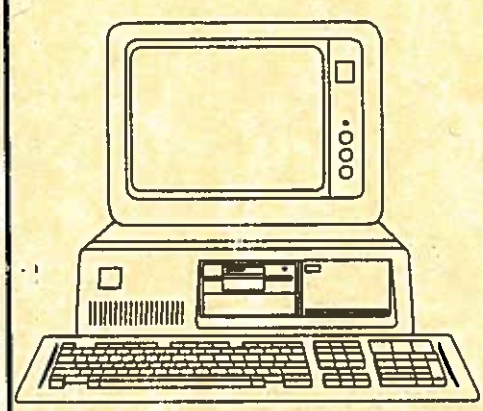
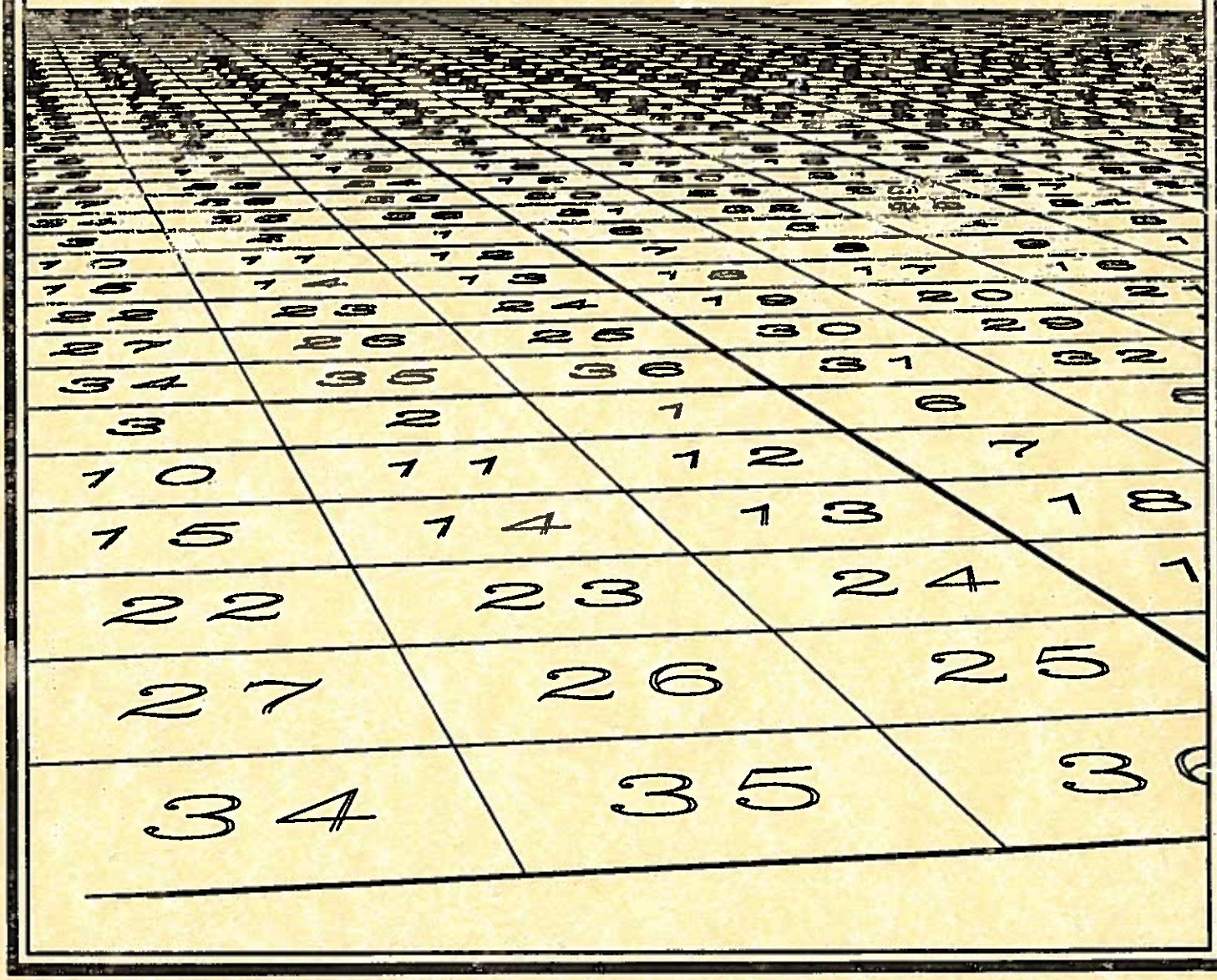
Cadastral Survey

Measurement Management

Version 1.0



CMM



CADASTRAL SURVEY MEASUREMENT MANAGEMENT SYSTEM

Version 1.0
dated 03/91

Documentation

Revision 1.0: /jlw 03/18/91

CONTENTS

Introduction

What this is: This documentation and the accompanying diskette(s) are the Version 1.0 release of the ***Cadastral Measurement Management (CMM)*** system. The system has undergone about a year of testing and evolution. CMM must still be considered as a prototype, it takes a considerable amount of time for such a new and extensive system to be tested. Until recently it has not been in the hands of a great number of users. Primary test sites and other individuals have been involved in the 'alpha' and 'beta' test releases, with the result of an easier to use, more capable and more bug free working release. Software development, to be effective and meet user needs, must be an evolution. In this case we are already aware of many potential improvements and new capabilities that could eventually be incorporated into the system. But it is also important to get the system into the hands of user, both to better determine the course of the evolution, and to allow people to benefit from the capabilities that exist.

We would especially like to encourage all Cadastral personnel to try out the software. You can expect that this will not be a simple task. In addition to working with software that is new and unfamiliar, there are a few other aspects of **CMM** that can tend to raise the slope of the learning curve. Many of these aspects are the result of necessary evils. Things that we have come to recognize are necessary attributes of the system that were needed to properly handle automated computations in **PLSS** retracement work.

Two of these factors that will be discussed at more length below are:

* Using **Least Squares Analysis** as a means to handle the inherent misclosure commonly carried in BLM Cadastral surveys.

* Using **State Plane coordinates** as the means to dealing with the geodetic peculiarities of the PLSS.

Some or both of these methods are new things to most of us in BLM Cadastral. Use of the CMM system will be a lot easier once the user gains some understanding of these two factors. This is particularly true of the Least Squares Analysis portion.

With this software we have at our disposal some extremely powerful tools that have not previously been readily available to most land surveyors. The methods and capabilities are *state-of-the-art* for the PC. In order to effectively use the least squares 'measurement management' tool kit, you need to plunge into it and gain an understand of some of the terminology and idea behind the least squares process. Like many aspects of surveying, in addition to reading about it here, the best teacher is experience and experimentation with your actual survey data. After a while we hope most of you will begin to see some of the advantages and power that are made available to you with the least-squares capability.

This system is not like a spreadsheet program, or even that much like a simple COGO package that can almost be operated without a manual. Please take some time to read the documentation we have to date, to ask questions of other users, and to avail yourself of whatever training sessions we will be able to put together this winter.

A good and responsive way to obtain support and get questions answered after you get started is through the use of the Email system and the Cadastral Forum we have on CompuServe. Using these systems is still another learning process, however once conquered the benefits are many.

How to Proceed: The first thing we would suggest first time users of this system to do is to read through this documentation until you get to the tutorial example. At that time refer to the installation section and install the software, and then return and go through the example step by step. Then you may refer to the reference section and appendix for additional information on capabilities of the system.

What it doesn't do: (as of Release 1.0 03/91)

* There is no solar or polaris program. This will be provided in a seperate but integrated package during the next year.

* The links to data collection included are preliminary pending user feedback and testing.

Purpose: The purpose of CMM is to provide a first shot at a PC based Cadastral Computation System, primarily for lower-48 retracement survey applications, that would be able to do the job and also:

Recognize the special geodetic nature of the PLSS, *the PLSS Datum*

Perform the many special Cadastral Survey procedures, adjustments, requirements and problems.

In the process of tackling these goals we have bitten off a big chunk of work, but it was clear at the outset that if we were going to take the time to develop software for the PC, then we should make it as capable and technically correct as possible within the limits allowed by existing systems as well as our knowledge of the problems.

What you can expect: Software and automation are supposed to make your life easier, right? Maybe, but sometimes it may seem like the reverse. In this case you are likely to encounter a pretty steep learning curve. This will be worse if you are not that familiar with using a PC and PC software. Even if that is not the case there are still a number of other hurdles you will have to climb in order to effectively take advantage of this system. As we continue to improve the software and documentation, and begin to provide training sessions these learning curves will become less steep. Your reward for climbing the curve will be the ability to take advantage of many powerful

capabilities that have not been available to us before.

The CMM system is modular, so that sometimes one portion of it may currently be a little inconsistent or more confusing than others, but it also means that it is not too difficult to make improvements and advancements in the system.

Some of the goals we have for continued development and evolution of CMM are:

To assure that the user interface becomes as understandable and usable as possible.

To assure that the software produces the correct technical and legal results.

That the user interface or methodology does not lead the user towards computing WRONG answers.

That there are methods available to verify the computations or allow for easy detection of errors.

This last item is one of some concern. One troubling aspect of automation is the ability to quickly produce a lot of incorrect information, and because you are more isolated from the process, not be aware of it. This is closely akin to the old *GIGO* (garbage in garbage out) phenomena, and is one of the corollaries to Murphy's law. In general the computer is not a time saver, but provides powerful tools that allow a user to extend capabilities further than before.

The computer has also made it possible to mess up magnitudes more data and work, faster than you can say IBM. *Keep that in mind* as you work with this system on your real survey data. Protect you work, backup jobs and think before storing data back to copies and archives.

Why is it so great?

This is our first attempt at bringing a Cadastral Computation system to the PC. Why is that special? Well, there are a lot of unique things about how we in Cadastral Survey BLM, both technically and procedurally, that make it a challenge to automate. We have a traditional manual process handed down that many in Cadastral still use. That manual process if conscientiously followed produces good and technically correct surveys. In thinking of automating the cadastral survey field computation process Looking at these aspects there are a few big problems we have to overcome. As we stated above, this system attempts to deal with these:

+ The Geodetic aspects of the PLSS: things like true mean bearings, application of curvature to survey lines, the effects of convergency of the meridians and latitudinal arcs.

+ Special Cadastral computations: like double proportion, irregular boundary adjustment, single proportion on latitudinal arc, etc.

What about these State Plane Coordinates?

Many of us in Cadastral Survey have a built in aversion to the word coordinate, and even more so for the things called State Plane Coordinates. Practicioners from the private sector are usually amazed at this, but do not work day to day on large scale surveys. The traditional methods allowed a pragmatic, correct and efficient method to be applied to getting large scale Cadastral surveys done. This traditional concern about coordinates is not without justification as we have all seen coordinate surveying abused. A lot of this abuse occurred at the advent of electronic surveying at the same time as electronic computation became available in the early '70's. People started doing things (it was easy) that did not represent good survey practice. Traversing became easy, it was especially easy if you did not have to close into anything. The ambiguity created by having two coordinates on a point was best swept under the carpet, often adjusted away. Some people developed a belief that if they could compute a coordinate on a point that it was surveyed, never mind any kind of checks or analysis.

The state plane coordinate systems were developed before the electronic revolution to allow the local surveyor to make use of the network of geodetic control points that so much money had been spent establishing. Using stations over long distances could not be accomodated with local plane coordinate systems, and the computational tools used by the average surveyor were minimal. Books of tables, sliderules and kurta's. A simple method was developed along with projection tables that had a sound geodetic projection background, that could be used to perform geodetic computations and use the control net, without too many corrections you could keep within 1:5000 of the right answer. This was pretty tight stuff at the time.

Things are a little different today with respect to State Plane Coordinates. With the computer and properly designed software all corrections can be applied to survey data to obtain very high accuracies with the system. In the case of **CMM**, State Plane coordinates are just a means to the end of dealing with geodetics and making the least squares process a little easier to do. In the future this aspect may change to work directly with geodetics. To the user there is little difference, the answers are the same, the software does the work.

The traditional Cadastral way to compute and handle large scale survey areas was to compute using actual measured lines in terms of true courses defined by latitudes and departures (lats/deps). These lines were reported as measured by chain and solar transit. Closure was the proof of the precision of the work and the sum of a large number of independent distance angle and azimuth measurements. As we have migrated away from the solar compass/transit in the last 20 years, things have gotten a little more confusing.

The traditional process in Cadastral Survey was **good** because it provided a simple manual way to properly deal with both the geodetic stuff and to avoid dealing with the misclosures. However it is not very susceptible to being automated. Generally automated systems like to use coordinates.

Coordinates and the PLSS. There are a lot of particular problems associated with using coordinate systems in the PLSS datum that are significant. Any useful coordinate system will be close to orthogonal, that is north is at right angles to east and all N-S lines are parallel. But the PLSS Datum is <u>not</u> that way. E-W lines are not even straight, but are instead curves called latitudinal arcs, and N-S lines are true meridians which converge, that is get closer together as you go north along them. Working in any projection or coordinate system while also working with PLSS data requires some pretty good tricks to deal with those transformations. You never had to worry about any of that with true lats/deps.

A coordinate system's **north** can only be the same as true north at *one* meridian. Almost no matter what approach you take there are complications.

> If you attempt to maintain a rectangular local (non true bearing based) coordinate system then you will have to deal with rotating bearings to true, correcting some lines to the latitudinal arc and other problems. This can be called a basis of bearing system, as it's bearing may be based upon a reference azimuth at one point but is not corrected to true everywhere.
>
> If you attempt to use full true bearing (lat/dep) non-orthogonal, coordinate system by adding up the curvature corrected lats and deps, then you will have to deal with misclosure due to convergency which will cause you to have different coordinates for 1 point depending on how you got compute or traverse there.

To use a coordinate system base on a projection has to account for a lot of problems too. The PLSS system reports distances at ground elevation, whereas true projection coordinate systems require correction of ground distances by both an elevation and a grid scale factor to get to the grid distance. This in addition to rotating bearing to true and usually complex formula are need to figure anything.

These things make would make working between PLSS data, bearings and distances, and projection grids manually a pain in the neck. These problems can be handled today by not judging the problem in terms of how complex it is to handle manually since it is possible to deal with much of that complexity with software.

In the rest of the world coordinate systems simplify computations, it is hard to think about computing without them. The traditional Cadastral manual process dealt with courses rather than coordinates. A computation system could be developed based on courses rather than coordinates, but this has never been done before, and would be tackling a whole new computational method.

Use of a projection coordinate system also removes the computational problem of convergency. When we go to generate the final true line notes and plats we convert the lines back to the PLSS datum of true mean bearings and ground distance and the convergency reappears where it belongs. But even after eliminating that part of the problem, the dilemma that still remains is that we cannot get very far when our measurements misclose and that part of the problem results in 2, 3 or 4 coordinates for the same point. This is common problem we have all seen in trying to apply calculation systems and software to Cadastral work. About the only way is to keep track of which coordinate came from what line and only use it with computations on that line. And we need some way to work along latitudinal arcs. Some method would be handy to allow us to get rid of this coordinate-measurement ambiguity. One way is to adjust the data.

