates are of reasonable magnitude, and if not change default settings regarding error estimation and reprocess your data. See the beginning of this document if one has questions on assigning error estimates.

```
    STANDARD ERROR OF UNIT WEIGHT IS      3.551
    WITH    6 DEGREES OF FREEDOM
CHI SQUARED TEST ON ANALYSIS
  .454 <  3.551 <  1.449
  (LOW)             (HIGH)
DOES NOT PASS AT THE 5 % SIGNIFICANCE LEVEL
```

This message displays the results of the Chi Squares test. This is a statistical test that shows your error estimates are reasonable.

Failing the chi squared test does not indicate a bad survey. Making sure all of your residuals are reasonable in magnitude is more important than any statistical test.

Do not be too alarmed if the processed results do not pass the chi-squared test as being 95% confident of measurement data is difficult to obtain.

TRAVERSE CLOSURES NOT POSSIBLE TO COMPUTE

This message indicates that the angles and distances which are present in the *SEGMENT.OBS* file were measured in a way that does not allow the program to compute traverse closures. If your survey is supposed to satisfy Minimum Technical Standards of Florida you may want to add some measurements which make computation of closure possible.

```
TRAVERSE CLOSURE REPORT
SUM OF DISTANCES ALONG TRAVERSE IS        839.503
CLOSURE IN X =     .010 CLOSURE IN Y =    -.024
ANGULAR CLOSURE =    -9.0 SECONDS
LINEAR ERROR OF CLOSURE (AFTER ROTATION) IS         .024
BEFORE ROTATION PRECISION IS 1/       32550.
AFTER  ROTATION PRECISION IS 1/       35381.
```

This is the report given for a typical traverse closure. Links between adjusted coordinates are computed (not loops). Traversing starts on the inverse bearing between adjusted coordinates of the first leg. Coordinates are computed based on measured angles and distances (raw) until the terminating station is reached. Closure in X and Y is a comparison between adjusted and computed coordinates. Angular closure is based on comparing the computed bearing of the last leg to the bearing derived from inversing adjusted coordinates. To eliminate rotation error of the bearing of the first leg, the after rotation error linear error of closure compares the computed distance inverse between end stations to the distance inverse based on adjusted coordinates. The after rotation precision is better than the before rotation precision because it uses the compared distance inverses, which is independent of the initial direction of the first leg. Measurements are reduced to grid in all computations if a state plane zone has been selected.

TOTAL LENGTH OF EVALUATED TRAVERSE DISTANCE = .553 MILES

PRECISION BASED ON LATITUDE AND DEPARTURE CLOSURES = 1 / 3331.

PRECISION AFTER ORIENTATION CORRECTION = 1 / 3623.

This is an evaluation which is based on summing all linear errors of closure and sums of all individual traverse closure distances. This provides an overall 1/X if someone asks you for it.

Horizontal Sideshot And .XYZ/.SOE Generation Messages

The following error messages are typically generated during the generation of sideshot coordinates following the least squares adjustment.

****** COORDINATES UNDETERMINED FOR STATION A23***

This message indicate that the coordinates for the specified point could not be determined. If point A23 was part of differential leveling, this warning can be ignored. You may also not be interested in A23's coordinates. Normally this indicates a station naming problem or a lack of data.

STATION A23 IN Z DATA BUT NOT IN X,Y DATA

This message indicates that only an elevation was computed for the specified point. If point A23 was part of differential leveling this warning can be ignored. You may also not be interested in A23's coordinates. Normally, this indicates a station naming problem or a lack of data.

STATION A23 IN GRAPH DATA BUT NOT IN X,Y,Z DATA - IGNORED

This message indicates that no coordinates were computed for the specified point. Point A23 was assigned a feature code and other attribute information but has no coordinates. All setups in differential leveling result in this warning which can be ignored.

STATION A23 IN GRAPH DATA BUT NO SOE INFO - IGNORED

This message indicates that no coordinates were computed for the specified point. Point A23 was assigned a feature code and other attribute information but has no station-offset data.

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Chapter Twelve - EFBP Files and Utilities

The following described EFBP utility programs were developed to aid in the data processing process. These utility programs are typically used fairly infrequently but still provide a valuable service to the surveyor using EFBP. These utility files are described as they exist and function at the time this handbook was prepared. These console programs must be run with the user sitting in the folder containing the EFB data after it has been exported to OBS, and in some cases an attempt at processing with EFBP has occurred.

CHK.EXE

This utility program allows the user to compute traverse closures for any desired traverse link. To execute this program type CHK at the **C:>** prompt. The user may elect to hold an unknown station's adjusted coordinates as control to force a closure into it.

This program outputs the resulting closure data to a .CHK file. The computed closure's are presented in 3-D if the third dimension closure can be computed.

LCHK.EXE

This utility program allows the user to compute vertical closures for any desired traverse link. To execute this program type LCHK at the **C:>** prompt. The user may elect to hold an unknown station’s adjusted coordinates to force a closure into it. This program outputs the resulting closure data to a .CHL file. The LCHK utility will work with both trigonometric leveling and/or differential leveling.

If the data is in the form of 3-wire or trigonometric leveling, a precision will be computed based on the distance traversed or leveled based upon assuming a stadia constant in leveling of 100.

FIXIT.EXE

This utility program allows the user to alter slope distances, height of instruments, and height of targets by scale and constant values buy entering a specific series of corrections and having them applied to the *entire* .OBS file. To execute this program type FIXIT at the **C:>** prompt. This process is very useful for cleaning up a prism constant error, or converting an entire English .OBS file from feet to metric units or vice-versa. It has been used to clean up decimal point problems that the old DOS

EFB in the field created. This utility will not correct eccentric distances. Station, offset, and level rod readings can also be corrected for scale and constant errors.

The FIXIT utility will allows the user to enter corrections for the following :

Slope Distance Scale Factor
Slope Distance Constant
Instrument Height Scale Factor
Instrument Height Constant
Target Height Scale Factor
Target Height Constant
Station Scale Factor
Station Constant
Offset Scale Factor
Offset Constant
Level Rod Scale Factor
Level Rod Constant

In order for the program to function properly, a value must be entered for each item. If no correction is desired, hitting the **[ENTER]** key will enter the default value which is typically one (1). For example, if an EFB segment of data had been collected in Metric and should have been collected in English, FIXIT can be used to alter all of the recorded data. To perform this correction, simply run FIXIT and enter 3.2808 for the Slope Distance Scale Factor, Instrument Height Scale Factor and Target Height Scale Factor. The program will then search the specified .OBS file and correct each slope distance, instrument height and target height. However, as stated previously, FIXIT will not correct any eccentric measurements.

Office Files

The following is a list of the files which are required for, or produced during EFB data processing :

filename.OBS - ASCII text file of all field survey measurements (required for processing)
filename.CTL - control information (required for processing)
filename.GEN - abstracting and initial coordinate generation report
filename.1D - 1D least squares report
filename.2D - 2D least squares report
filename.XYZ - final coordinate and point attribute file
filename.SOE - final station, offset, elevation, attribute file
filename.LSA - redundant abstracted 2D survey data
filename.2SD - redundant abstracted 2D survey data error estimates
filename.COR - final redundant coordinates, scale factors, convergence angles
filename.GEO - final redundant latitude & longitude
filename.RED - file of redundant data

Chapter Thirteen - A General Processing Strategy

Experienced users of EFBP all have their own special techniques on how to most efficiently process data. This short synopsis is just one person's opinion on how to do it but it works!