Why is adjusting good now, when we have always said it's bad?

Least Squares Principals: The evil word lurking in the background here is *adjustment*. This is another aspect of BLM Cadastral work that usually amazes the private survey practicioner. Traditional Cadastral dogma has also maintained that adjustment as well as coordinates was a bad word. Why might this be? Well, there was good reason! The process of adjusting has a bad name because it is so often and so easily abused. It is easily used as a way to 'FIX' bad data. If you have a lot of traverses connecting, like in a township, *a network* results, but simple common adjustments commonly available to the average survey practitioner have to be looped. After a while some good data is being warped to some adjusted bad data and perfectly good field work starts to become more and more a distorted figure as you progress through loops on loops.

One symptom of this problem is how easy it is for this **one loop at a time** adjustment practice to change data more than it should. A distance you measured accurately with EDM as 1000 ft. ends up being 1000.6 ft. Lots of times the surveyor isn't offended by this because the program does not printout how much each measurement changed.

But you have no choice, or do you? Is there a better way, some kind of adjustment process that was intelligent, that would allow you to include all of your network at once, not just loops hooked onto loops degrading data as you go. Is there some way that would allow you to define how accurate the measurements were, and then would let you know if all those constraints were consistent, that is, how much each measurement was required to change to meet those constraints and if there are UNACCEPTABLE errors?

Well of course the Least Squares process in **CMM** has all of these attributes and more. Unlike the magic "ADJUST" button contained in many commercial COGO's, least squares analysis is an intelligent tool that is USER ACCOUNTABLE. That is you make estimates of your reasonable measurement errors, the process tries to meet all the geometric constraints of your entire system simultaneously and then provides you with data about what happened. Data that can be interpreted to tell you if your estimates were correct, or if there was likely an unacceptable error or blunder. And provides a number of other benefits.

The following pages are an explanation from an expert. After you have digested all he has to say, we would also like to recommend that you read over another paper contained in Appendix II, that talks about the results of this type of analysis with actual Cadastral data on several large scale day-to-day Cadastral survey projects.

After you have experimented with the software some you may want to review these documents, as it may make more sense then.

Acknowledgements

The production of this software owes a great deal to a large number of individuals throughout BLM Cadastral Survey and students and staff of the University of Maine, at Orono, and the primary test site BLM Montana State Office, and the Eastern States Office. It would take a page to list and give proper credit to all of these individuals, we would however like to express special thanks to Bernie Hostrop, Chief WO Division of Cadastral Surveys, through whose support and encouragement this project was made possible.

Chapter 2 - The PLSS Datum

Introduction:

One of the characteristics of BLM Cadastral Surveying that strongly affects the ability to automate field computations is the unusual nature of the reference system in which Surveys are reported. Traditional methods have provided a way to work within this system without the necessity of a thorough understanding of all of it's aspects. However those traditional systems and methods do not lend themselves well to automating, and with the proliferation of computing systems, it becones more and more necessary to re-examine how we measure in Cadastral, and what implications that has in automating it. To the non-BLM Cadastral surveyor, this information should also prove of value in understanding the nature of the PLSS records and *Manual* procedures. In other words, in order to effectively automate we need to achieve a common understanding of how we do our job in terms of measurement technique and computational methods.

The PLSS Datum - or the Geodetics of Cadastral Survey

The ***PLSS Datum*** is the reference system by which the majority of the PLSS surveys are theoretically reported. The data being reported on a BLM or GLO Cadastral Survey plat are, of course, bearings and distances. But bearings and distances with reference to what? The datum that surveys of the Public Land Survey System have been reported in for over 200 years is discussed in various sections of the Bureau of Land Management's current edition of ***The Manual of Surveying Instructions, 1973.***

Some of the *Manual* References you may want to review are as follows:

1-3. "Details of the plan and its methods go beyond the scope of textbooks on surveying. The application to large-scale area requires an understanding of the stellar and solar methods for making observations to determine the true meridian, the treatment of the convergency of the meridians, the running of the true parallels of latitude, and the conversion in the direction of lines so that at any point the angular value will be referred to the true north at that place."

2-1. "The law prescribes the chain as the unit of linear measure for the survey of the public lands. All returns of measurements in the rectangular system are made in the true horizontal distance in miles, chains and links...."

2-17. "The direction of each line of the public land surveys is determined with reference to the true meridian as defined by the axis of the earth's rotation. Bearings are stated in terms of angular measure referred to the true north or south."

2-19. Describes 3 Basic methods prescribed as *current practice* to determine true bearings, 1) Direct Sun, star or polaris observations; 2) Solar attachment; 3) Angles from the horizontal control network. Use of the gyro-theodolite is also mentioned.

2-74. This entire section is very important on this issue and describes in detail methods for carrying forward true bearing, and defines mean bearing and many other critical concepts. ".... By basic law and the Manual requirements, the directions of all lines are stated in terms of angular measure referred to the true north (or south) at the point of record."

2-76. Defines the solar method for laying out the true parallel of latitude.

2-79. Contain formulas for computing Convergency of two meridians, and mentions the corrections to closure as a factor of area, and to compute Rb, effective radius of a parallel.

2-80. Describes use of the *Standard Field Tables* to determine convergency.

2-81 & 82. Describe the use of M and P factors for converting measurements to differences in latitude and longitude.

3-87. Subdivision of Sections, refers to use of intersecting "straight lines".

5-25. Double proportion - 'Cardinal equivalents' to be used in reducing record, and cardinal offsets made to determine proportioned point.

5-31. Single Proportion to allow for latitudinal curve, or curvature.

5-36. Other adjustments to allow for latitudinal curve, or curvature.

PLSS Datum Defined

Distances: These and other references in the BLM and GLO Manuals make it clear that the frame of reference for **distances** is defined as *horizontal measure in chains based on the U.S. Survey Foot at actual ground elevation.*

Bearings: The above Manual sections and others identify the frame of reference for **direction** in the PLSS as something called ***Mean True Bearings*** referenced to the true astronomic meridian ... *at the point of record.*

For surveyors familiar with basic geodesy you will recognize that this is a geodetic datum and that the basis of bearing changes as you go east and west since the reference meridians at different eastings are not parallel but converge towards the pole.

Because this is a changing reference the direction of a straight line on the ground can be described with a **forward bearing** based on the meridian at the beginning point, or by a different **back bearing** based on the meridian at the end point. The difference between these two is equivalent to the angle of convergency of the two meridians.

If we want to accurately describe how far north or west a non-cardinal line goes in a geodetic sense, we need to use the average or '**mean**' of these two values. This *mean bearing* is essentially equal to the bearing of the traverse line with reference to it's midpoint. Thus the *point of record* for determining the bearing of a straight traverse line can be said to be the meridian at the midpoint of the line.

There are other geodetic affects that occur in large scale surveys, but this changing reference direction in the PLSS datum is by far the most significant.

Straight Lines: Therefore, one unusual byproduct of the PLSS datum is that:

I. ***Straight lines on the ground are lines of constantly changing bearing.***

A straight line is basically what you would lay out by double centering or projecting a direct line of sight. The only straight line that does have a constant bearing is the meridian or north and south line. An example of a boundary that might be a *straight* line is one that is described as a straight line running from one physical monument to another. Such a line, if reported in the PLSS Datum would have different forward bearing and back bearing, and different bearings at any point along it.

Another term used to describe straight lines is Great Circle. That is the line formed by the intersection of a plane which passes through the earth center and the earth's surface. In the real world such a line is actually not exactly straight to both the ellipsoidal shape of the earth and local gravity anomalies a line you double centered would be a 'geodesic'.

Rhumb Lines: It is also apparent from the various GLO and BLM Survey Manuals *and* the actual methods prescribed and used to lay out the system on the ground that most boundary lines in the PLSS are intended to be lines of constant bearing or Rhumb lines, *NOT* straight lines. Such lines cross every meridian at the same angle and are thus curved as viewed on the ground. Therefore, another unusual byproduct of the ***'PLSS datum'*** is that:

II. ***Lines of constant bearing appear curved on the ground.***

For example, the solar compass and transit were instruments that determined bearing at each setup, and when matched with traditional chaining, measured or laid out lines of constant bearing.

The ***'Manual'*** discussion of latitudinal arcs illustrates one example of a rhumb line. A parallel of latitude is a line that is due East and West in the **PLSS Datum**, thus one case of a line of constant bearing. Since it crosses each meridian at a 90 degree angle, it has a mean bearing of East or West. All lines of constant bearing in the PLSS datum except meridians will appear curved on the ground.

It also turns out that:

III. ***The mean bearing of any chord or sub-chord connecting any two points along a PLSS rhumb line will be the same as the bearing of the rhumb line itself.***

Thus it is possible to lay out points on a rhumb line by correcting traverse lines to their mean bearing in computations.

Most PLSS boundaries are RHUMB lines. This includes standard parallels, township exteriors, section lines, many grant and reservation lines, some portions of state lines, etc. The effect is not necessarily limited to E-W lines. Examples that can be seen on any map are the largest portion of the North boundary of the U.S., and the N and S boundaries of many states, such as Colorado, Wyoming, Kansas, etc.

Some boundaries *are* straight lines. This includes specifically described portions of grant or reservation boundaries, some portions of state lines. Subdivision of Section, (see Section 3-87 of the *Manual*). There is some controversy about this, and in fact we are dealing with pretty trivial distinctions in the case of a line a mile or less in length.

Examples that can be seen on a map are the diagonal portion of the East boundary of California as well as the South boundary of California.

The amount of curvature of these lines is dependent on the project latitude, at higher latitudes, such as in Alaska, the effect can be very great, for example the change in bearing over a mile E-W line is about 2' 23" per mile at 70° N latitude in Alaska, or in southern Arizona: 32 secs. at 32° N latitude.

Information on the amount of curvature for different latitudes can be obtained from a number of formulas, as well as derived from the Standard Field Tables, also known as the Red Book, in either **Table 11 - *Convergency of Meridians, Six Miles Long and Six Miles Apart...***, or **Table 26 - *Increments of Curvature***.

Note: If you apply curvature corrections to your traverses, you will in essence be surveying as if you were using a Solar attachment, see Manual Section 2-76. For purposes of line proportions no further corrections for latitudinal arc need be made. This is the essence of being *in the Datum*. That is, to survey in the datum and to then apply secant or chord offsets as described in the manual would be applying the correction twice.

Coordinate Systems and the PLSS Datum

If you were to try to develope and use coordinates based on the true mean bearings of your traverse lines, you would begin to run into some problems, why? The reason is a by product of an effect that we will call 'apparent misclosure due to convergency of the meridians'. And it results in coordinates that depend upon the path you used to compute to the point, and as such become pretty useless as coordinates as they no longer represent in themselves a proper relation between the points.

Therefore in the PLSS Datum:

IV. ***A theoretically perfect survey will appear to misclose in the PLSS datum.***

The effect will be called *'apparent misclosure due to convergency of the meridians'* and is a function of latitude and the area of the loop closed.

Since the sum of true mean lats and deps to a point will depend on the area between the path to the point and a true line directly to the point, the only correct answer is one obtained by running the straight line to the point.

Coordinates systems based on mean bearings will always have difficulty because the math and trigonometric functions we are used to using are based on an orthogonal (axis are all at 90 degrees to each other and straight) coordinate system, and we are dealing with a different shaped system.

DOUBLE PROPORTION

Now let's look at the definition of double proportion as stated in the BLM *Manual of Surveying Instructions, 1973*, which states:

> "5-25. The term 'double proportionate measurement' is applied to a new measurement made between four known corners, two each on intersecting meridional and latitudinal lines, for the purpose of relating the intersection to both.
>
> In effect, by double proportionate measurement the record directions are disregarded, excepting only where there is some acceptable supplemental survey record, some physical evidence, or testimony that may be brought into the control. Corners to the north and south control any intermediate latitudinal position. Corners to the east and west control the position in longitude."
> .....
>
> "Lengths of proportioned lines are comparable only when reduced to their cardinal equivalents. "

Cardinal Equivalents: The last sentence in the above quote is one that requires some explanation. What it means is that only the easterly components (or departures) of the E-W controlling record lines are used to compute the E and W position, and only the northerly components (or latitudes) of the N-S controlling record lines are used to compute the N and S position. This is different than using the line lengths or distances on the record line.

Neglecting to correct the record for cardinal equivalents won't usually get you in trouble since most section lines in the original surveys are very near to cardinal and the correction is insignificant. There are, however, many situations in public land surveys where this is not the case. This situation will also occur where a retracement or subsequent GLO or BLM resurvey has reported new measurements in the PLSS datum, and the lines are distorted.

Cardinal offsets

The Manual of Surveying Instructions, 1973 Section 5-26 describes a process for performing a double proportion. The Manual section states:

> "5-26. In order to restore a lost corner of four townships, a retracement will first be made between the nearest known corners on the meridional line, north and south of the missing corner, and upon that line a temporary stake will be placed at the proper proportionate distance; this will determine the latitude of the lost corner.
>
> "Next, the nearest corners on the latitudinal line will be connected, and a second point will be marked for the proportionate measurement east and west; this point will determine the position of the lost corner in departure (or longitude).

> "Then, through the first temporary stake run a line east or west, and through the second temporary stake a line north or south, as relative situations may determine; the intersection of these two lines will fix the position for the restored corner."

Such a process would probably be impractical in the field if followed to the letter. It is, however, a valuable way to conceptualize a proper solution of a double proportion and a good way to model a computational method. In brief, the three part process as described consists of:

1) A single proportion using the record E-W cardinal equivalents between the control E and W. In the Figure 1 example this would be point 'A'.

2) A single proportion using the record N-S cardinal equivalents between the control N and S. In the Figure 1 example this would be point 'B'.

3) Cardinal (true mean) offsets to intersection from those two points. In the Figure this results in point 'C'.

This last requirement can be a problem if you are not careful using coordinates, since to make the offsets *cardinal* requires knowledge of and proper correction to true north at those points. The common process of using the East coordinate of the E-W proportion and the North coordinate of the N-S proportion is equivalent to making a GRID offset, exagerrated In Figure 1 as point 'D', which can be incorrect.

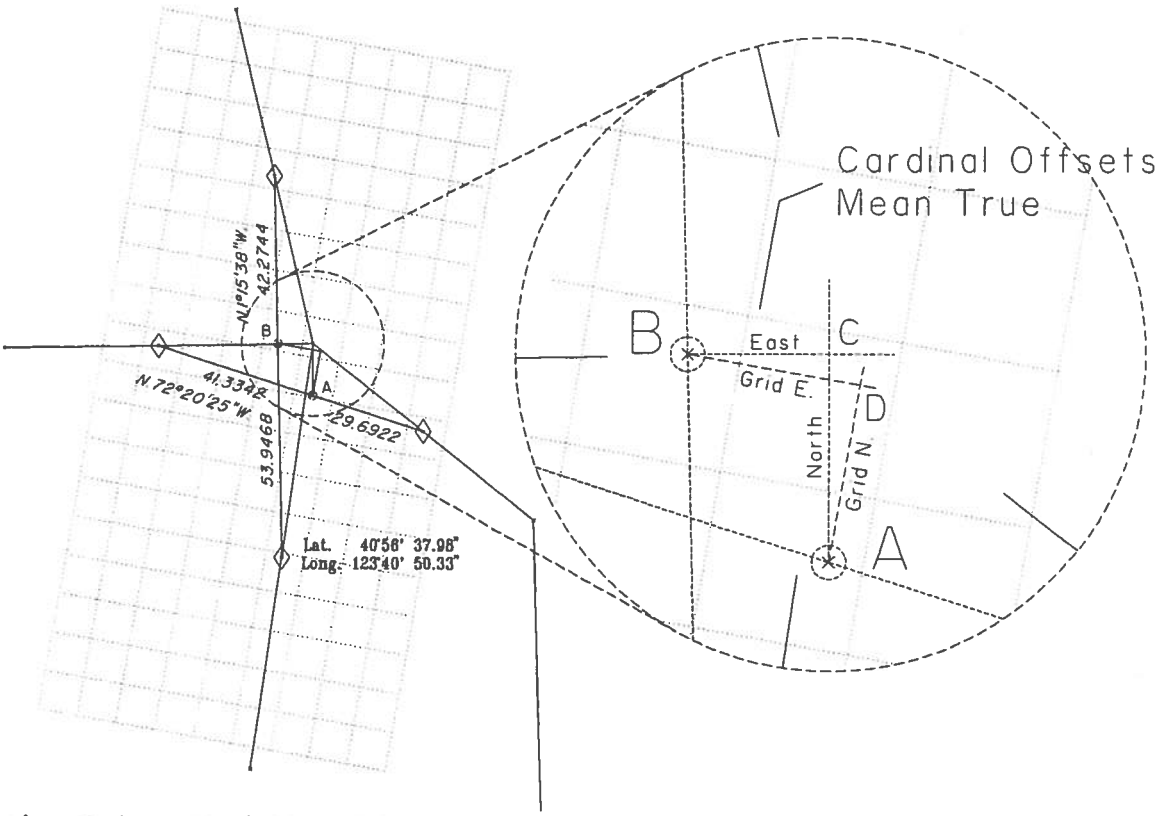


Figure 1 - Cardinal Offsets True vs. Grid

Chapter 3 - Understanding Least Squares and Adjustment

Understanding Least Squares and Adjustment
A Basic Approach for Utilization

by Ray Hintz

This is a draft copy of a paper that was prepared for presentation at the Cadastral Survey 1990 New Technology Seminar, which was never held. Its intent is to help people feel comfortable with some of the processes which are involved in measurement management. The author thanks Corky Rodine and Jerry Wahl for their contributions to this paper.

Introduction

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 4 second adjustment of a horizontal angle measured twice with a 6 second least count theodolite is obviously within the expected error range of the angle. A 30 second adjustment of that angle could easily be termed intolerable, and a surveyor should 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 paper is to explain why adjustment can be a valid procedure, and how to judge when it is not valid.

A large number 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 paper will illustrate that is really an analysis technique in surveying, too. Adjustment actually exists in any redundant survey network - misclosures are simply 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 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 paper is the accepted lack of under- standing 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 that it requires a computer for it to be implemented in a production environment. The personal computer revolution is a recent

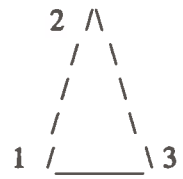
phenomena which has allowed a surveyor access to least squares for survey network analysis, and efficient PC based software is still a difficult commodity to locate.

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 are required. This paper does not replace hands-on instruction and use, but can serve as a primer for those who are unfamiliar with this approach. This paper is directed to a 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.



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)*180 degrees, and 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)*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 totalling 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.

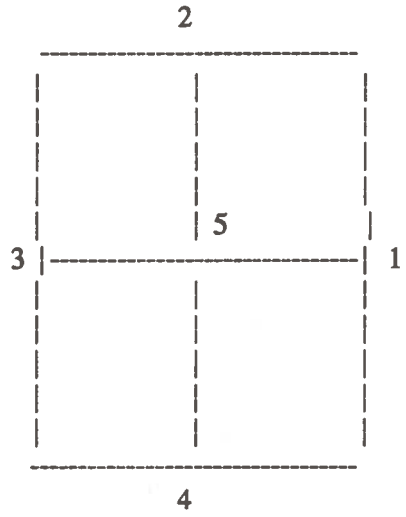
As stated before, one should observe if the amounts of angular and distance adjustment are within reasonable random error limits. If this is true, the amounts of adjustment are within the limits of one's measuring abilities. If the amount of adjustment to various measurements is not within acceptable 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. Geometric constraints prevent all measurements to remain 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.



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 PLSS 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. (1/error estimate) residual is equal to (1/feet)* feet in unit terms so the determined quantity becomes 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 his/her 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 several 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 number.

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 outstandingly 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 outstandingly 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 of 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 indicates 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 you can use you 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)*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" 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 do 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 X, 1000 Y). 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 of 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 = meas. elev. 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:

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

Conventional traverse computations are the most effective approach to approximate coordinate generation. This has been implemented for any traverse network configuration in computer program **GENER** of the **LSAQ**, etc. software package developed by the author. **GENER** 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.
(Editors note: Current version of GENER does not use compass rule.)

(2) 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.

(3) 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 (produced by **GENER**) for obvious blunders, which can be corrected, prior to running the least squares adjustment.

(4) 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. Multiplying the standard error by three produces 98.6% confidence. 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 accuracies of least squares adjusted station positions.

(5) *What is meant by re-weighting for blunder detection purposes (robustness)?*

Least squares can be used as an extremely effective tool in blunder detection. Often simply looking at residuals will isolate blunders. A technique often termed robustness serves as a filter for bad measurements. It involves running the adjustment once with your error estimates, then averaging the error estimate with the residual (absolute value) for a measurement. This quantity becomes the new error estimate, and the adjustment is run again. Measurements with small "first run" residuals will get decreased error estimates in the subsequent run, and the opposite effect occurs for measurements with large residuals. This will shift the bigger adjustments to those measurements with larger error estimates. This filtering affect is very effective in blunder isolation. A weighted average can also be used in determining new error estimates if desired. One can robust all measurements, or only certain ones (such as angles only). The blunders should then be corrected and the adjustment re-processed.

(6) *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 minimum band is found in an iterative process. 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.

Conclusions

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. "Measurement Management" is an integrated process with adjustment, and will undoubtedly be the topic of another paper such as this. Hopefully this information will allow hands-on experience to be a more fruitful learning procedure.

AUTOMATION AND PRECISION IN A CADASTRAL SURVEYING ENVIRONMENT

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ABSTRACT

The surveyor confronting dependent resurveys of federal lands is often working in an environment which is thought to not be conducive to high levels of precision. Hilly terrain and thick vegetation lead to short sight distances and difficult instrument setups. A complete retracement of an entire township can easily require 2000 instrument setups. The demonstrative amount of data can also force one to use non-rigorous methods of survey measurement analysis.

Analysis of measurements from dependent resurveys of 4 townships, the largest requiring nearly 1800 instrument setups, will be presented to illustrate that efficient field techniques, combined with effective measurement analysis, can produce very reliable results. An efficient interface between a total station/ data collector system and PC-based least squares analysis software capable of simultaneous adjustment of entire townships will be demonstrated. The interface is not restricted to any form of field procedure. Software and procedures for the quality control and maintenance of these large data sets will also be discussed.

INTRODUCTION

One of the major elements of a dependent resurvey is the traverse data used in searching for evidence of the original and subsequent surveys. Traverse data which is lacking in quality could result in searching for evidence in improper locations. It also follows that poor traverse data will result in proportionate measurement, the Manual of Surveying Instructions (USDI-BLM, 1973) procedure for reestablishment of lost corners, will result in a mathematically correct solution in a totally inappropriate relative position.

Rigorous mathematical analysis of surveying data has traditionally been restricted to geodetic control surveys. The personal computer revolution has only recently made it possible for all land surveyors to have data techniques such as least squares analysis at their disposal.

A recent joint effort between the Eastern States Office of the Bureau of Land Management and the University of Maine resulted in the testing of dependent resurvey measurement data in a least squares analysis environment. The Eastern States Office is responsible for surveys of federal lands in 31 states. The difficult surveying situations encountered range from swampland such as the Florida Everglades to Appalachian and Ozark mountains.

It is anticipated many would question the benefits which would be derived from statistical analysis of survey data which has been collected under very difficult field conditions. This paper hopefully will illustrate the importance of this type of analysis, and further illustrate that it is possible to perform precise survey work in difficult field conditions. The integration of quality field procedures and effective mathematical analysis must both exist. If both do indeed exist, it will be shown that "adjustment" of survey data truly becomes analysis, as the amounts of adjustment can be controlled to be statistically insignificant.

EASTERN STATES OFFICE FIELD COLLECTION PROCEDURES

The Eastern States Office of BLM has been using total stations and data collectors for 3 years. The data collector system is HP-41 based and was developed in-house to specifically meet the Office's needs. While it presents the problem of additional field equipment, a second tripod is used with a tribrach mounted prism on all foresights. The tripod, as opposed to pole, mounted prism has proven to add a level of precision which is well worth the problems associated with carrying the added equipment.

In standard operation the backsight is a tack mounted on a lath. All horizontal angles are measured once each in the direct and reverse positions. Re-measurement occurs if the difference between the direct and reverse measurements if greater than 10-15 seconds (subject to setup conditions). The data collector stores the average horizontal angle and horizontal distance resulting from the two repetitions.

Solar/polaris observations for azimuth determination are taken approximately every 30-50 setups on the traverse covering the perimeter of the township. The number and location of the solar/polaris observations are a function of the visibility of the sun or star as well as terrain considerations. A solar/polaris observation consists of 8 repetitions.

One geodetic control station in the area is tied into the dependent resurvey traverse.

The cadastral computation system used by the Eastern States Office is also HP-41 based and has been developed in-house. The advent of PC-based CAD produced the need for communication between the HP-41 and the computer. The same type of data transfer was used to bring the traverse measurements into a MS-DOS environment.

BASICS OF THE LEAST SQUARES ANALYSIS

Once the dependent resurvey traverse data had been transferred to the computer a translator program was written to reformat the data for the least squares analysis. The least squares analysis software package used was developed by the principal author, and has evolved over the last 5 years from comments from a number of users in both private practice and government surveying positions. The observation equation approach is used and all measurements can be automatically reduced to an appropriate state plane grid. An automatic coordinate generation program supplies approximate coordinates for the least squares analysis. In addition these approximate coordinates are used to generate unique scale factors for each distance measurement and unique convergence angles for each measured azimuth. While the software allows multiple elevations to be used in the reduction to the ellipsoid ("sea level" reduction), a project elevation was assigned to each data set. The use of a project elevation mirrored the approach used in the HP-41 system.

A post-adjustment traverse closure routine enabled calculation of conventional linear closures, angular closures, and precisions. The methodolgy used in these computations will be more fully described in the presentation of these results.

TEST DATA SETS

Table 1 lists the four sites of the data sets.

Test #	State Plane Zone	Project Elev. (ft.)
1	Missouri East Mercator - NAD 27	1225
2	Michigan West Mercator - NAD 27	1171
3	Missouri East Mercator - NAD 27	1200
4	Arkansas South Lambert - NAD 27	932

Table 1. Test site zones and project elevations.

Figure 1 (a) - (d) are plots of the traverse data for test sites 1 - 4 respectively. The small triangles represent stations which were held fixed in the least squares analysis. Since the plots are based on state plane grid north, the direction of the traverse data illustrates the angular difference between grid and geodetic north. One can see that some lines were not traversed for logical reasons such as encountering a body of water. It should also be apparent some tests were partial retracements of a township.

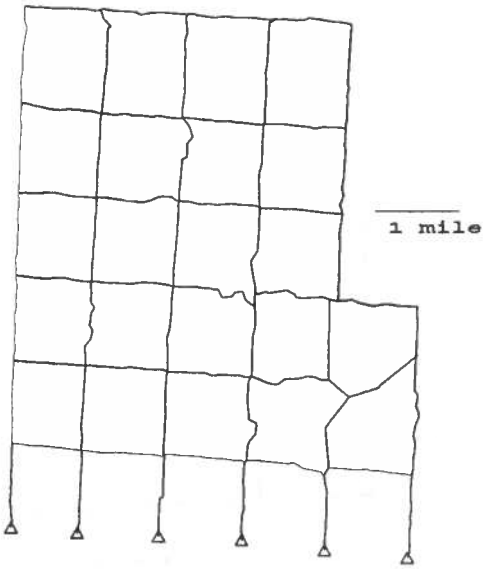
A traverse "link" always had a beginning and closing angle measured to existing traverse lines, enabling calculation of angular closures in addition to linear closures.

Table 2 illustrates the amount of data in each test.

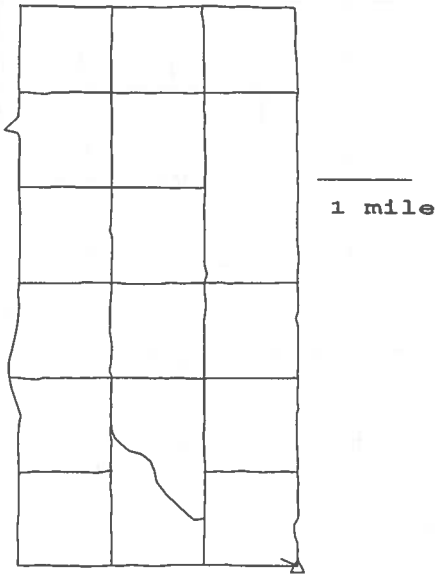
Statistic	Test #1	Test #2	Test #3	Test #4
# of control points	6	1	1	1
total # of stations	1036	644	1789	1708
# of distances	1057	660	1823	1742
# of angles	1077	676	1857	1773
# of azimuths	14	17	24	31

Table 2. Amounts of data in each test.

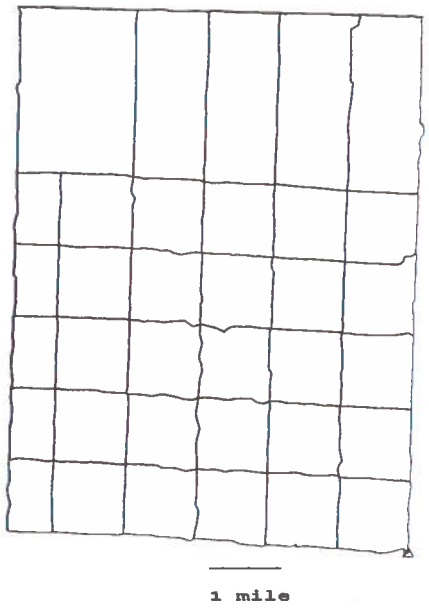
The section corners on the south township line of test #1 had coordinates computed for them from a prior survey of the township immediately to the south. These coordinates were held as control. As one can see, the amount of data is truly demonstative. A significant amount of blunder detection techniques have been built into the pre-least squares analysis coordinate generation algorithm, the analysis itself, and the post-adjustment analysis routines (Hintz, 1988). Since least squares requires the solution of a system of equations that is equal to the number of unknown coordinates (3714 equations, 3714 unknowns in test #3) you do not want to have to run the least squares analysis multiple times.