Step One - Create a working directory called to store you EFB data.

Step Two - Download field files into this directory.

Step Three - Export .EFB file into .OBS file, and if not feeling too lazy, quickly look at it in a text editor for any obvious problems or any important comments from the field. If feeling lazy, do not look at .OBS and leave it up to EFBP to find the problems.

Step Four - Build a control file and export the CTL. If at all possible, use the control is in an existing .CTL, .XYZ. Import this data without having to type in any coordinates as that type of input (typing) is very prone to blunders.

Step Five - Run EFBP in first pass mode where you are only processing through step 1 - abstracting and preliminary coordinate generation - to produce the .GEN report. Correct error estimates if necessary . Carefully define maximum spread tolerances above which tolerance values are asterisked (*).

Step Six - Review the .GEN report by looking for asterisks in a text editor using the search mode. If one finds a problem, open up the .OBS file in split screen mode and try to eliminate any problems. If problems were found, go to Step Eight. If no problems were found, go to Step Nine.

Step Seven - Re-process only as far as the .GEN report and return to Step Six.

Step Eight - Re-process to final .XYZ (and possibly .SOE) in the hopes that the .GEN report indicated all problems.

Step Nine - Look at the vertical least squares .1D report. Do not look closely at elevation difference comparisons because that already was reported on in .GEN . View the snoop numbers of all elevation difference residuals and see if any problems exist. Problems are usually those above 3.0 though if the snoop number RMS is high (above 1.5) also make sure the residuals are not systematic (all plus or minus in nature). Make sure the standard error of unit weight is reasonable.

If things are reasonable, you are finished evaluating the .1D report and go to Step Twelve. If things are not reasonable, it is probably a benchmark problem and go to Step Ten. Note, measuring to a point which was not really the benchmark is the same as a bad benchmark elevation.

Step Ten - Replace non-fixed error estimates on all benchmarks. Suitable values would be 0.10 ft. or. 0.03 m. Reprocess only as far as .1D, but turn on robustness using the EFBP menu. It is recommended to robust twice in succession.

Step Eleven - Review the robusted .1D file results and hopefully find the problem(s). Fix any problems, and re-set benchmark elevation error estimates to fixed (0.001). Return to Step Eight.

Step Twelve - Look at the horizontal least squares .2D report. View the snoop numbers of all measurement residuals and see if any problems exist. Problems are usually those above 3.0 though if the snoop number RMS is high (above 1.5) also make sure the residuals are not systematic (all plus or minus in nature). Make sure the standard error of unit weight is reasonable.

If things are reasonable, you are finished evaluating the .2D report and go to Step Sixteen. If things are not reasonable, it is probably a horizontal control problem and go to Step thirteen. Note, measuring to a point which was not really the control is the same as a bad control coordinate.

Step Thirteen - Place non-fixed error estimates on all horizontal control. Suitable values would be 0.10 ft. or. 0.03 m. Reprocess only as far as creating the .2D file but turn on robustness using the EFBP menu. Usually robust twice in succession for best results.

Step Fourteen - Review the robusted .2D file results and hopefully find the problem(s). Fix any problems, and re-set horizontal control error estimates to fixed (0.001). Re-process to .XYZ and return to Step Twelve.

Step Fifteen - You have acceptable .GEN, .1D, and .2D reports. Review the .XYZ and/or .SOE files to ensure all stations have the required coordinate information (though the last part of processing usually indicates if a problem exists).

Step Sixteen - If desired, but not necessary, copy the .XYZ, .SOE, chain, and tape files to a directory where all subsequent surveying/engineering calculations will occur.

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Chapter Fourteen - Example Data And Output

The redundant portion of a job, named BRIDGE, has been extracted from a larger job to illustrate the numerical processing of EFBP. Note, the .OBS file only reflects the total station measurement data (no taping, chains, prefixes, or other types of data) as that is all that is intended to be presented here.

Control File - BRIDGE.CTL

```
G 00 BRIDGE
G 01 FCI1     55-72-A16                                                0903 27 29
G 02  2086126.879   524842.335                 .100     .100
G 01 NP1      55-84-19A                                                0903 27 29
G 02  2086150.710   529045.338                 .100     .100
G 01 BM1      55-84-A09                                                0903 27 29
G 02                             96.231                                   .010
```