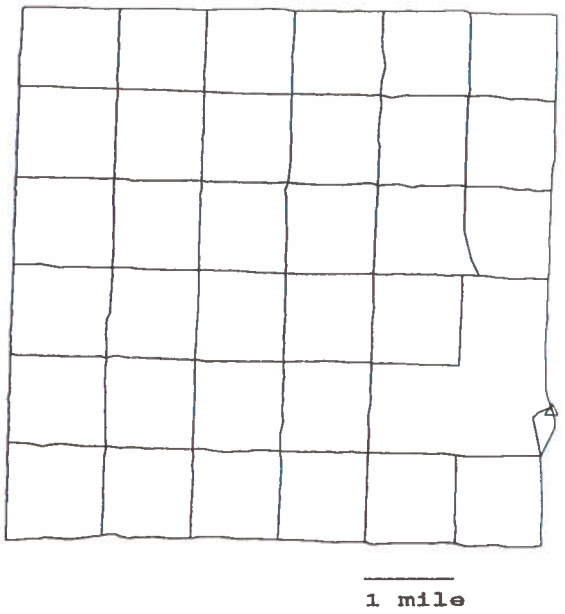
(a) Missouri Test #1



(b) Michigan Test #2



(c) Missouri Test #3



(d) Arkansas Test #4

LEAST SQUARES ANALYSIS RESULTS

The least squares results are illustrated in table 3 in a fashion that highlights the amount of adjustment that was applied to the measurements. In all tests control was held fixed, distances received error estimates of 0.02 ft plus 2 ppm, angles received error estimates of 10 seconds, and azimuths received error estimates of 6 seconds. These error estimates were suggested by Eastern States staff based on their instrumentation and field techniques.

Statistic	Test #1	Test #2	Test #3	Test #4
Dist. RMS residual (ft)	.003	.002	.002	.002
Max. Dist. residual (ft)	.019	.004	.007	.006
Angle RMS residual (seconds)	3.0	2.5	2.4	2.8
Max. Angle residual (seconds)	16.3	12.4	17.6	18.9
Azimuth RMS residual (seconds)	2.3	1.9	2.0	2.9
Max. Azimuth residual (seconds)	7.1	5.5	6.4	12.2
degrees of freedom	88	67	128	132
stan. error of unit wgt.	1.13	0.87	0.96	1.11

Table 3. Least squares analysis test statistics.

For an in-depth explanation of the terms in table 3, one may refer to Wolf (1985).

All residuals in table 3 are reported in absolute value form. We are certain many will find these results hard to believe. The authors also experienced this feeling in initial testing stages. As stated earlier, these results are the combination of effective field procedures plus a simultaneous statistically based approach toward analysis of survey measurements.

In the introduction it was stated it was important to verify that the amounts of adjustment applied to your measurements is insignificant. The worst distance residual of 0.019 ft. was on a fairly long line and is well within most EDM precision specifications. The largest angle residuals by inspection were found to be restricted to extremely short lines of less than 200 ft. Maximum residuals of less than 20 seconds on these lines is quite insignificant when one correlates the distance that shift is equivalent to in ground distance. The azimuth residuals are well within the limits of azimuth determination by solar observation. As a final verification of error estimation, the final standard error of unit weight for each test was very close to one. Statistical testing of this value indicates a high confidence level in all tests. Though not intended to be a focus of this paper, the analysis provided maximum absolute error ellipse axes (one sigma) of 0.58, 0.45, 0.62, and 0.69 ft. for tests 1 - 4 respectively. These were appropriately at stations furthest from the control points.

POST-LEAST SQUARES ANALYSIS RESULTS

The goal of the post-least squares analysis processor was to obtain conventional survey closure estimates which are meaningful in a traverse network which is very interconnected. While loop traverse closures are a conventional survey product they do not reflect the amount of adjustment that has been applied to measurements. Loop closures also do not reflect how the traverse interconnections affect each another.

An example of the decribed situation is two loop traverses with a common portion. The loop closures indicate nothing with regards to how the two loops "fit" one another in a simultaneous solution.

For these reasons it was decided to output traverse "link" closures between "junction" points in the traverse network. A junction point in the township retracement scenario ends up being relatively close to a section corner location. For the Eastern States Office data sets it follows that most of the traverse links will be approximately one mile in length.

All computations use the unadjusted traverse measurements reduced to their grid equivalents. No adjustment to angles is applied. An initial direction is determined by inversing the adjusted coordinates of the end points of the first traverse leg. Computations proceed along the link traverse using measurements reduced to grid. On the last traverse leg into the junction point the computed direction from traversing can be compared to the direction computed from inversing adjusted coordinates. This comparison is the angular closure for the link traverse.

Two types of precisions are determined. The first is a conventional precision derived from the the linear error of closure, computed from latitude and departure closures, divided by the sum of the traverse distances for the link traverse. Unfortunately, in a link traverse the precision derived in this way is directly related to the "fit" of the starting direction for the link traverse computations which was derived from an inverse of the adjusted coordinates.

The second precision is a comparison of the traverse link length based on measurements reduced to grid to the traverse link length derived from an inverse of adjusted coordinates. The difference between these two lengths divided by the sum of the traverse link distances results in a precision based on "distance inverse". The distance inverse precision will undoubtedly yield quality results since the least squares analysis adjusted all distances small amounts.

A overall precision for the traverse network is computed from the sum of all the link closures divided by the sum of all the link traverse distances.

The post - least squares analysis results are highlighted in table 4.

Statistic	Test #1	Test #2	Test #3	Test #4
evaluated traverse miles	61.0	44.5	90.5	83.3
Lat. / Dep. Precision	1/13300	1/17900	1/12900	1/11800
Distance Inv. Inv. Precision	1/129100	1/164200	1/86400	1/94800
Ave. Angular Closure	24.3	20.6	25.1	32.1
Largest Angular Closure	110.0	80.0	92.0	144.0

Table 4. Post - least squares analysis results.

These results are not intended to reflect a standard way in which traverse networks should be evaluated. These procedures were simply developed to help the authors evaluate these data sets.

CONCLUSIONS

The applicability of least squares analysis to dependent resurvey traverse has been illustrated. As a byproduct, it has also been shown that it is possible to perform relatively precise traverse under difficult topographic environments. Possible approaches for illustrating precision of results has been discussed and demonstrated.

ACKNOWLEDGEMENTS

The authors appreciate the efforts of the field crews of the Eastern States Office of BLM. Without their dedication the results documentated in this paper could not be realized.

REFERENCES

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MANUAL OF SURVEYING INSTRUCTIONS (1973), United States Department of the Interior - Bureau of Land Management, Washington, D.C., 333p.

Wolf, P.R. (1985), ADJUSTMENT COMPUTATIONS, Landmark Publications, Rancho Cordova, California, 182 p.

Chapter 4 - Overview and Introduction to the *Tool Box*

CMM contains many functions, many of these functions are in modular form and currently are actually contained in separate programs. Later on in the *Reference* chapter there will be a more in depth description of some of these programs, however at this point we would like to give you a short introduction to most of these programs grouped into rough functional areas. This ist does not necessarly represent the order in which you might use these program.

Data Input Programs

GENER

GENER's ultimate purpose is first coordinate approximation generation, which is necessary for the Least Squares analysis process. However, it's front end is designed for *manual data entry* and editing of the primary measurement data.

ESO

Data Collection conversion for Eastern States Office data collection files. These files must first be transferred to the PC.

TDSLSA

Data Collection conversion program for the *Tripod Data Systems (TDS) CO-OP41* data collection format. This program is preliminary.

ARIZONA

Data Collection conversion program for the *Custom BLM CO-OP41* data collection format as designed by Olian Shockley. This program is preliminary.

LIETZ

Data Collection conversion program for the LIETZ SDR24 (and other) data collector. This program is preliminary.

Measurement Processing

CMM

Is the command you type to get into the system. CMM is actually a DOS batch file created by the INSTALL program and runs **MANAGE**.

MANAGE

Is the **CMM** Main Menu. Besides providing menu access to several of the measurement functions. **MANAGE** allows you to create, select and define project parameters such as State Plane Zone. It, through **CMM** provides access to the work horses **GENER, LSAQ, DXFLSA**, your text editor and access to the Cadastral Utilities sub menu.

GENER

Discussed above under data entry, also serves as an important role in processing by providing the basic data file for the system (the **LSA** file), and computing initial coordinates and closures for the traverse data to date.

SD

SD allows you to supply individual (rather than cross the board) error estimates. **CMM** and Manage prompt you for default error estimates for your measurements, such as control, azimuths (solars), angles and distances. This is important since one frequently encounter situations where the default errors are not valid such as when you go thru some short shots, or unstable setups, etc.

SSHOT

You can put your sideshots into **GENER** along with your other data, but they do not do anything to help the analysis, they cannot provide any redundancy to the system and end up slowing the processing down for nothing. If sideshots are ALWAYS going to remain so (you have no intent to ever tie in the point another way), they are best entered here. Not used much it happens.

<u>Measurement Analysis</u>

GENER

As above, but **GENER**'s closure's are your first indication of errors. Because of it's methods, it cannot be relied upon for precise closure numbers, but the first large misclosure it encountered points to problems in that loops data. Subsequent loops may look bad but could be okay.

BLUNDER

Used to be part of **GENER**, now a standalone. **BLUNDER** applies a few geometric methods to try to find angle and distance blunders. This will be added to. It's current methods sometimes fail on rectangular data. So don't believe it if it doesn't tell you anything.

RAW

A special version of **GENER**. This program runs your traverse data from the LSA file without adjustment. If a major blunder exists in the data it can usually be seen more clearly here than with **GENER**'s report. **RAW** creates a **VIEW**able file as well as a report.

LSAQ

The main Least Squares Analysis program. Through the process of error estimates, and looking at the results of the adjustment contained in the .LSA file there is a great deal of information about large and particularly small errors. The combination of all your measurements and their redundancy is the key.

CHECKER

Serves two purposes: First compares closing raw measurements to adjusted connection points, and is the closest analogy to "What is the precision ratio" for this type of system. Carefully used, **CHECKER** can also lead you to locate many errors and blunders in your data. This is true because while many measurements 'give' because of bad data, the line with the error will likely have the largest misclosure.

VIEW

A screen graphics program that allows you to view your traverse files. This version allows panning and zooming as well as toggling point id's and has many other options.

DXFLSA (a batch file which runs **DRAW**)

Creates a graphics DXF file which can be viewed or exported to a CAD system and used to obtain hardcopy. Graphics can point to strange things that the system is doing to your data when you have very large problems.

LOOPER

Allows you to cut out a section of raw data from a large project and create a smaller data set. This can be of help for two reasons. 1) to help locate errors or blunders known to be in one area. To eliminate excess processing time recomputing good data in other areas of the project.

COMBIN

Combines projects. You can work separate projects or parts of projects, then **COMBIN**e them into one once they are connected.

COMPARE

Compares two **.COR** coordinate files. This is useful after trying different weighting options, or comparing common lines between data sets to see if the real difference is of any importance.

PLSS datum handling computations

CSTUF

Provides a multitude of PLSS datum computations. See extensive documentation in the Reference Section. True and/or Plane traversing, inversing, all kinds of intersections. Can be used readily to develop search areas, one, two and 3 point control and subdivide sections, inverse to get Mean True line. AREA computation is not fully worked out yet.

INREC

Inrec is a very important program that allows you to easily create the .REC record file that is used by the **PROPORT** and **AUTOPROP** proportion programs. This is essentially a digital record plat upon which all proports are based and thus it is very important to verify all entries are correct since all future proportions are base upon them. It is possible to use non-standard corner naming but in general the system functions best and is really designed to take advantage of the organisational attributes of the standard numbering scheme.

WHATIS

Another important program. **WHATIS** is the means we have to define which of the traverse points in your project ARE to be considered or are accepted as corners, and thus to be used for proportions. It is also possible to tag each traverse point and/or corner with attributes such as original, local etc. This does not serve any function at present, but may be used in the future to provide symbology with the output graphics. The programs **AUTOPROP, PROPORT, SECTSHOW** all use this record file for proportions.

PROPORT

The corner by corner **PROPORT**ion program, performs single and double proportions geodetically correct.

AUTOPROP

A wonderful program that performs mass proportions and even normal subdivision of section automatically based upon the control you have currently defined with **WHATIS** and the record file you have built with **INREC.** Primarily developed to allow for generation of search areas, may be used also as a independent check on **PROPORT** for proportions and **CSTUF** for subdivision of sections.

CMOVE

A program that computes corner moves and/or offsets to true line.

ADJUST

A program that provides for Grant boundary, Irregular boundary and Compass (non-riparian meander line) adjustments, as well as 1, 2 and 3 point control and *manual* versions of single and double proportions.

Other Programs

UTCOMM

The Utilities menu program. Uses the file UTCOMM.PRG to define any number of user programs. This program has been enhanced to work with a broader range of graphics cards and the definition file it uses is customisable by the user in terms of colors as well as to add programs. (See installation section Appendix 1.

CONVERT

General purpose State Plane <--> Geodetic conversion program. The initial Least Squares Analysis produces a geographic coordinate file, however subsequent programs, and many of the utilities work primarily with the .COR file, so if lat/longs are desired for those additional points the .COR file can be processed into geographic coordinates with **CONVERT**.

PROJEC

A direct program to create a project definition file (.DEF). Normally not needed because the **CMM-MANAGE** Main Menu System performs essentially the same function. However, the **MANAGE** does not allow you to assign extreme unrealistic error estimate values. Sometimes that is useful in searching fof blunders. **PROJEC** has no such limitation.

LOOK

Look is a file browsing utility. CMM operation produces many report and output files, many of which it is essential to examine. **LOOK** allows the user to select from amoung the files produced for the project and view (without edit ability) them.

TE/RUNTE

A public domain text editor supplied with the system. Associated documentation files and configuration programs are included with the system.

Cadastral Measurement Management FILE Naming

All input/output files are based on the project name followed by a **DOS** extension which describes the file. If a project is called HOSTROP, all files will be named HOSTROP with different extensions beyond the DOS".".

Program	Input Files	Output Files
CMM	.DEF	.DEF
GENER	.DEF .LSA	.LSA .GEN
LSAQ	.DEF .LSA	.ADJ .COR .GEO
BLUNDER	.DEF .LSA	.LSA .BLU
CHECKER	.DEF .LSA .COR	.CHK
SD	.DEF .LSA .SD	.SD
DXFLSA	.DEF .LSA .COR .ADJ (for error ellipse info.)	.DXF
SSHOT	.DEF .SSS .COR	.SSS .COR
all utility programs	.DEF .COR	Various Reports .COR

LSAQ, CHECKER, and SSHOT also use **project.LEV** for elevation information if this option is selected in **CMM**.

Preliminary Details:

Types of Data - Measurements:

CMM processes measurements that are already reduced. Such as:

Meaned Angles Right

Angles left may be entered, but they are converted to angles right.

Horizontal Distances at ground elevation.

Default units are feet, this can be changed within an entry session or overridden per entry to Feet, Chains and/or Meters entry.

Other data that is required before a job can be completed are:

Geodetic Control

For at least one point on the job site. Scaled data is adequate to allow the system to properly compute proportions, etc. and return correct true bearings. If good control is later tied in it can be added to the data and the project quickly rerun to produce true values.

Azimuth Control

This will usually be in the form of astronomical observations, azimuth marks OR more than one control point on the project. Azimuths can be either true forward azimuths, OR grid azimuths, but grid & true cannot be mixed within one project.

Basics of data entry?

In the future the goal we hope to have most of the field data transferred from a data collector that will collect and maintain raw measurement data and create files compatible with CMM. This version of CMM contains a few data collection conversion programs, these are rudimentary at this time.

For many users data will have to be manually entered. This is most efficiently done thru the front end functions of the **GENER** program.

Other skills of value

Knowledge of DOS - This system has made an attempt to provide a functional and understandable user interface. This can always use improvement and this is recognized. The system is also operating a rather complex mix of functions that creates quit a few *files* on your PC. For this reason a good working knowledge of the PC's operating system **DOS** will usually be of benefit to any user. Particular familiarity with file management functions such as copying, and hard disk management functions such as creating and using subdirectories and changing drives are useful.

In the future there will be more job management functions in the system, for now it is useful to know how to copy files so that you can get old jobs out of the working CMM directory, make copies for testing to protect the original data, and renaming files for some of the same reasons.

Special installation or customisation of the system also requires a moderate knowledge of **DOS**.

Additional Program Documentation

There are several utility programs that are included with the system that can help you manage your jobs. Documentation for these programs is contained in DOC files that are included with the CMM system. These utilities are:

TE This is a basic Text Editor, information on it's commands is available both in a DOC file installed with the system and by using the *<F1>* key while in the editor. The editor is exited with the *<F4>* key, giving you the option to save a modified file or exit without changes.

LHARC This is a file compression utility. This is useful for job storage as you can save all the files associated with a job in one file, and in addition they will occupy much less space. Documentation is contained in a DOC file installed with the system, and simple operational reminder is available by typing LHARC(Enter) at the DOS prompt.

BAT2EXEC
This program allows you to compile DOS batch files into executable files. This allows then to be incorporated into the Uilities menu through the UTCOMM.PRG definition file.

KC
This is a capslock (and other) keyboard toggle utility. Documentation is supplied in a file called KC.DOC.

Getting Hard Copy

Since files are the primary means of output for CMM, a direct method of obtaining hard copy is not provided. In many cases the files and reports do not need to be printed, but in some cases printouts will be essential. For example a corner move report. Hard copy provides additional assurance that what you did is documented.

Use your editor:

WordPerfect: ASCII or text files can be imported into WordPerfect and then printed. Using a wordprocessor to perform this function allows you the maximum flexibility to document multiple files in you job, and to print to a wide variety of printer hardware.

MultiMate: same as for WordPerfect.

Other: There are a number of other editors you may use or install with the system, for example WordPerfect's Program Editor has a print option.

DOS's PRINT command:

Dos contains several ways to print files, one of which is the PRINT command, check your DOS manual for how this operates.

TE

Allows sections of text to be blocked and sent to a printer.

LOOK

Allows sections of text to be blocked and sent to a printer.

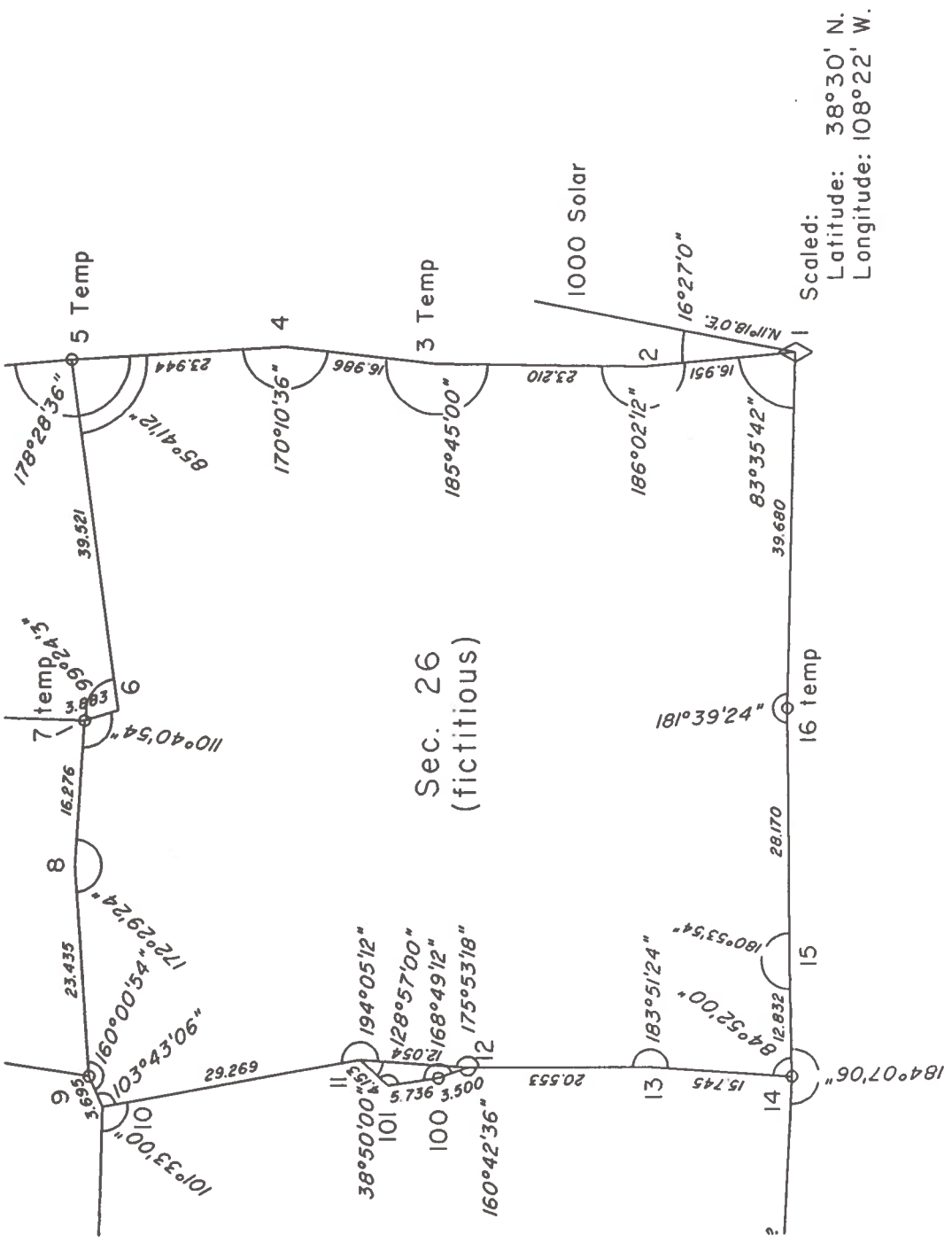


Figure 2 - Example 1 Diagram *(Colorado Central Zone)*

Chapter 5 - Working out Example 1

Starting at a Point #1, with scaled lat/long of:

Latitude: 38° 30' N.
Longitude: 108° 22' W.

at the original Cor. at the SE Cor. of our fictitious Section 26. This location is somewhere in West Central Colorado (Colorado Central Zone). It is usually easier to deal with simple point numbering when you start out with this system. **CMM** will take up to 16 character station names. There is no distinction between upper and lower case, however, so point 'aa' will be considered the same as 'AA'. The diagram shows the following data.

SAMPLE PROBLEM 1

Inst. @	BS	FS	Desc.	Angle Right	Dist. FS Hor Chains
1	2	1000	Solar	16°27'00"	(none)
1		2			16.951c
2	1	3	Temp	186°02'12"	23.210c
3	2	4		185°45'00"	16.986c
4	3	5	Temp	170°10'36"	23.944c
5	4	6		85°41'12"	39.521c
6	7	5	BS 7 Temp	99°24'03"	3.883c
7	6	8		110°40'54"	16.276c
8	7	9	Temp	172°29'24"	23.435c
9	8	10		160°00'54"	3.695c
10	9	11		103°43'06"	29.269c
11	10	12		194°05'12"	12.054c
12	11	13		175°53'18"	20.553c
13	12	14	Local SC	183°51'24"	15.745c
14	13	15		84°52'00"	12.832c
15	14	16	Temp	180°53'54"	28.170c
16	15	1	Beginning	181°39'24"	39.680c

Note: In a few cases the forward point was sighted first.

Figure 2 -- Traverse data for sample problem

Let's enter this traverse into **CMM** from scratch. First we will have to invoke **CMM** and setup a new job.

1) Start **CMM** by typing:

CMM(enter)

at the DOS prompt.

Note: In the following documentation the *(enter)* is implied. Normally prompts provided by the program will be displayed in sans-serif font, and any responses and data typed by the user will be indicated in italics. Like this:

Prompt: ***User supplied***

Enter Bearing: ***89.2233*** ***(enter inferred)***

If nothing happens, check through your installation as discussed in the Installation Appendix I.

2) If you don't see the screen shown in Figure 3, skip to **3).** You will only get the Screen in Figure 2 if this is the very first time you have run the system. This occurs whenever a file named **TEMP.JOB** does not exist. This file stores the default job name. Otherwise you should see the screen show in Figure 4.

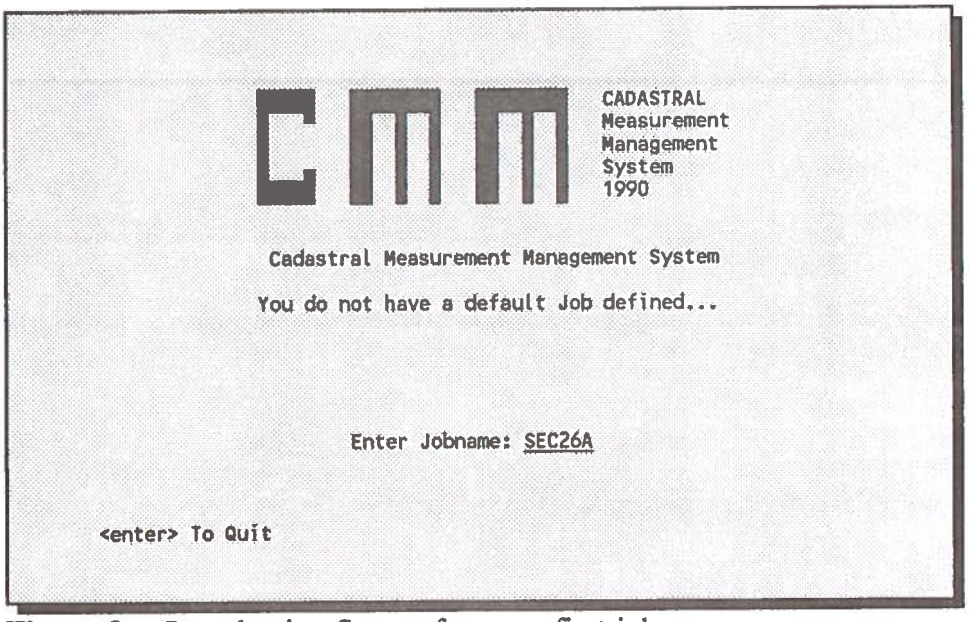


Figure 3 -- Introduction Screen for your first job.

If you do get to this screen, enter your first job name at the prompt or type (enter) to quit as indicated. In the figure we have already typed in the name.

Job names, *also called projects,* are restricted by the normal DOS file naming conventions since the project name is actually used to create all the files associated with the job. Briefly, the name can be only up to 8 characters in length and cannot contain any of the following characters

| \ , . < > ? / : ; " [ ] * + =

Upper and lower case letters are treated alike, and you should not include any DOS file extension in the system UNLESS specifically prompted to, as the **CMM** system adds that for each of the variety of it's different files.

3) You should now see the Cadastral Measurement Management Main Menu roughly as shown in Figure 4. This menu covers the primary measurement processing programs.

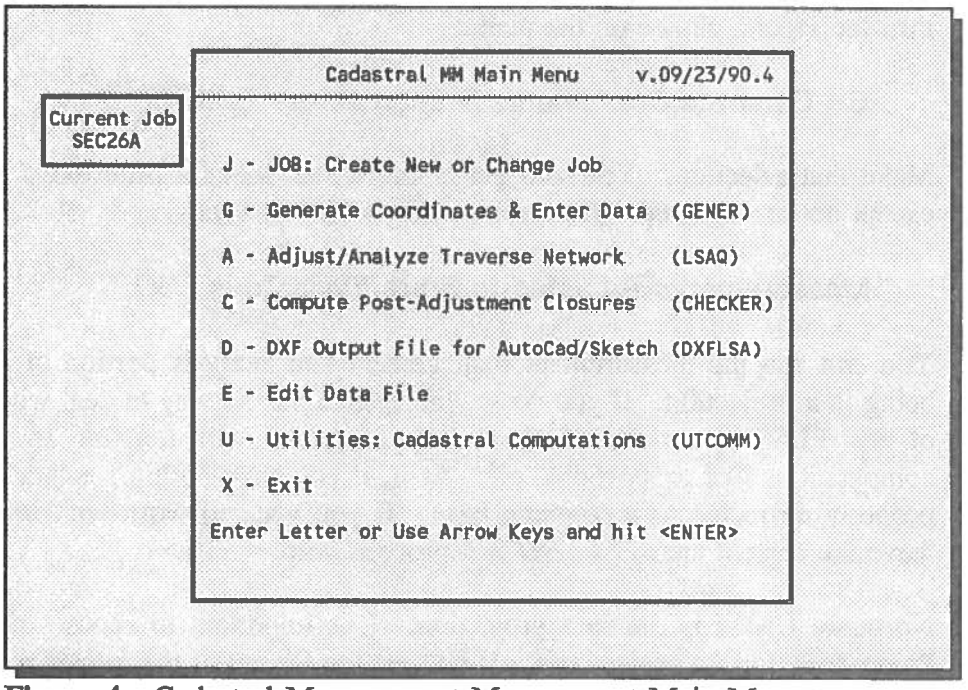


Figure 4 - Cadastral Measurement Management Main Menu

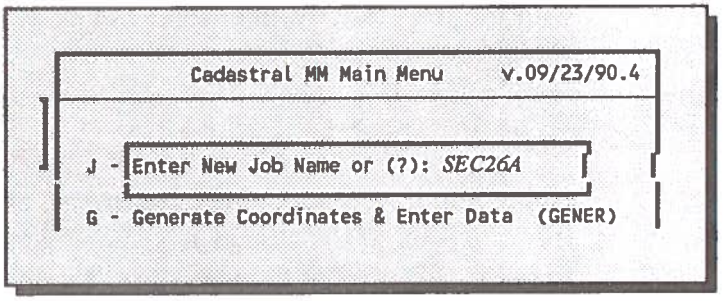
The choices in the menu are in the approximate order you might use them in a project. We will get to all of them in the course of this example, rather than describe them all at once. The choice you would normally make first would be to select **J** to name a new job. Unless it is the very first job executed in the system or the **TEMP.JOB** file has been inadvertently deleted, *(see 2. above)* you will define the new project name here.