Observation File - BRIDGE.OBS

```
H 00 319-RR-BRIDGE-REHAB     13:19:02 11/23/88  13:19:02 11/23/88
H 99 THIS IS A PRODUCTION PROJECT FOR STRUCTURES, AT SR319 SOUTH OF US 90 E ON
H 99 CAPITOL CIRCLE.
C 00 13:22:15 11/23/88  70 30.0 122222 BMD TLH WGC DOT
C 01 TOPCON     GTS-3B     Q31296     02 05 100
S 00 NP1      55-84-19A        P G1
S 01 14:18:00 11/23/88  5.400
O 00 BM1      55-84-A09        P G1
O 01 14:25:21    5.000           1 D 358 30  7.0  89 37 49     695.400 S
O 01 14:31:15    5.000           1 R 178 29 59.0 270 22 37     695.350 S
O 01 14:37:31    5.000           2 R  82 41 14.0 270 22 31     695.310 S
O 01 14:46:01    5.000           2 D 262 41 18.0  89 37 52     695.300 S
O 01 14:53:05    5.000           4 D 161 21 17.0  89 37 52     695.340 S
O 01 14:57:04    5.000           4 R 341 21 39.0 270 22 33     695.390 S
O 01 15:07:17    5.000           5 D  69 25  2.0  89 37 53     695.300 S
O 01 15:02:29    5.000           5 R 249 25 22.0 270 22 27     695.370 S
O 00 BM2                       P G1
O 01 15:13:10    5.000           5 R 260 16 44.0 271 24  7     236.400 S
O 01 15:11:36    5.000           5 D  80 16 54.0  88 36 15     236.290 S
O 00 FCI1     55-17-A16        P G1
O 01 14:33:48    5.850           1 D 359 59 59.0  89  8 51    4203.670 S
O 01 14:34:37    5.850           1 R 179 59 56.0 270 51 22    4203.660 S
O 01 14:50:04    5.850           4 D 162 50 54.0  89  8 42    4203.680 S
O 01 14:59:26    5.850           4 R 342 51  8.0 270 51 28    4203.630 S
O 01 15:00:39    5.850           5 R 250 54 54.0 270 51 23    4203.670 S
O 01 15:10:03    5.850           5 D  70 54 51.0  89  8 44    4203.670 S
O 00 SP1                       P G1
O 01 14:26:55    3.430           1 D 359 50 52.0  89 31 30     511.230 S
O 01 14:36:18    3.430           1 R 179 50 36.0 270 28 55     511.230 S
O 01 14:51:38    3.430           4 D 162 41 51.0  89 31 18     511.230 S
O 01 14:57:58    3.430           4 R 342 41 42.0 270 28 57     511.230 S
O 01 15:01:30    3.430           5 R 250 45 28.0 270 28 49     511.230 S
O 01 15:08:29    3.430           5 D  70 45 34.0  89 31 21     511.230 S
```

```
O 00 TOM1                       P G1
O 01 14:29:37    5.360            1 R 110  9  5.0 265 19 48     336.010 S
O 01 14:28:15    5.360            1 D 290  9  2.0  94 40 24     336.010 S
O 01 14:43:01    5.360            2 D 194 19 49.0  94 40 26     336.020 S
O 01 14:41:06    5.360            2 R  14 19 44.0 265 19 58     336.020 S
O 01 14:55:52    5.360            4 R 273  0  9.0 265 19 58     336.020 S
O 01 14:54:53    5.360            4 D  93  0  5.0  94 40 27     336.020 S
O 01 15:04:26    5.360            5 R 181  4  4.0 265 19 55     336.020 S
O 01 15:05:57    5.360            5 D   1  3 55.0  94 40 21     336.010 S
S 00 SP1                        P G1
S 01 16:21:59 11/23/88  3.680
O 00 BM1      55-84-A09         P G1
O 01 16:32:52    5.000            1 R 354 45 13.0 269 59 39     184.640 S
O 01 16:33:53    5.000            1 D 174 45 46.0  90  0 28     184.640 S
O 01 16:42:43    5.000            2 R  88 24 41.0 269 59 46     184.630 S
O 01 16:41:28    5.000            2 D 268 24 17.0  90  0 27     184.630 S
O 01 16:48:12    5.000            3 D 177 15  0.0  90  0 27     184.620 S
O 01 16:47:29    5.000            3 R 357 14 35.0 269 59 42     184.660 S
O 01 16:53:10    5.000            4 R 253  4 35.0 269 59 44     184.640 S
O 01 16:52:35    5.000            4 D  73  4 49.0  90  0 26     184.630 S
O 00 FCI1     55-72-A16         P G1
O 01 16:24:15    5.850            1 R   0  0  1.0 270 53 49    3692.450 S
O 01 16:38:03    5.850            1 D 179 59 44.0  89  6  4    3692.450 S
O 00 NP1      55-84-19A         P G1
O 01 16:35:39    5.140            1 D 359 49 31.0  90 32 39     511.230 S
O 01 16:25:39    5.140            1 R 179 49 24.0 269 27 38     511.220 S
O 01 16:44:59    5.140            2 R 273 28 55.0 269 27 36     511.230 S
O 01 16:40:04    5.140            2 D  93 28 48.0  90 32 35     511.230 S
O 01 16:49:36    5.140            3 D   2 19  4.0  90 32 38     511.230 S
O 01 16:46:22    5.140            3 R 182 18 59.0 269 27 34     511.230 S
O 01 16:50:54    5.140            4 D 258  8 31.0  90 32 38     511.230 S
O 01 16:54:45    5.140            4 R  78  8 54.0 269 27 43     511.230 S
O 00 TOM1                       P G1
O 01 16:34:51    5.360            1 D  38 19  6.0  93 37  5     505.650 S
O 01 16:28:43    5.360            1 R 218 18 59.0 266 23  0     505.650 S
O 01 16:40:40    5.360            2 D 131 58 14.0  93 37  6     505.640 S
O 01 16:43:37    5.360            2 R 311 58 16.0 266 23  2     505.650 S
O 01 16:46:58    5.360            3 R 220 48 26.0 266 23  5     505.650 S
O 01 16:48:54    5.360            3 D  40 48 22.0  93 37 13     505.650 S
O 01 16:51:30    5.360            4 D 296 38  0.0  93 37 12     505.650 S
O 01 16:53:41    5.360            4 R 116 38 22.0 266 23  6     505.650 S
S 00 SP1                        P G1
S 01 16:59:17 11/23/88  3.680
O 00 FCI1     55-72-A16         P G1
O 01 17:01:02    5.850            1 R 258 19 27.0 270 54 12    3692.440 S
O 01 17:03:38    5.850            1 D  78 19 28.0  89  6 16    3692.450 S
O 01 17:04:55    5.850            2 D 344 10 10.0  89  6  0    3692.450 S
O 01 17:07:34    5.850            2 R 164 10  6.0 270 53 52    3692.440 S
O 00 TOM1                       P G1
O 01 17:02:55    5.360            1 D 296 38 30.0  93 37 10     505.640 S
O 01 17:02:13    5.360            1 R 116 38 27.0 266 23 10     505.640 S
O 01 17:05:38    5.360            2 D 202 29 12.0  93 37  4     505.650 S
O 01 17:06:20    5.360            2 R  22 29  8.0 266 23  8     505.650 S
S 00 TOM1                       P G1
S 01 17:45:58 11/23/88  5.360
O 00 NP1      55-84-19A         P G1
O 01 18:01:42    5.140            1 D  71 48  3.0  85 22 37     335.980 S
O 01 18:02:29    5.140            1 R 251 47 50.0 274 37 32     335.990 S
O 01 18:16:04    5.140            2 D 318 47 51.0  85 22 42     335.980 S
O 01 18:10:09    5.140            2 R 138 47 42.0 274 37 27     336.000 S
```

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O 01 18:21:54    5.140          3 R  46 15  9.0 274 37 30     335.980 S
O 01 18:16:54    5.140          3 D 226 15  7.0  85 22 40     335.990 S
O 01 18:23:17    5.140          4 R 303 57 51.0 274 37 27     335.990 S
O 01 18:34:40    5.140          4 D 123 57 58.0  85 22 39     335.990 S
OD01 18:38:34    5.140          4 R 303 57 59.0 274 37 34     335.990 S
O 00 SP1                      P G1
O 01 18:04:38    3.450          1 R 179 58 59.0 273 35 10     505.630 S
O 01 17:52:33    3.450          1 D 359 59 58.0  86 24 56     505.630 S
O 01 18:11:27    3.450          2 R  66 58 53.0 273 35 13     505.630 S
O 01 18:12:43    3.450          2 D 246 58 58.0  86 25  2     505.640 S
O 01 18:20:02    3.450          3 R 334 26 19.0 273 35 15     505.640 S
O 01 18:19:17    3.450          3 D 154 26 15.0  86 25  0     505.630 S
O 01 18:25:47    3.450          4 R 232  9  0.0 273 35 13     505.640 S
O 01 18:32:01    3.450          4 D  52  9 10.0  86 24 55     505.630 S
OD01 18:45:18    3.450          4 R 232  9 33.0 273 35 12     505.640 S
O 00 TBM1                     P G1
O 01 17:59:39    0.760          1 D  38 30 28.0  89 38 40     330.010 S
O 01 18:03:11    0.760          1 R 218 30 26.0 270 21 31     330.010 S
O 01 18:13:21    0.760          2 D 285 30 26.0  89 38 42     330.020 S
O 01 18:08:31    0.760          2 R 105 30 20.0 270 21 24     330.040 S
O 01 18:18:30    0.760          3 D 192 57 43.0  89 38 45     330.010 S
O 01 18:20:35    0.760          3 R  12 57 49.0 270 21 27     330.020 S
O 01 18:42:51    0.760          4 R 270 39 48.0 270 21 24     329.930 S
O 01 18:33:21    0.760          4 D  90 40 36.0  89 38 38     330.050 S
OD01 18:25:03    0.760          4 R 270 40 25.0 270 21 29     330.020 S
O 00 WP1                      P G1
O 01 18:05:53    5.220          1 R 222  1 58.0 270 18 42     500.790 S
O 01 17:58:24    5.220          1 D  42  1 51.0  89 41 24     500.780 S
O 01 18:07:17    5.220          2 R 109  1 48.0 270 18 43     500.790 S
O 01 18:14:47    5.220          2 D 289  1 52.0  89 41 27     500.790 S
O 01 18:21:14    5.220          3 R  16 29  6.0 270 18 45     500.790 S
O 01 18:17:28    5.220          3 D 196 29  5.0  89 41 32     500.790 S
O 01 18:23:54    5.220          4 R 274 11 54.0 270 18 49     500.790 S
O 01 18:33:57    5.220          4 D  94 12 13.0  89 41 34     500.790 S
OD01 18:41:18    5.220          4 R 274 12 26.0 270 18 45     500.800 S
C 00 14:20:55 11/29/88  50 30.2 000000 BMD BMD GWF TLH
C 01 TOPCON     GTS-3B     Q31296      2  5 100
S 00 SP1                      P G1
S 01 14:21:23 11/29/88  5.000
O 00 BM1      55-84-A09       P G1
O 01 14:25:28    5.000          1 D 359 58 58.0  90 24 25     184.630 S
O 01 14:26:49    5.000          1 R 179 59 18.0 269 36 14     184.680 S
O 00 BM2                      P F1
O 01 14:30:38    5.000          1 D 177  3 36.0  90  0 57     281.020 S
O 01 14:29:45    5.000          1 R 357  3 26.0 269 59 35     280.990 S
O 00 NP1      55-84-19A       P G1
O 01 14:33:27    5.000          1 D 185  4 15.0  90 42 24     511.230 S
O 01 14:34:42    5.000          1 R   5  4 12.0 269 18  3     511.280 S
```

Abstracting And Preliminary Traverse Report - BRIDGE.GEN

```
PROJECT BRIDGE   PARAMETERS
USE REPETITION ERRORS PLUS ADD-ONS IN ERROR ESTIMATION
COMPUTE COORDINATE STANDARD ERRORS AND ERROR ELLIPSES
CORRECT FOR EARTH CURVATURE AND ATMOSPHERIC REFRACTION
ROBUST ERROR ESTIMATE PROMPT WILL NOT APPEAR
PROCESS TO FINAL COORDINATE .XYZ FILE

FOLLOWING USED AS ADD-ONS TO ERROR FROM REPETITON
DISTANCE   DISTANCE     HORZ.     AZIMUTH   TRIG. LEV.   TRIG. LEV.  DIFF. LEV
CONSTANT     PPM     ANGLE (SEC)   (SEC)     CONSTANT        PPM      CONSTANT
     .010      5.00       6.0         10.0       .030       100.00        .010

FOLLOWING ARE USER DEFINED ERROR ESTIMATES
  DISTANCE   DISTANCE     HORZ.      AZIMUTH    TRIG. LEV.   DIFF. LEV.
  CONSTANT     PPM     ANGLE (SEC)    (SEC)      CONSTANT     CONSTANT
      .020       5.00         12.0       10.0         .050         .010

SETUP ERROR (ALWAYS USED) =   .005
FLAG MAXIMUM SPREADS ABOVE
(23) DISTANCE =   .030 (24) ANGLES =   20.0 (25) ELEV. DIFFERENCES =   .100


WARNING - CALIBRATION RECORD WITHOUT DATA

PROCESSING SETUP #   1 AT STATION NP1
REPETITION STANDARD ERRORS
SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.           COMPARE
STATION      SD      SD     MAX        SD    SD       MAX      HORZ.     ELEV.
                   (MEAN)  SPREAD          (MEAN)   SPREAD     DIST.     DIFF.
BM1        .040    .014 *  .055*    .044   .015     .056
BM2        .077    .055 *  .055*    .020   .014     .014
FCI1       .019    .008 *  .036*    .134   .055 *   .210*
SP1        .000    .000    .000     .026   .010     .038
TOM1       .006    .002    .007     .018   .006     .021
REPETITION STANDARD ERRORS FOR ANGLES
BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
BM1            BM2            21.       15.         15.
BM1            FCI1           12.        5.         14.
BM1            SP1            17.        7.     *   23.*
BM1            TOM1           13.        5.     *   22.*

PROCESSING SETUP #   1 AT STATION SP1
REPETITION STANDARD ERRORS
SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.           COMPARE
STATION      SD      SD     MAX        SD    SD       MAX      HORZ.     ELEV.
                   (MEAN)  SPREAD          (MEAN)   SPREAD     DIST.     DIFF.
BM1        .012    .004    .024     .005   .002     .007
FCI1       .001    .001    .001     .089   .063     .063
NP1        .003    .001    .009     .021   .008     .032       .006     -.036
TOM1       .004    .001    .009     .018   .006     .025
REPETITION STANDARD ERRORS FOR ANGLES
BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
BM1            FCI1           35.       25.     *   25.*
BM1            NP1            18.        6.     *   27.*
BM1            TOM1           17.        6.     *   25.*
```

```
 PROCESSING SETUP #   2 AT STATION SP1
  REPETITION STANDARD ERRORS
  SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.            COMPARE
  STATION      SD      SD     MAX        SD     SD      MAX      HORZ.     ELEV.
                   (MEAN)  SPREAD           (MEAN)   SPREAD     DIST.     DIFF.
  FCI1       .008    .004    .009     .214   .107 *   .268*      .006      .080
  TOM1       .006    .003    .007     .023   .012     .027       .003      .010
  REPETITION STANDARD ERRORS FOR ANGLES
  BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
  FCI1           TOM1            1.        0.          2.

  PROCESSING SETUP #   1 AT STATION TOM1
  REPETITION STANDARD ERRORS
  SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.            COMPARE
  STATION      SD      SD     MAX        SD     SD      MAX      HORZ.     ELEV.
                   (MEAN)  SPREAD           (MEAN)   SPREAD     DIST.     DIFF.
  NP1        .007    .002    .012     .008   .003     .012       .006     -.014
  SP1        .005    .002    .008     .016   .006     .022      -.004     -.043
  TBM1       .036    .013 *  .081*    .008   .003     .013
  WP1        .004    .001    .009     .020   .007     .029
  REPETITION STANDARD ERRORS FOR ANGLES
  BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
  NP1            SP1            16.        6.     *   40.*
  NP1            TBM1           14.        5.     *   34.*
  NP1            WP1             8.        3.         14.
  WARNING - CALIBRATION RECORD WITHOUT DATA

  PROCESSING SETUP #   3 AT STATION SP1
  REPETITION STANDARD ERRORS
  SIGHTED      HORIZONTAL DISTANCE      ELEVATION DIFF.            COMPARE
  STATION      SD      SD     MAX        SD     SD      MAX      HORZ.     ELEV.
                   (MEAN)  SPREAD           (MEAN)   SPREAD     DIST.     DIFF.
  BM1        .036    .025    .025     .024   .017     .017      -.014      .046
  BM2        .021    .015    .015     .031   .022     .022
  NP1        .036    .025    .025     .047   .033     .033      -.007     -.015
  REPETITION STANDARD ERRORS FOR ANGLES
  BS STATION     FS STATION     SD    SD (MEAN)  MAX SPREAD
  BM1            BM2            21.       15.         15.
  BM1            NP1            16.       11.         11.
      2 OF     8 STATIONS ARE HORIZONTAL SIDESHOTS

  TRAVERSE CLOSURE REPORT
  LINEAR ERROR OF CLOSURE IS         .114 FT.