All choices in this menu can be selected either by moving the light bar to your choice then hitting (enter), or by keying the single letter next to the item.

Therefore to create a new job, etc. key:

J

This should bring up an overlaying window prompting for the Job Name as shown on the right. If the job is already the default it will show.



4) After defining your new job name by either or both 2) and 3)

The next step is to setup the parameters for the job and begin data entry. This is done thru the second choice on the menu:

G - Generate Coordinates & Enter Data (GENER)

Make that selection. You will get a screen that looks a little like Figure 5 below, except not as cluttered. The prompt that is hidden says:

Measurements Adjusted to State Plane Zone? NO

5) You ***can*** run the measurement management and analysis portion of **CMM** without being in a projection. If you do so, the system has no way to deal with the geodetics of the **PLSS** and none of the utility programs will function to do any **PLSS** computations like proportions, etc. Also, if you have multiple solars they cannot be properly corrected to a common base. If you want to work with local coordinates leave the current answer as ***NO*** and proceed with <F10>.

Normally **CMM** is run in a projection. It is important to choose the correct State Plane Zone for the project area. If you get too far out of the proper zone some of the computations will start to accumulate strange errors.

6) In this case we are in the *Colorado Central Zone* (a guess), and so following the prompts at the bottom of the screen we first hit:

<F2>

Now we can change the answer to the ZONE question to Yes by hitting:

Y

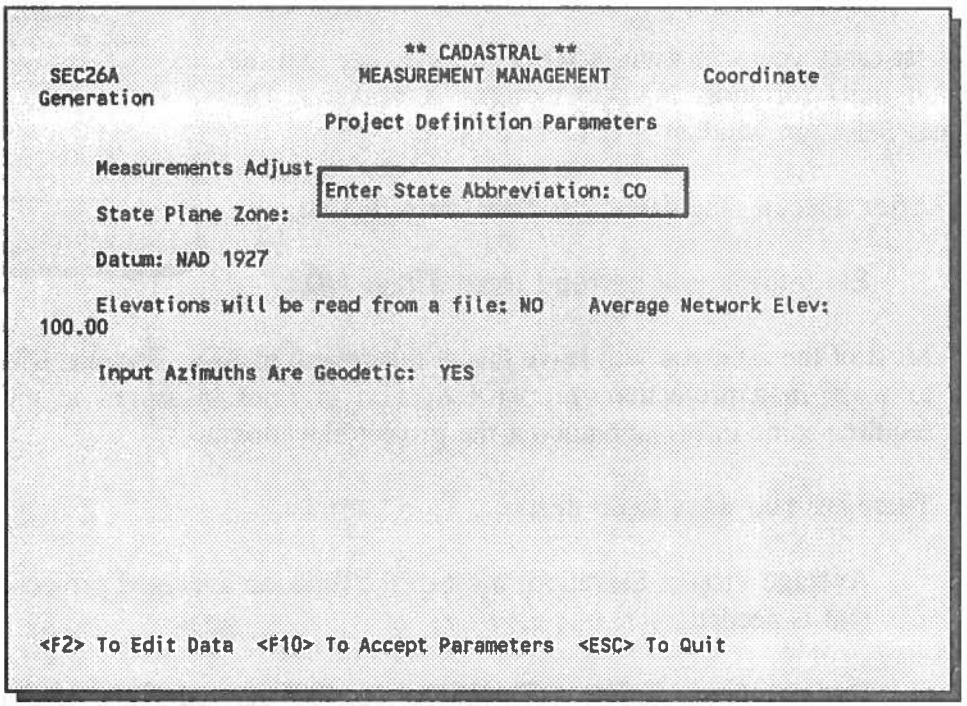
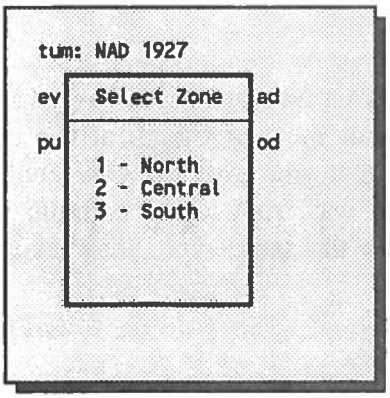


Figure 5 - Project Definition Parameter Screen

7) As soon as you hit the ***Y***, the State Abbreviation Prompt window shown above appears. The state abbreviation is the Postal Zip Code two character code. In this case:

CO

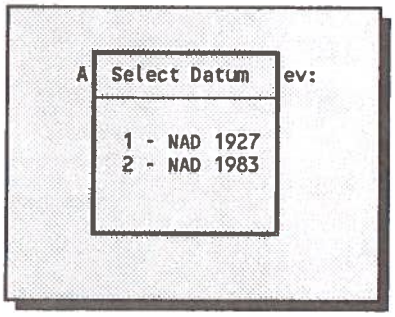
as soon as you enter the State, prompts for a lot of additional parameters appear on your screen and your cursor is place to respond to each in turn. The screen now should look like Figure 5 above.



When you hit enter at each prompt an additional option selection window opens. In this case we first get the Zone selection window and select the Central Zone with the light bar and *(enter)*, or by keying the corresponding menu choice. In this case key:

2

Next you are prompted to select the datum.



In most cases you will want **NAD27**. Remember that the default units for most **NAD83** systems is *metres*. The Datum Selection window is illustrated on the right.

8) After selecting the datum your next selection is:

Elevations will be read from a file: ***NO***

Most of the time you will leave this at the default of NO. Because **CMM** is designed to work in a projection, proper reduction of lines measured at ground elevation requires some information about the project elevation.

There are two ways to do this.

Average Project Elevation: most of the time, an averaged project elevation is all that is needed.

Derived from a file: Elevations can be derived from terrain information contained in a file. In some cases where there are large variations of elevation over a project it will affect accuracy of computations. This variation can be modeled with sample points contained in an elevation file. There is no program that will create such a file. This mode may become more practical with data collection systems. For information on what the elevation file should look like see the detailed documentation for **LSAQ** in the reference section of this document.

Answer the default: ***NO***

9) The next prompt is the other option for elevation as discussed above, the average project elevation. As long as this is within a few hundred feet there should be no adverse affect on computations. The imaginary average elevation for this project was not stated above, but is:

Average Network Elev: ***6200***

10) The last thing you have to define for this project is what type of Azimuths (Solars and Polaris observation bearings) you want to input. For most of Cadastral the answer will be **Geodetic** or *True*. The option would be that you have pre corrected your observations to grid, or perhaps your only azimuth was from a grid azimuth mark. Once you make this choice *ALL* azimuths must be the same type, they cannot be mixed.

Input Azimuths Are Geodetic: ***YES***

11) Now successive entries will take you around in a circle thru the prompts. When you have them all correct follow the information at the bottom of the screen and hit the ***<F10>*** key to accept the entries and continue.

12) As soon as you hit the ***<F10>*** key, the program **GENER** is started with the default project you have just defined (set-up). **GENER** has 2 jobs, its ultimate goal is to generate by any means possible coordinate ***estimates*** for all of your traverse stations. This is necessary to help out the least squares process coming up. **GENER** does not always do the logical thing, or the best thing, it just gets a coordinate that should be close. Remember it's an estimate!!

    GENER's other big capability is that it is the primary means of manual data entry. That is entry of your traverse measurement information. The following pages contain a complete dialogue of the entry of the data from the example. Comments and explanations are shown in italics on the right side of the page. This job was entered in such a way as to illustrate several of the options that are available.

    We strongly suggest you take a zerox copy of the example diagram and/or data and follow along closely with this dialogue.

```
COMPUTER PROGRAM GENER       VERSION 9-5-90
```
<--- *This is the screen I/O with GENER Most programs will show a header, with Version Date & Job Name.*

```
          PROJECT NAME IS SEC26A

DO YOU WANT TO INPUT NEW DATA OR EDIT EXISTING DATA? (Y/N):
y
```
You will almost always answer Yes to enter or change data

```
*** PLEASE PRESS THE CAPS LOCK ON YOUR KEYBOARD ***
    ALL STATION NAMES SHOULD USE CAPITAL LETTERS AND/OR NUMBERS
    DO NOT PUT SPACES IN STATION NAMES - THANK YOU

DO YOU WANT TO INPUT NEW DATA OR EDIT EXISTING DATA? (Y/N):
Y
```
Note: We got the message because we were using lower case.

We changed to CAPS.

```
1-INPUT OR DELETE CONTROL POINTS
2-INPUT OR DELETE DISTANCES
3-INPUT OR DELETE ANGLES/ DISTANCES
4-INPUT OR DELETE AZIMUTHS OR BEARINGS
5-LIST CONTROL STATIONS AND COORDINATES
6-LIST DISTANCES
7-LIST ANGLES AND DISTANCES
8-LIST AZIMUTHS
9-VIEW/CHANGE CURRENT DISTANCE ENTRY/EDIT UNITS
10-CHANGE (EDIT) EXISTING DATA
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #
9
```
This is GENER's main menu
1 Use to enter control stations
2 Use to enter distances ONLY
3 Use to enter ANGLES & DISTS
4 Use for SOLARS or other Azimuth

*9 Set Default Units *IMPORTANT**
10 Used to change ANYTHING
11 End entry and GENERate approx coords

Selected 9: Suggest you always choose default UNITS if they are NOT feet.

```
DISTANCE ENTRY/DISPLAY UNIT IS FEET
```
Prompt tells us the default now is Feet

```
CHANGE UNITS (Y/N) ?
Y
```
Yes, because this data is in chains

```
DO YOU WANT DISTANCE ENTRY/DISPLAY UNIT TO BE
(1) FEET
(2) CHAINS
(3) METERS
PICK A #
2
```
Note: You can override the default individual distance entries when entering later by adding C M or F.

Select Chains for new default

```
DISTANCE ENTRY/DISPLAY UNIT IS CHAINS
```
Tells us we are now in Chains

Main Menu again

```
1-INPUT OR DELETE CONTROL POINTS
2-INPUT OR DELETE DISTANCES
3-INPUT OR DELETE ANGLES/ DISTANCES
4-INPUT OR DELETE AZIMUTHS OR BEARINGS
5-LIST CONTROL STATIONS AND COORDINATES
6-LIST DISTANCES
7-LIST ANGLES AND DISTANCES
8-LIST AZIMUTHS
9-VIEW/CHANGE CURRENT DISTANCE ENTRY/EDIT UNITS
10-CHANGE (EDIT) EXISTING DATA
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #
1
DO YOU WANT TO?
    1-ADD DATA
    2-DELETE DATA
    3-QUIT
INPUT THE # OF YOUR CHOICE:
1
```
I choose to enter an estimated value for my starting station. This can be changed later. But you can use a scaled position until you tie in (if ever) and your relative comps will still be fine.

```
ENTERING A "U" FOR UNDO ALLOWS ONE TO ELIMINATE PREVIOUS ENTRIES
```
Note: the Undo option is available at many of GENER's data entry prompts.

```
ARE INPUT COORDINATES
(1) LATITUDE , LONGITUDE
(2) NORTHING (Y), EASTING (X)
PICK A #
1
```
We have a scaled lat/long

```
INPUT CONTROL STATION NAME (ZERO IF FINISHED):
1
```
It is best to use simple station names when you are just learning CMM.

```
INPUT LATITUDE IN DDD.MMSSSSS FORMAT
38.3
INPUT LONGITUDE IN DDD.MMSSSSS FORMAT
108.22
STATE PLANE COORDINATES
NORTHING (Y) =   255737.008  EASTING (X) =  1179694.126
INPUT CONTROL STATION NAME (ZERO IF FINISHED):
0

1-INPUT OR DELETE CONTROL POINTS
2-INPUT OR DELETE DISTANCES
3-INPUT OR DELETE ANGLES/ DISTANCES
4-INPUT OR DELETE AZIMUTHS OR BEARINGS
5-LIST CONTROL STATIONS AND COORDINATES
6-LIST DISTANCES
7-LIST ANGLES AND DISTANCES
8-LIST AZIMUTHS
9-VIEW/CHANGE CURRENT DISTANCE ENTRY/EDIT UNITS
10-CHANGE (EDIT) EXISTING DATA
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #
4
DO YOU WANT TO?
    1-ADD DATA
    2-DELETE DATA
    3-QUIT
INPUT THE # OF YOUR CHOICE:
1

ENTERING A "U" FOR UNDO ALLOWS ONE TO ELIMINATE PREVIOUS ENTRIES

WILL INPUT BE (1) AZIMUTHS OR (2) BEARINGS - SELECT A #
2
INPUT THE OCCUPIED STATION NAME (ZERO IF FINISHED):
1
STATION NAME EXISTS

INPUT THE SIGHTED STATION NAME:
1000
NEW STATION NAME

INPUT QUADRANT # OR N,S,E,W FOR CARDINAL DIRECTION
1
INPUT BEARING IN DD.MMSSSS FORMAT
11.18
INPUT DISTANCE 1              -1000              ZERO IF NONE OR
PREVIOUSLY INPUT
99.999
OCCUPIED STATION ASSUMED TO BE 1000
INPUT SIGHTED STATION NAME (ZERO IF INCORRECT):
0
INPUT THE OCCUPIED STATION NAME (ZERO IF FINISHED):
0

1-INPUT OR DELETE CONTROL POINTS
2-INPUT OR DELETE DISTANCES
3-INPUT OR DELETE ANGLES/ DISTANCES
4-INPUT OR DELETE AZIMUTHS OR BEARINGS
5-LIST CONTROL STATIONS AND COORDINATES
6-LIST DISTANCES
7-LIST ANGLES AND DISTANCES
8-LIST AZIMUTHS
9-VIEW/CHANGE CURRENT DISTANCE ENTRY/EDIT UNITS
10-CHANGE (EDIT) EXISTING DATA
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #
3
```

Note the HP41 DD.MMSS type format.

GENER computes the State Plane's and stores them for your station. Entering 0 (zero) is the way CMM programs commonly stop input.

Back to Main Menu

Now this example starts out at a found corner and a Solar was taken. We want to enter it now. An azimuth does not have to be on the first point, but GENER must have at least one azimuth OR more than one control point in order to orient your job to the coordinate system.

Normally azimuths are forward true, If you have already corrected solars to Grid you had to have specified GRID Azimuths in the initial setup menu.

I have a bearing

I took Solar at Station '1'

This little warning is a way to warn you about using an already used a name In this case it's okay as I want the same point. You should come up with a station naming scheme for Solars.

A weird thing is that you have to have some kind of distance to your astro object Zero won't do. We suggest you use something obviously made up.

The system tries to move me up. 0 to quit I am only entering 1 solar at this time. You can come back later to change, delete or edit any of these in the future.