  PRECISION IS 1/       39844.


  STATION                  X COOR.         Y COOR.

  FCI1                 2086126.879      524842.335
  SP1                  2086149.179      528534.161
  TOM1                 2086464.440      528928.191
  NP1                  2086150.710      529045.338

  STATION  BM1      HAS COORDINATES GENERATED BY ANGLE AND DISTANCE
  FROM KNOWN BACKSIGHT
  X=  2086164.912 Y=   528350.153
```

STATION BM2 HAS COORDINATES GENERATED BY ANGLE AND DISTANCE
FROM KNOWN BACKSIGHT
X= 2086110.941 Y= 528812.434

FINAL GENERATED COORDINATES

STATION	X COOR.	Y COOR.
FCI1	2086126.879	524842.335
NP1	2086150.710	529045.338
BM1	2086164.912	528350.153
BM2	2086110.941	528812.434
SP1	2086149.179	528534.161
TOM1	2086464.440	528928.191

DISTANCE RESIDUALS

DISTANCE		RESIDUAL
NP1	- BM1	.000
NP1	- BM2	.000
NP1	- FCI1	.124
NP1	- SP1	.032
NP1	- TOM1	.009
SP1	- BM1	-.040
SP1	- FCI1	.100
SP1	- TOM1	.014
SP1	- BM2	.117

ANGLE RESIDUALS

ANGLE			RESIDUAL (SEC)
BM1	- NP1	- BM2	.0
BM1	- NP1	- FCI1	.0
BM1	- NP1	- SP1	-4.9
BM1	- NP1	- TOM1	-1.0
BM1	- SP1	- FCI1	23.9
BM1	- SP1	- NP1	37.6
BM1	- SP1	- TOM1	35.5
FCI1	- SP1	- TOM1	.0
NP1	- TOM1	- SP1	.0
BM1	- SP1	- BM2	36.3
BM1	- SP1	- NP1	94.3

Vertical Least Squares Report - BRIDGE.1D

```
MISCLOSURE OF MULTIPLE ELEV. DIFFERENCE MEASUREMENTS
  STATIONS           MISCLOSURE
NP1      - SP1             .036
SP1      - FCI1            .080
SP1      - TOM1            .010
NP1      - TOM1            .014
SP1      - TOM1            .039
SP1      - BM1             .046
NP1      - SP1             .003
END OF MISCLOSURE REPORT

    2 OF     8 STATIONS IDENTIFIED AS VERTICAL SIDESHOTS
BAND IS   4 STATIONS
LEVEL NETWORK ADJUSTMENT

NUMBER OF BENCHMARKS =     1
NUMBER OF STATIONS =     6
NUMBER OF MEASUREMENTS =     9
NUMBER OF REQUIRED TERMS FOR NORMAL EQUATIONS =       26

RESULTS OF ADJUSTMENT

BENCHMARK ELEVATION RESIDUALS

  STATION       INPUT ELEV.     ADJUSTED ELEV.     ERROR EST.     RESIDUAL

  BM1               96.231            96.231         .010        .000  ( .0)

BENCHMARK RMS ERROR =       .000 SNOOP RMS =   .0
MAX. BENCHMARK RESIDUAL AT STATION         BM1      OF       .000


RESIDUALS

  FROM          TO            MEASURED      RESIDUAL      EST. ERROR

  NP1           BM1              4.928          .007  ( .1)    .115
  NP1           BM2              6.171          .012  ( .2)    .068
  NP1           FCI1            62.668         -.274  ( .5)    .505
  NP1           SP1              6.269         -.014  ( .2)    .058
  NP1           TOM1           -27.313          .005  ( .1)    .048
  SP1           BM1             -1.319         -.001  ( .0)    .040
  SP1           FCI1            56.013          .126  ( .4)    .341
  SP1           TOM1           -33.557         -.005  ( .1)    .052
  SP1           BM2              -.054         -.017  ( .2)    .080

ELEV. DIFF.  RMS ERROR =       .101 SNOOP RMS =   .3
MAX. ELEV. DIFF. RESIDUAL         NP1      -         FCI1     OF       .274


95% CONFIDENCE F STATISTIC STANDARD ERROR MULTIPLIER FOR    4 D.F. IS  3.73

   STATION        ADJUSTED ELEV.     STANDARD ERROR

   BM1                  96.231                .014
   NP1                  91.296                .075
   SP1                  97.551                .057
```

```
   BM2                   97.480                .097
   FCI1                 153.690                .410
   TOM1                  63.988                .079

    STANDARD ERROR OF UNIT WEIGHT IS       .384
     WITH    4 DEGREES OF FREEDOM

CHI SQUARED TEST ON ANALYSIS
  .348 <   .384 <  1.540
  (LOW)             (HIGH)
PASSES AT THE 5 % SIGNIFICANCE LEVEL
```

Horizontal Least Squares Report - BRIDGE.2D

PARAMETRIC HORIZONTAL LEAST SQUARES ADJUSTMENT

ALL MEASUREMENTS ARE REDUCED TO THE NAD 27
0903 FLORIDA NORTH LAMBERT

COORDINATE AND DISTANCE UNITS ARE U.S. SURVEY FEET
BAND IS 4 STATIONS
NUMBER OF TERMS REQUIRED IN NORMAL EQUATIONS = 111

95% CONFIDENCE F STATISTIC STANDARD ERROR MULTIPLIER FOR 12 D.F. IS 2.77

RESULTS OF ADJUSTMENT

STATION	ADJUSTED X	ADJUSTED Y	STANDARD ERRORS IN X	IN Y	ERROR ELLIPSE INFO. SU	SV	T
BM2	2086110.939	528812.487	.308	.240	.308	.240	88.0
NP1	2086150.710	529045.307	.318	.227	.318	.227	-89.7
SP1	2086149.164	528534.124	.286	.227	.286	.227	-89.8
BM1	2086164.926	528350.164	.278	.231	.278	.231	-89.1
FCI1	2086126.879	524842.366	.318	.227	.318	.227	-89.7
TOM1	2086464.428	528928.151	.311	.232	.313	.229	-80.8

RESIDUALS IN THE OBSERVATIONS

CONTROL POINT COORDINATES

STATION	X RESIDUAL	X EST. ERROR	Y RESIDUAL	Y EST. ERROR
FCI1	.000 (.0)	.100	-.031 (.3)	.100
NP1	.000 (.0)	.100	.031 (.3)	.100

EASTING CONTROL RMS = .000 SNOOP RMS = .0
MAX. EASTING RESIDUAL AT FCI1 OF .000
NORTHING CONTROL RMS = .031 SNOOP RMS = .3
MAX. NORTHING RESIDUAL AT FCI1 OF .031

DISTANCES

OCCUPIED STATION	SIGHTED STATION	DISTANCE	RESIDUAL	EST. ERROR
NP1	BM1	695.300	.012 (.4)	.027
NP1	BM2	236.264	.072 (1.1)	.066
NP1	FCI1	4203.004	-.004 (.1)	.039
NP1	SP1	511.188	.004 (.3)	.011
NP1	TOM1	334.883	.003 (.3)	.010
SP1	BM1	184.632	-.002 (.2)	.015
SP1	FCI1	3691.825	.000 (.0)	.022
SP1	TOM1	504.620	-.007 (.8)	.009
SP1	BM2	280.993	.018 (.7)	.026

DISTANCE RMS ERROR = .025 SNOOP RMS = .6
MAX. DISTANCE RESIDUAL NP1 - BM2 OF .072

ANGLES

BACKSIGHT STATION	OCCUPIED STATION	FORESIGHT STATION	ANGLE	RESIDUAL (SECONDS)		EST. ERROR (SECONDS)
BM1	NP1	BM2	10-51-37.0	-17.9	(.8)	21.5
BM1	NP1	FCI1	1-29-42.7	-4.4	(.4)	10.8
BM1	NP1	SP1	1-20-26.2	-15.1	(1.1)	13.3
BM1	NP1	TOM1	291-38-44.4	-13.1	(1.2)	11.3
BM1	SP1	FCI1	5-14-23.0	-11.5	(.4)	31.5
BM1	SP1	NP1	185- 4- 8.7	-4.3	(.3)	13.6
BM1	SP1	TOM1	223-33-36.1	-1.9	(.1)	13.3
FCI1	SP1	TOM1	218-19- 1.5	-2.1	(.3)	6.8
NP1	TOM1	SP1	288-11-15.1	6.3	(.5)	12.3
BM1	SP1	BM2	177- 4-23.0	-18.1	(.8)	22.0
BM1	SP1	NP1	185- 5- 5.5	52.5	(2.8)	18.5

ANGLE RMS ERROR = 19.1 SECONDS SNOOP RMS = 1.1
MAXIMUM ANGLE RESIDUAL BM1 - SP1 - NP1
OF 52.5 SEC.

STANDARD ERROR OF UNIT WEIGHT IS 1.148
WITH 12 DEGREES OF FREEDOM
CHI SQUARED TEST ON ANALYSIS
.606 < 1.148 < 1.324
(LOW) (HIGH)
PASSES AT THE 5 % SIGNIFICANCE LEVEL

TRAVERSE CLOSURE REPORT
SUM OF DISTANCES ALONG TRAVERSE IS 4531.328
CLOSURE IN X = .016 CLOSURE IN Y = .014
ANGULAR CLOSURE = 8.4 SECONDS
LINEAR ERROR OF CLOSURE (AFTER ROTATION) IS .014
BEFORE ROTATION PRECISION IS 1/ 210529.
AFTER ROTATION PRECISION IS 1/ 320339.

STATION	BEARING	DISTANCE	X	Y
FCI1			2086126.879	524842.366
SP1	N 0-20-45.1E	3691.825	2086149.164	528534.124
TOM1	N38-39-48.7E	504.627	2086464.428	528928.151
NP1	N69-31-20.1W	334.880	2086150.710	529045.307

TOTAL LENGTH OF EVALUATED TRAVERSE DISTANCE = .858 MILES

PRECISION BASED ON LATITUDE AND DEPARTURE CLOSURES = 1 / 210529.

PRECISION AFTER ORIENTATION CORRECTION = 1 / 320339.

Output Adjusted State Plane Coordinate File - BRIDGE.COR

STATION	X COOR.	Y COOR.	SCALE FACTOR	CONVERGENCE
BM1	2086164.926	528350.164	.99996078	+ 0- 8- 14.7
BM2	2086110.939	528812.487	.99996089	+ 0- 8- 14.4
FCI1	2086126.879	524842.366	.99995996	+ 0- 8- 14.4
NP1	2086150.710	529045.307	.99996095	+ 0- 8- 14.6
SP1	2086149.164	528534.124	.99996083	+ 0- 8- 14.6
TOM1	2086464.428	528928.151	.99996092	+ 0- 8- 16.4

Output Adjusted Geodetic Coordinate File - BRIDGE.GEO

STATION	LATITUDE	LONGITUDE
BM1	30-27- 9.27887	84-13- 35.57970
BM2	30-27- 13.85650	84-13- 36.18382
FCI1	30-26- 34.55742	84-13- 36.11044
NP1	30-27- 16.16015	84-13- 35.72307
SP1	30-27- 11.10020	84-13- 35.75473
TOM1	30-27- 14.99302	84-13- 32.14206

Input Redundant Horizontal Measurement File - BRIDGE.LSA

```
FCI1        2086126.879       524842.335    0
NP1         2086150.710       529045.338    1
NP1             BM1                    695.330    0
NP1             BM2                    236.275    0
NP1             FCI1                  4203.195    0
NP1             SP1                    511.211    0
NP1             TOM1                   334.897    0
SP1             BM1                    184.640    0
SP1             FCI1                  3691.994    0
SP1             TOM1                   504.642    0
SP1             BM2                    281.005    1
BM1        NP1      BM2         10 51 37.00 0
BM1        NP1      FCI1         1 29 42.67 0
BM1        NP1      SP1          1 20 26.17 0
BM1        NP1      TOM1       291 38 44.37 0
BM1        SP1      FCI1         5 14 23.00 0
BM1        SP1      NP1        185  4  8.75 0
BM1        SP1      TOM1       223 33 36.13 0
FCI1       SP1      TOM1       218 19  1.50 0
NP1        TOM1     SP1        288 11 15.13 0
BM1        SP1      BM2        177  4 23.00 0
BM1        SP1      NP1        185  5  5.50 1
0               0                0  0    .00   1
BM1               2086164.912            528350.153    0
BM2               2086110.941            528812.434    0
SP1               2086149.179            528534.161    0
TOM1              2086464.440            528928.191    1
```

Input Redundant Horizontal Measurement Error Estimate File - BRIDGE.2SD

```
FCI1             .100         .100    0
NP1              .100         .100    1
NP1               BM1                        .027    0
NP1               BM2                        .066    0
NP1               FCI1                       .039    0
NP1               SP1                        .011    0
NP1               TOM1                       .010    0
SP1               BM1                        .015    0
SP1               FCI1                       .022    0
SP1               TOM1                       .009    0
SP1               BM2                        .026    1
BM1         NP1         BM2          21.00 0
BM1         NP1         FCI1         10.71 0
BM1         NP1         SP1          13.10 0
BM1         NP1         TOM1         10.75 0
BM1         SP1         FCI1         31.00 0
BM1         SP1         NP1          12.22 0
BM1         SP1         TOM1         11.92 0
FCI1        SP1         TOM1          6.50 0
NP1         TOM1        SP1          11.72 0
BM1         SP1         BM2          21.00 0
BM1         SP1         NP1          17.50 1
```

Final Coordinate File - BRIDGE.XYZ

```
G 00 BRIDGE.XYZ
G 01 FCI1     55-17-A16       P G1                             0903 27 29
G 02  2086126.879  524842.366   153.690     .318     .227     .410
G 01 NP1      55-84-19A       P G1                             0903 27 29
G 02  2086150.710  529045.307    91.296     .318     .227     .075
G 01 BM1      55-84-A09       P G1                             0903 27 29
G 02  2086164.926  528350.164    96.231     .278     .231     .014
G 01 BM2                      P G1                             0903 27 29
G 02  2086110.939  528812.487    97.480     .308     .240     .097
G 01 SP1                      P G1                             0903 27 29
G 02  2086149.164  528534.124    97.551     .286     .227     .057
G 01 TOM1                     P G1                             0903 27 29
G 02  2086464.428  528928.151    63.988     .311     .232     .079
G 01 TBM1                     P G1                             0903 27 29
G 02  2086142.655  528854.965    70.643
G 01 WP1                      P G1                             0903 27 29
G 02  2085970.233  528847.327    66.847
```

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Chapter Fifteen - Glossary

The following represents a brief glossary of selected EFB Processing terms. For a more detailed explanation, please consult the EFB Processing Technical Handbook.

- A -

AFTER ROTATION PRECISION - based on LINEAR ERROR OF CLOSURE (AFTER ROTATION).

ANGULAR CLOSURE - The last line in the traverse has its least squares adjusted coordinates inversed for direction, and the azimuth computed from the traverse computations is subtracted from this value to obtain the angular closure.

- B -

BANDWIDTH OPTIMIZATION - There are many ways to speed up the solution of a system of equations and reduce the number of terms in the equations. Some methods other than bandwidth optimization include column profile minimization, Helmert blocking, and recursive partitioning. If a computer program does not use one of these methods the results will be produced very slowly. LSAQ uses a bandwidth optimization routine which has been extensively modified for better performance. For most survey networks the bandwidth will probably range from 5-30% of the total number of stations. This process enables more efficient solution of least squares problems, and especially allows "big" problems to be solved on a personal computer

BEFORE ROTATION PRECISION - based on latitude and departure closures.

- C -

CHI-SQUARED TEST - A statistical test of the standard error of unit weight to see which verifies if the adjustment is statistically reasonable. It is usually performed at the 95% (.05) confidence level.

CLOSURE IN NORTHING OR EASTING - EFBP inverses the adjusted coordinates of the first line to get a starting azimuth, and then uses measured angles and distances reduced to grid in coordinate computations until the closing station is reached. The computed closing coordinate is subtracted from its least squares adjusted equivalent to get a latitude or departure closure.

CONDITIONAL ADJUSTMENT - an approach to adjustments in which the results are based upon a series of conditions which must be satisfied - such as sum of latitudes and departures of a closed figure must be zero. In complicated surveys finding all of the conditions possible cannot be automated, and thus the parametric adjustment is the desired approach.

CONVERGENCE ANGLE - the angle between grid and geodetic north at a point. It is a function of location in the zone.

- D-

DEGREES OF FREEDOM - number of measurements minus number of unknowns or the number of measurements beyond what is necessary to uniquely define coordinates for each station

- E -

ELEVATION FACTOR - Both the ellipsoids that represent NAD 27 and NAD 83 are at sea level, and thus any measured distance must be reduced to a sea level equivalent by the elevation factor. The elevation factor is based on the average of the elevations at the two end points of a line. The factor is defined as ELEV. FACTOR = R / (R+h) where R = radius of the earth (20,906,000 ft) and h = elevation.

ERROR ELLIPSES - It should be apparent that the reliability of a traverse point's position will not usually be the same in all directions. The position is generally stronger in the traverse direction, and weakest away from the traverse directions. The error region is an ellipse, defined by a radius (semi-major axis) of maximum error (SU), radius (semi-minor axis) of minimum error (SV), and the angle from north (positive clockwise) of the direction of maximum error (T). Since an error ellipse is two-dimensional, the one sigma error ellipse only denotes 39% confidence (roughly 67% squared). The same statistical significance reasoning for coordinate standard errors applies to error ellipses - it is an internal evaluation of your data and does not relate to external information such as other surveys or existing coordinates. SU and S errors can be multiplied by a constant derived from an F statistic to obtain 95% confidence standard errors.

ERROR ESTIMATE - A surveyor's error estimates of measurements assigns appropriate weighting of measurements in a least squares adjustment. An angle with an error estimate of 2 seconds will be treated as more weighted (stronger, less chance of adjustment) than an angle with an error estimate of 10 seconds. This does not mean the angle with the smaller error estimate will always get a smaller adjustment since geometric constraints (such as sum of angles in a closed figure) also play a major role in dictating amount of adjustment. A distance error estimate is usually modeled by a constant plus a ppm addition to account for larger errors generally occurring in longer lines. An angle or azimuth error estimate is a function of the instrument's least count, the number of repetitions, the instrument operator's abilities, and the prevailing environmental conditions. Experience with instrumentation and the least squares adjustment will allow the surveyor to develop confidence in error estimation. Error estimating allows the simultaneous analysis of different measurement types (distances, angles, azimuths, control coordinates).

- G -

GEODETIC DISTANCE - a horizontal distance between two points measured on the earth at the average elevation of the endpoints. Geodetic Distance = Grid Distance / (Scale Factor * Elevation Factor).

GEODETIC BACK AZIMUTH - the direction of the line relative to geodetic north in the opposite direction of the forward azimuth. The forward and back geodetic azimuths do not differ by 180 degrees since north (meridian) lines are not parallel - they converge towards the north pole.

GEODETIC FORWARD AZIMUTH - the direction of a line relative to geodetic north.

GEODETIC MEAN BEARING (AZIMUTH) - the average of the forward and the back azimuth. It is a line of constant bearing (a curved line on the earth). It is equivalent to the path you would follow if walking along a compass bearing. Section and township lines are defined in the Manual of Instructions to be mean bearing lines.

GEODETIC AZIMUTH = Grid Azimuth + Conv. Angle - second term correction.

GRID AZIMUTH = Geodetic Azimuth - Conv. Angle + second term correction.

GRID DISTANCE - a geodetic distance which has had scale and elevation factors applied to it to reduce it to the state plane zone.

GRID NORTH - the direction of a line relative to state plane grid north. It will not equal geodetic north since in the state plane grid all north directions are parallel and in a geodetic system north lines converge to the poles.

- I -

ITERATION - one update of the solution of a set of linearized equations. In horizontal traverses the solution is updates to N,E coordinates. Iteration generally ceases when all updates to coordinates are insignificant (less than 0.005 ft. is appropriate).

INITIAL APPROXIMATIONS - the solution of linearized equations requires initial estimates of all unknown coordinates as first "guesses"; The updates in each iteration refine the approximations towards their least squares adjusted results.

- L -

LINEAR ERROR OF CLOSURE (AFTER ROTATION) - This is a comparison of the inverse distances of traverse endpoints (least squares adjusted vs. computed by Compass Rule). It is the equivalent of rotating the computed traverse so its endpoint falls on the line defined by the least squares coordinate values of the endpoints. Thus the rotational error in the computed traverse has been removed.

LINEAR EQUATION - this is an equation which has no trigonometric functions in it or variables to powers (or square roots). An equation defining an elevation difference is a linear equation.

LINEARIZATION - a process which transforms a non-linear equation into a linear equation. Since nothing in this world is free, by linearizing equations you force a least squares adjustment to use an iterative approach in the solution process. Differential leveling networks have linear equations and thus require no iteration. Traverses have non-linear equations and thus iterate to a solution.

- N -

NAD 27 - North American Datum of 1927 - a datum based on the Clarke Ellipsoid of 1866, and fixed position and orientation at Meade's Ranch in Kansas. Based upon this information latitudes and longitudes were calculated for all National Geodetic Survey control points based primarily on triangulation. The calculation involved a least squares adjustment by hand calculations! These are based on zone constants which include false northings and eastings so that negative coordinates do not result. The published units are U.S. Survey Feet.

NAD 83 - North American Datum of 1983 - a datum based on the GRS 80 Ellipsoid, and fixed position and orientation at the center of the earth. The measurements used in NAD 27, and additional measurements made by the National Geodetic Survey subsequent to 1927, were subjected to a least squares adjustment - this time using a computer. This results in a different latitude and longitude for a station when compared to its NAD 27 values, with the difference often amounting to hundreds of feet. These are based on different zone constants than NAD 27. The most notable change is that different values were assigned for false northings and eastings, and the coordinates published by NGS are in meters instead of U.S. Survey Feet. Even when converted to feet, NAD 83 coordinates look dramatically different than the NAD 27 coordinates for the same point because the false northings and eastings are different.

NON-LINEAR EQUATION - An equation with trigonometric functions and/or powers in it, such as the inverse distance or azimuth equations

NUMBER OF MEASUREMENTS - equals number of distances + number of angles + number of azimuths + number of control coordinates (horizontal case)

NUMBER OF UNKNOWNS - Two (2) x total number of stations. A station is defined as having one (1) Northing and one (1) Easting coordinate (horizontal case).

- O -

OBSERVATION - a fancy word for measurement.

OVERALL PRECISIONS - These are computed by summing all of the linear errors of closure and dividing by the sum of all the sum of the distances of all reported traverses.

- P -

PARAMETRIC ADJUSTMENT - also called the observation equation method - it is an approach to adjustments in which each measurement is described in equation form (such as describing a distance by inverse coordinates)

- R -

REDUNDANCY - measurements which are not required to determine unique coordinates for stations in a traverse. These measurements could include closing angles, closing distances, or multiple solar/Polaris shots.

RESIDUAL - the difference between a measurement and its computed quantity based on coordinates; It is how much the measurement adjusted.

RESIDUAL vs. ERROR ESTIMATE - These quantities should be of approximately the same magnitude. Since measurements contain random error a plot of residuals should look like the "bell-shaped" curve from statistics which centers about zero. If residuals tend to be predominantly of one sign this means systematic error may exist. This would occur if your survey tied into two precise control coordinates and your EDM was measuring systematically long. All adjusted distances would be shorter than their measured values. It could also occur if horizontal angles were only measured in the direct position and a large horizontal collimation error existed. Residuals which are larger than three times their respective error estimate are generally considered suspect.

RMS ERROR - Also known as *root mean square* error. It is the average of a series of residuals in which the sign of the residual is eliminated through summing squared residuals, dividing by the number of that type of measurement, then computed that value's square root.

- S -

SCALE FACTOR - Since a state plane zone intersects the earth geodetic distances must be projected to the zone. If the distance is inside where the zone intersects the earth the scale factor is less than one since the projection is inwards. If the distance is outside where the zone intersects the earth the scale factor is greater than one since the projection is outwards. The scale factor for a distance is the average of the scale factors at the two end points. The value of the scale factor is a function of location in the zone, which has a one-to-one relationship with geodetic position.

SECOND TERM CORRECTION - Second term correction - If converting a geodetic azimuth for a line to a grid azimuth (or vice-versa), a small correction must be applied to convergence angle which accounts for the fact that a geodetic azimuth exists on a curved surface (the earth) and a grid azimuth is on a flat surface (the projection). It is a function of the length of the line and its location in the zone, and is generally less than an arc second. This correction must also be applied to horizontal angles to reduce them to their grid equivalents. The second term correction must also be applied to horizontal angles to obtain the grid equivalent value, though the correction is often less than 0.1 seconds, so it is insignificant.

SIMULTANEOUS SOLUTION - this means all coordinates are being solved for in one solution. In the compass rule process you must adjust one traverse into another traverse which is held as "fixed". This is not correct since the fixed traverse contains error.

SOLUTION CONVERGENCE - the last iteration has insignificant updates and thus the solution terminates.

SOLUTION DIVERGENCE - blunders or poor initial approximations will cause updates to grow as iterations proceed. This indicates something is wrong with the data, and it needs to be corrected.

STANDARD ERROR OF ADJUSTED COORDINATES - these are the least squares error estimates of adjusting N,E coordinates. They are a function of proximity to existing control points. The statistical significance of these quantities is that if you went and made the same measurements with the same instrument using the same procedures, you would have a one sigma (67% confidence) chance of being within plus or minus the standard error of the first solution's coordinate. It has nothing to do with additional traverse legs and readjustment, comparing to someone else's coordinates, or evaluating retracement evidence. These standard errors can be multiplied by a constant derived from an F statistic to obtain 95% confidence standard errors

STANDARD ERROR OF UNIT WEIGHT - This is a number which tells you how well it appears you that you are estimating your measurement errors. It is generated by the summing the squares of all residuals divided by their error estimates. That quantity is divided by the degrees of freedom and the square root is taken. If a residual and error estimate are of the same magnitude note that the residual divided by the error estimate will generally produce a number close to one. The standard error of unit weight is a number that evaluates all residuals and corresponding error estimates. If the standard error of unit weight is near one (0.7-2.5) you are estimating your errors well. Uncorrected systematic errors, blunders, or generally poor measurements will result in larger residuals and thus a large standard error of unit weight. If you are pessimistic in error estimation or you have very few redundant measurements a very small standard error of unit weight will result.

STATE PLANE COORDINATES - projections which uniquely relates a geodetic position (latitude, longitude) to a plane coordinate pair (N,E). The relation is truly a one-to-one correspondence; for a unique state plane coordinate pair there is only one latitude, longitude pair, and vice-versa. The two (2) types of projections that exist are ***Lambert Conformal*** - a conic projection for states elongated east-west, and ***Transverse Mercator*** - a cylindrical projection for states elongated north-south. The size of a zone was limited by defining a state plane distance which will not differ from its geodetic counterpart by 1/10000 of the distance. Thus larger states are covered by more than one zone.

SYSTEM OF EQUATIONS - in a least squares adjustment you solve an "n x n" system of equations each iteration where n equals the number of unknown quantities. In a 20 station traverse there are 40 unknowns (20 N, 20 E coordinates). This means a 40 equations, 40 unknowns system of equations must be solved. Even for a computer this is a slow process.

Table of Figures

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