Back to main menu

Most traverse data entry will be with #3.

```
DO YOU WANT TO?
    1-ADD DATA
    2-DELETE DATA
    3-QUIT
INPUT THE # OF YOUR CHOICE:
1

SPECIAL INPUT CHARACTERS ARE                                    <--
U - UNDO LAST OPERATION
S - SIDESHOT FROM PREVIOUS BACKSIGHT AND OCCUPIED
B - CHANGE BACKSIGHT OF PREVIOUS OCCUPIED AND FORESIGHT

ALWAYS ENTER SIDESHOTS BEFORE THE ANGLE TO NEXT TRAVERSE STATION.
IT ENHANCES THE DATA ENTRY ROUTINE.
A NEGATIVE ANGLE IMPLIES ANGLE LEFT (BS AND FS STATIONS WILL BE SWAPPED)

INPUT THE BACKSIGHT STATION NAME  (ZERO IF FINISHED):
1000
STATION NAME EXISTS

INPUT THE OCCUPIED STATION NAME:
1
STATION NAME EXISTS

INPUT DISTANCE 1              -1000             ZERO IF NONE OR
PREVIOUSLY INPUT
0

TRAVERSE MODE
BACKSIGHT STATION : 1000
OCCUPIED STATION : 1
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
2
NEW STATION NAME

INPUT DISTANCE 1              -2                ZERO IF NONE OR
PREVIOUSLY INPUT
16.951
INPUT ANGLE IN DD.MMSSSS FORMAT
-16.27

TRAVERSE MODE
BACKSIGHT STATION : 1
OCCUPIED STATION : 2
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
3
NEW STATION NAME

INPUT DISTANCE 2              -3                ZERO IF NONE OR
PREVIOUSLY INPUT
23.21
INPUT ANGLE IN DD.MMSSSS FORMAT
186.0212

TRAVERSE MODE
BACKSIGHT STATION : 2
OCCUPIED STATION : 3
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
4
NEW STATION NAME

INPUT DISTANCE 3              -4                ZERO IF NONE OR
PREVIOUSLY INPUT
16.986
INPUT ANGLE IN DD.MMSSSS FORMAT
185.45
```

There are a lot of options and short cuts in this portion. Besides the (U)ndo option, you can say that the entry you just finished entering was a sideshot and back up to last occupied. You can change backsights for check shots. Also - for angle left (or reverse BS-FS) enter B after. Options not shown here are that you can append C F or M to distance entries to define non default units of Chains Feet or Meters

Entering - angle is interior left.

I decide to BS my Solar Point for data entry

Prompts the distance to BS on first This comes in handy some times. Enter 0 because we already have it.

Note: the Traverse Prompt show the BS and the occupied station names.

Prompt for first FS: distance first

Prompt for angle, use - since this angle left with this BS-FS

Move up & ready for next leg.

```
TRAVERSE MODE
BACKSIGHT STATION : 3
OCCUPIED STATION : 4
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
5
NEW STATION NAME

INPUT DISTANCE 4              -5              ZERO IF NONE OR
PREVIOUSLY INPUT
23.944
INPUT ANGLE IN DD.MMSSSS FORMAT
170.1036

TRAVERSE MODE
BACKSIGHT STATION : 4
OCCUPIED STATION : 5
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
6
NEW STATION NAME

INPUT DISTANCE 5              -6              ZERO IF NONE OR
PREVIOUSLY INPUT
39.521
INPUT ANGLE IN DD.MMSSSS FORMAT
85.4112

TRAVERSE MODE
BACKSIGHT STATION : 5
OCCUPIED STATION : 6
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
7
NEW STATION NAME

INPUT DISTANCE 6              -7              ZERO IF NONE OR
PREVIOUSLY INPUT
3.883
INPUT ANGLE IN DD.MMSSSS FORMAT                   Another angle left because I have odd example
-99.2403

TRAVERSE MODE
BACKSIGHT STATION : 6
OCCUPIED STATION : 7
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
8
NEW STATION NAME

INPUT DISTANCE 7              -8              ZERO IF NONE OR
PREVIOUSLY INPUT
16.276
INPUT ANGLE IN DD.MMSSSS FORMAT                   I am now going to make a deliberate mistake
172.2924                                          Wrong angle

TRAVERSE MODE                                     Continue for a while till I discover mistake
BACKSIGHT STATION : 7
OCCUPIED STATION : 8
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
9
NEW STATION NAME

INPUT DISTANCE 8              -9              ZERO IF NONE OR
PREVIOUSLY INPUT
23.435
INPUT ANGLE IN DD.MMSSSS FORMAT                   Realize mistake and use U (undo) to back up
U                                                 Back up to distance prompt
INPUT DISTANCE 8              -9              ZERO IF NONE OR
PREVIOUSLY INPUT
U                                                 Back up to previous station prompt
```

```
TRAVERSE MODE
BACKSIGHT STATION : 7
OCCUPIED STATION : 8
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
U                                                    Back up to previous Angle prompt (mistake)
INPUT ANGLE IN DD.MMSSSS FORMAT
110.4054                                             Enter correct angle

TRAVERSE MODE
BACKSIGHT STATION : 7
OCCUPIED STATION : 8
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):    Re-enter data forward again
9
STATION NAME EXISTS

INPUT DISTANCE 8              -9              ZERO IF NONE OR
PREVIOUSLY INPUT
23.435
INPUT ANGLE IN DD.MMSSSS FORMAT
172.2924

TRAVERSE MODE
BACKSIGHT STATION : 8
OCCUPIED STATION : 9
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
10
NEW STATION NAME

INPUT DISTANCE 9              -10             ZERO IF NONE OR
PREVIOUSLY INPUT
3.695
INPUT ANGLE IN DD.MMSSSS FORMAT
160.0054

TRAVERSE MODE
BACKSIGHT STATION : 9
OCCUPIED STATION : 10                                Decide to stop, say at the end of a day's work
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
0                                                    "Zero Out" to menu
INPUT THE BACKSIGHT STATION NAME  (ZERO IF FINISHED):
0

1-INPUT OR DELETE CONTROL POINTS                     Main Menu again
2-INPUT OR DELETE DISTANCES
.                                                    There is only ONE way out of this program
.  (shortened menu in docs only)                     that is: item 11
.
10-CHANGE (EDIT) EXISTING DATA
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #
11
```

GENER will compute all coordinates it can. If it cannot, you can still quit and return later.

```
STATION  2              HAS COORDINATES GENERATED BY ANGLE    AND DISTANCE
FROM KNOWN BACKSIGHT
NORTHING (Y) =    256809.651 EASTING (X) =   1179377.413

STATION  3              HAS COORDINATES GENERATED BY ANGLE    AND DISTANCE
FROM KNOWN BACKSIGHT
NORTHING (Y) =    258315.819 EASTING (X) =   1179100.617

STATION  4              HAS COORDINATES GENERATED BY ANGLE    AND DISTANCE
FROM KNOWN BACKSIGHT
NORTHING (Y) =    259432.840 EASTING (X) =   1179009.501

STATION  5              HAS COORDINATES GENERATED BY ANGLE    AND DISTANCE
FROM KNOWN BACKSIGHT
NORTHING (Y) =    260962.429 EASTING (X) =   1178614.302

STATION  6              HAS COORDINATES GENERATED BY ANGLE    AND DISTANCE
FROM KNOWN BACKSIGHT
NORTHING (Y) =    260122.095 EASTING (X) =   1176145.837

STATION  7              HAS COORDINATES GENERATED BY ANGLE    AND DISTANCE
FROM KNOWN BACKSIGHT
NORTHING (Y) =    260347.883 EASTING (X) =   1176024.767

STATION  8              HAS COORDINATES GENERATED BY ANGLE    AND DISTANCE
FROM KNOWN BACKSIGHT
NORTHING (Y) =    260207.356 EASTING (X) =   1174960.116

STATION  9              HAS COORDINATES GENERATED BY ANGLE    AND DISTANCE
FROM KNOWN BACKSIGHT
NORTHING (Y) =    259806.401 EASTING (X) =   1173466.773

STATION  10             HAS COORDINATES GENERATED BY ANGLE    AND DISTANCE
FROM KNOWN BACKSIGHT
NORTHING (Y) =    259666.517 EASTING (X) =   1173267.102
DIRECTION ASSUMPTION HAS BEEN CORRECTED
Stop - Program terminated.
```

GENER computes coordinates first then rotates the work in to your azimuths

GENER has also just created a file SEC26A.GEN that contains some of the above data. Note that it indicates what points were computed, how they were computed and the values. If bad things happen, and coordinates cannot be computed that information will also be shown on the screen and in the report. Next time we run **GENER** this report will be overwritten with the current one for that run.

At this point control returns to the **CMM** main menu. **GENER** has just created a file called SEC26A.GEN that contains the above output. The data you have entered is in the file SEC26A.LSA, and the data that defines the project parameters you have is contained in the file SEC26A.DEF. We will take a look at some of these files when we finish a loop and have a closure.

What we have just done is attempt to illustrate:

* How to **define** a project
* How to start data **entry** in **GENER**
* Enter **Control**
* Enter **Azimuths**
* Enter **Angles and Distances**
* Enter Angles **Left** with a -
* Correct mistakes with **U** (undo)
* End after a days work.
* Generate **approximate** coordinates for work to date.

If you have been diligently working through this example this is an ideal place to take a break.

* * * * * * * * * * * * *

Creating Graphics:

Now let's try to get a graphic of the work to this point. Graphics provides a way to see what you've done which is a great aid in noticing larger errors. This is especially true if you are looking at your own data.

There are several ways to get graphics.

First way: Use the utility **VIEW**. This program will give you a quick look at the traverse. It has the capability to pan and zoom thus allowing a good graphic look at your job. To do this select V from the Utilities Menu.

Second way: Create a DXF file with the ***<D>*** choice on the **CMM** main menu. DXF stands for a file format that was developed by the makers of AutoCad, and it has become a defacto standard for interchange of graphic data between PC based CAD systems.

There a few ways to use DXF files either to view or obtain hard copy.

1) Load the file into AutoCad with the DXFIN command, then you can view, edit, plot or printer plot the drawing. Of course not everyone has access to AutoCad and plotters and such.

2) Load the file into AutoSketch or other basic CAD package. There are a number of such inexpensive packages that can read DXF files. This can be in effective way to accomplish what we want.

3) Convert the DXF to a WPG WordPerfect 5.0 or 5.1 graphic file, then create a WP document graphic which can then be viewed and printed.

In this example we will just create the DXF, and bring the DXF file into this WordPerfect Document by using the GRAPHCNV program with WP.

GRAPHCNV SEC26A.DXF SEC26A.WPG

Now:

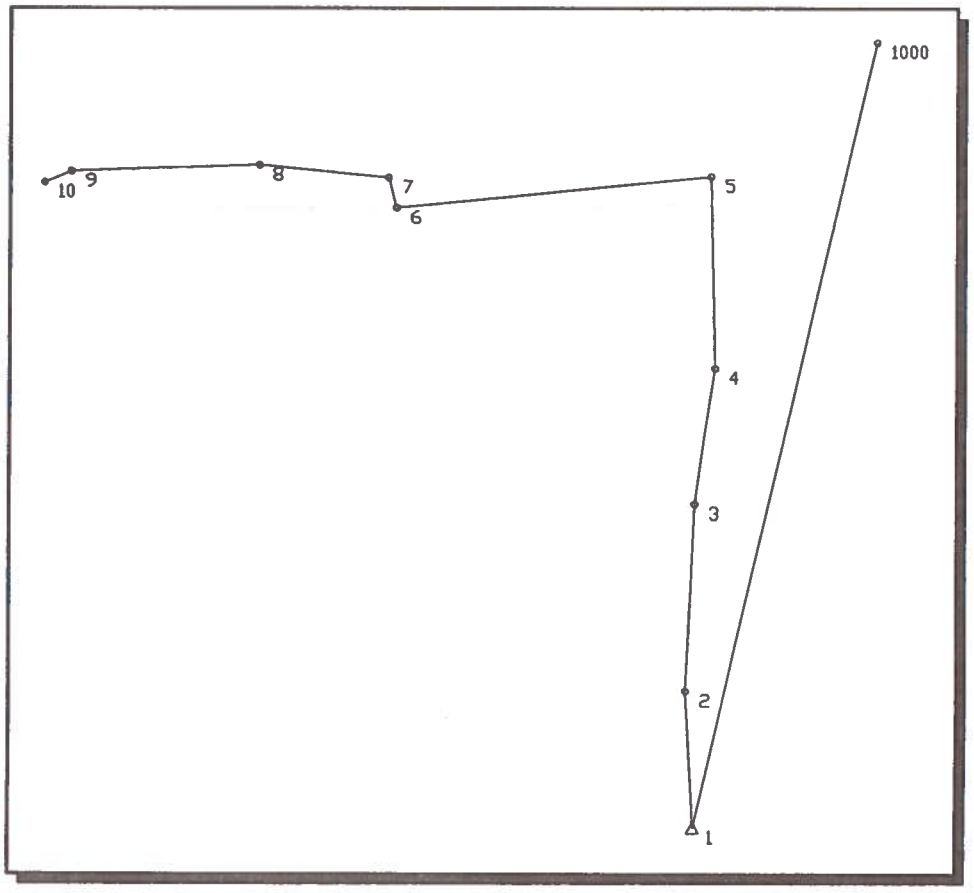
1) Go back into **CMM** as earlier, then select: ***D***

2) Follow the dialogue shown on the next page. Note most of the responses are (enter) which selects the default shown.

```
COMPUTER PROGRAM DRAW (PART OF DXFLSA) VER. 8-3-90
THIS PROGRAM ALLOWS HITTING ENTER TO ACCEPT WHAT IS IN < > OR
YOU CAN INPUT AS NORMAL.
IT ALSO ALLOWS ENTRY OF CHAINS FROM THE KEYBOARD WHICH WILL ALSO BE STORED IN A FILE
                PROJECT IS SEC26A
DO YOU WANT ALL STATIONS MOVED TO GRAPHICS (Y/N)?
A NO ANSWER IMPLIES ONLY CHAINS WILL MOVE TO GRAPHICS <Y>

DO YOU WANT COORDINATES READ FROM
(1) ADJUSTED COORDINATE .COR FILE
(2) INPUT MEASUREMENT .LSA FILE
PICK A # <1>
2
DO YOU WANT LINES DRAWN REPRESENTING MEASURED
DISTANCES? <Y>

DO YOU WANT TO DRAW LINES FROM CHAIN FILES? <N>

INPUT TEXT HEIGHT IN GROUND UNITS (100 IS TYPICAL)
ZERO IF NO TEXT DESIRED <100>

INPUT UNK. STATION SYMBOL RADIUS (25 IS TYPICAL)
ZERO IF NONE DESIRED <25>

INPUT CONTROL SYMBOL SIZE (100 IS TYPICAL)
ZERO IF NONE DESIRED <100>

DO YOU WANT TO PLOT ERROR ELLIPSES? <N>
```

DXFLSA runs the DRAW program
Note: this program accepts defaults
A chain file is a list of points to draw lines between. Can be used to create true lines.
(Enter to accept default)
We do not have a .COR file yet so we must Select 2
(Enter to accept default)
(Enter to accept default)
(Enter to accept default)
(Enter to accept default)
(Enter to accept default)

Here is the result:



Finish Section Exterior data entry

We would now like to resume data entry as if we were putting in the next days work. In this case:

Restart **CMM** as before, then

Select the ***G*** choice from the menu

The parameters you defined before for the project should be okay, therefore hit ***<F10>*** to go ahead and invoke **GENER**.

```
COMPUTER PROGRAM GENER      VERSION 9-5-90

         PROJECT NAME IS SEC26A

DO YOU WANT TO INPUT NEW DATA OR EDIT EXISTING DATA? (Y/N):
Y                                                    Yes again, we are going to add new data

1-INPUT OR DELETE CONTROL POINTS
2-INPUT OR DELETE DISTANCES
3-INPUT OR DELETE ANGLES/ DISTANCES
4-INPUT OR DELETE AZIMUTHS OR BEARINGS
5-LIST CONTROL STATIONS AND COORDINATES
6-LIST DISTANCES
7-LIST ANGLES AND DISTANCES
8-LIST AZIMUTHS
9-VIEW/CHANGE CURRENT DISTANCE ENTRY/EDIT UNITS
10-CHANGE (EDIT) EXISTING DATA
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #                                           I decide to see what I have entered before
7
TOTAL NUMBER OF THIS MEASUREMENT TYPE IS     9       Tells you how big the list is
INPUT MINIMUM LIST #
1                                                    I choose the whole list 1 to 9
INPUT MAXIMUM LIST #
9

NUMBER OF ANGLES IS   9                              Notice the distances are now in feet

LIST# BACKSIGHTED   OCCUPIED      FORESIGHTED            ANGLE
                                                    BS DISTANCE  FS DISTANCE
   1 2                1               1000          16-27-   .0
                                                      1118.766    6599.934
   2 1                2               3            186- 2- 12.0
                                                      1118.766    1531.860
   3 2                3               4            185-45-   .0
                                                      1531.860    1121.076
   4 3                4               5            170-10- 36.0
                                                      1121.076    1580.304
   5 4                5               6             85-41- 12.0
                                                      1580.304    2608.386
   6 7                6               5             99-24-  3.0
                                                       256.278    2608.386
   7 6                7               8            110-40- 54.0
                                                       256.278    1074.216
   8 7                8               9            172-29- 24.0
                                                      1074.216    1546.710
   9 8                9               10           160- 0- 54.0
                                                      1546.710     243.870
PRESS ENTER TO CONTINUE
```

```
1-INPUT OR DELETE CONTROL POINTS
2-INPUT OR DELETE DISTANCES
3-INPUT OR DELETE ANGLES/ DISTANCES
4-INPUT OR DELETE AZIMUTHS OR BEARINGS
5-LIST CONTROL STATIONS AND COORDINATES
6-LIST DISTANCES
7-LIST ANGLES AND DISTANCES
8-LIST AZIMUTHS
9-VIEW/CHANGE CURRENT DISTANCE ENTRY/EDIT UNITS
10-CHANGE (EDIT) EXISTING DATA
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #                                          The list reminds me to select units for
9                                                   the data I have in chains. The selection we
                                                    made last time does not matter
DISTANCE ENTRY/DISPLAY UNIT IS FEET
CHANGE UNITS (Y/N) ?
Y
DO YOU WANT DISTANCE ENTRY/DISPLAY UNIT TO BE
(1) FEET
(2) CHAINS
(3) METERS
PICK A #
2

DISTANCE ENTRY/DISPLAY UNIT IS CHAINS               Okay I am alright now!

1-INPUT OR DELETE CONTROL POINTS
2-INPUT OR DELETE DISTANCES
3-INPUT OR DELETE ANGLES/ DISTANCES
4-INPUT OR DELETE AZIMUTHS OR BEARINGS
.
.
.
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #
3                                                   Restart traverse entry
DO YOU WANT TO?
    1-ADD DATA
    2-DELETE DATA
    3-QUIT
INPUT THE # OF YOUR CHOICE:
1

SPECIAL INPUT CHARACTERS ARE                        Remember the options
U - UNDO LAST OPERATION
S - SIDESHOT FROM PREVIOUS BACKSIGHT AND OCCUPIED
B - CHANGE BACKSIGHT OF PREVIOUS OCCUPIED AND FORESIGHT

ALWAYS ENTER SIDESHOTS BEFORE THE ANGLE TO NEXT TRAVERSE STATION.
IT ENHANCES THE DATA ENTRY ROUTINE.
A NEGATIVE ANGLE IMPLIES ANGLE LEFT (BS AND FS STATIONS WILL BE SWAPPED)
                                                    Refer back to the example diagram & data
INPUT THE BACKSIGHT STATION NAME  (ZERO IF FINISHED):  Starting at 10 backsight 9
9
STATION NAME EXISTS                                 Good, it's there from the day before

INPUT THE OCCUPIED STATION NAME:
10
STATION NAME EXISTS

INPUT DISTANCE 10              -9              ZERO IF NONE OR
PREVIOUSLY INPUT                                    Always asks for BS distance FIRST time
11                                                  and I am ahead trying to enter the next
                                                    station by mistake
TRAVERSE MODE
BACKSIGHT STATION : 9
OCCUPIED STATION : 10
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
U                                                   Use Undo to re enter the thing I messed up
INPUT DISTANCE 10              -9              ZERO IF NONE OR
PREVIOUSLY INPUT
0
```

```
TRAVERSE MODE
BACKSIGHT STATION : 9
OCCUPIED STATION : 10
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):        Now I goof up and put in my occupied station
10

TRAVERSE MODE                                            It is rejected and I get a second chance
BACKSIGHT STATION : 9
OCCUPIED STATION : 10
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
11
NEW STATION NAME                                         As it should be new
                                                         We go ahead and continue entry
INPUT DISTANCE 10              -11              ZERO IF NONE OR
PREVIOUSLY INPUT
29.269
INPUT ANGLE IN DD.MMSSSS FORMAT
103.4306

TRAVERSE MODE
BACKSIGHT STATION : 10
OCCUPIED STATION : 11
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
12
NEW STATION NAME

INPUT DISTANCE 11              -12              ZERO IF NONE OR
PREVIOUSLY INPUT
12.054
INPUT ANGLE IN DD.MMSSSS FORMAT
194.0512

TRAVERSE MODE
BACKSIGHT STATION : 11
OCCUPIED STATION : 12
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
13
NEW STATION NAME

INPUT DISTANCE 12              -13              ZERO IF NONE OR
PREVIOUSLY INPUT
20.553
INPUT ANGLE IN DD.MMSSSS FORMAT
175.5318

TRAVERSE MODE
BACKSIGHT STATION : 12
OCCUPIED STATION : 13
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
14
NEW STATION NAME

INPUT DISTANCE 13              -14              ZERO IF NONE OR
PREVIOUSLY INPUT
15.745
INPUT ANGLE IN DD.MMSSSS FORMAT
183.5124

TRAVERSE MODE
BACKSIGHT STATION : 13
OCCUPIED STATION : 14
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
15
NEW STATION NAME

INPUT DISTANCE 14              -15              ZERO IF NONE OR
PREVIOUSLY INPUT
12.832
INPUT ANGLE IN DD.MMSSSS FORMAT
84.52
```

```
TRAVERSE MODE
BACKSIGHT STATION : 14
OCCUPIED STATION : 15
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
16
NEW STATION NAME

INPUT DISTANCE 15              -16              ZERO IF NONE OR
PREVIOUSLY INPUT
28.17
INPUT ANGLE IN DD.MMSSSS FORMAT
180.5354

TRAVERSE MODE                                          A VERY important concept in CMM is that points
BACKSIGHT STATION : 15                                 can only have one id therefore when you go back
OCCUPIED STATION : 16                                  to station 1 you MUST say so.  CMM does not
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):      create a new coordinate, we are only storing
1                                                      measurements between things.
STATION NAME EXISTS

INPUT DISTANCE 16              -1               ZERO IF NONE OR
PREVIOUSLY INPUT
39.68
INPUT ANGLE IN DD.MMSSSS FORMAT
181.3924

TRAVERSE MODE                                          Now we have to enter the closing angle, again
BACKSIGHT STATION : 16                                 we just tell it what we are actually doing
OCCUPIED STATION : 1
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
2
STATION NAME EXISTS                                    Yep, turning in to previous station.

INPUT DISTANCE 1               -2               ZERO IF NONE OR
PREVIOUSLY INPUT                                       Okay, try not to forget we already have dist, so
0                                                      Zero  to say so
INPUT ANGLE IN DD.MMSSSS FORMAT
83.3542

TRAVERSE MODE                                          I am done with this traverse so I have to
BACKSIGHT STATION : 1                                  Zero out to GENER menu.
OCCUPIED STATION : 2
INPUT FORESIGHT STATION NAME (ZERO IF INCORRECT):
0
INPUT THE BACKSIGHT STATION NAME  (ZERO IF FINISHED):
0

1-INPUT OR DELETE CONTROL POINTS
2-INPUT OR DELETE DISTANCES
3-INPUT OR DELETE ANGLES/ DISTANCES
4-INPUT OR DELETE AZIMUTHS OR BEARINGS
5-LIST CONTROL STATIONS AND COORDINATES
6-LIST DISTANCES
7-LIST ANGLES AND DISTANCES
8-LIST AZIMUTHS
9-VIEW/CHANGE CURRENT DISTANCE ENTRY/EDIT UNITS
10-CHANGE (EDIT) EXISTING DATA
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #                                             Choose to get a list to see how it all looks
7
TOTAL NUMBER OF THIS MEASUREMENT TYPE IS    17
INPUT MINIMUM LIST #
1
INPUT MAXIMUM LIST #
17

NUMBER OF ANGLES IS  17
```

```
LIST# BACKSIGHTED   OCCUPIED      FORESIGHTED          ANGLE
                                                  BS DISTANCE  FS DISTANCE
   1 2                1               1000        16-27-   .0
                                                      16.951       99.999
   2 1                2               3          186- 2- 12.0
                                                      16.951       23.210
   3 2                3               4          185-45-   .0
                                                      23.210       16.986
   4 3                4               5          170-10- 36.0
                                                      16.986       23.944
   5 4                5               6           85-41- 12.0
                                                      23.944       39.521
   6 7                6               5           99-24-  3.0
                                                       3.883       39.521
   7 6                7               8          110-40- 54.0
                                                       3.883       16.276
   8 7                8               9          172-29- 24.0
                                                      16.276       23.435
   9 8                9               10         160- 0- 54.0
                                                      23.435        3.695
  10 9               10               11         103-43-  6.0
                                                       3.695       29.269
  11 10              11               12         194- 5- 12.0
                                                      29.269       12.054
  12 11              12               13         175-53- 18.0
                                                      12.054       20.553
  13 12              13               14         183-51- 24.0
                                                      20.553       15.745
  14 13              14               15          84-52-   .0
                                                      15.745       12.832
  15 14              15               16         180-53- 54.0
                                                      12.832       28.170
  16 15              16               1          181-39- 24.0
                                                      28.170       39.680
  17 16              1                2           83-35- 42.0
                                                      39.680       16.951
PRESS ENTER TO CONTINUE
```

Notice that NOW all the distances show in chains because we set that for default They are still feet in the .LSA File though.

```
1-INPUT OR DELETE CONTROL POINTS
2-INPUT OR DELETE DISTANCES
.
.
.
10-CHANGE (EDIT) EXISTING DATA
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #
11
```

Now, let's see what we have for the loop

```
DO YOU WANT TO USE EXISTING COORDINATES (Y/N)?
N
```

"No" means that GENER will not waste time computing points you already have, saving time for large projects. Yes recomputes all fresh.

```
STATION  2              HAS COORDINATES GENERATED BY ANGLE     AND DISTANCE
FROM KNOWN BACKSIGHT
NORTHING (Y) =    256809.652 EASTING (X) =   1179377.412

TRAVERSE CLOSURE REPORT
ERROR IN NORTHING =    -.495 ERROR IN EASTING =      .146

LINEAR ERROR OF CLOSURE IS         .516 FT.

PRECISION IS 1/       39519.

ANGULAR CLOSURE IS         9. SECONDS
CLOSURES REFLECT ANGULAR ADJUSTMENT
```

Shows your loop closure and precision

This is okay, I can proceed with confidence I probably do not have any blunders

```
STATION          NORTHING (Y)      EASTING (X)
1                   255737.008     1179694.126
16                  255277.924     1177116.620
15                  254899.164     1175296.591
14                  254713.655     1174470.338
13                  255743.755     1174334.373
12                  257073.431     1174066.845
11                  257862.508     1173966.263
10                  259661.445     1173263.036
9                   259801.545     1173462.614
8                   260203.983     1174955.885
7                   260345.538     1176020.624
6                   260119.815     1176141.938
5                   260962.636     1178610.114
4                   259433.080     1179006.879
3                   258315.893     1179099.098
2                   256809.652     1179377.412
DIRECTION ASSUMPTION HAS BEEN CORRECTED
Stop - Program terminated.
```

GENER has created a report SEC26A.GEN, which is shown below. This file can be viewed with the E Edit option on your menu.

If you were following along and did not get the same closure, you have a problem with one of the data entries. Later on we will put in an error and show how to change them. You might try to find the bad entry from the list you made above, then correct with **GENER**'s ***<10>*** Change (EDIT) existing data entry.

```
<File SEC26A.GEN>

           PROJECT NAME IS SEC26A

 STATION  2                HAS COORDINATES GENERATED BY ANGLE    AND DISTANCE
 FROM KNOWN BACKSIGHT
 NORTHING (Y) =    256809.652 EASTING (X) =   1179377.412

 TRAVERSE CLOSURE REPORT
 ERROR IN NORTHING =    -.495 ERROR IN EASTING =      .146

 LINEAR ERROR OF CLOSURE IS          .516 FT.

 PRECISION IS 1/       39519.

 ANGULAR CLOSURE IS          9. SECONDS
 CLOSURES REFLECT ANGULAR ADJUSTMENT

 STATION             NORTHING (Y)      EASTING (X)
 1                      255737.008     1179694.126
 16                     255277.924     1177116.620
 15                     254899.164     1175296.591
 14                     254713.655     1174470.338
 13                     255743.755     1174334.373
 12                     257073.431     1174066.845
 11                     257862.508     1173966.263
 10                     259661.445     1173263.036
 9                      259801.545     1173462.614
 8                      260203.983     1174955.885
 7                      260345.538     1176020.624
 6                      260119.815     1176141.938
 5                      260962.636     1178610.114
 4                      259433.080     1179006.879
 3                      258315.893     1179099.098
 2                      256809.652     1179377.412
```

FINAL GENERATED COORDINATES

STATION	NORTHING (Y)	EASTING (X)
1	255737.008	1179694.126
1000	262163.010	1181190.447
2	256853.530	1179628.926
3	258383.643	1179699.459
4	259492.635	1179863.006
5	261072.319	1179823.463
6	260811.208	1177228.456
7	261058.562	1177161.493
8	261162.164	1176092.394
9	261108.866	1174546.763
10	261017.679	1174320.612
11	259106.131	1174597.542
12	258314.804	1174516.550
13	256959.101	1174475.555
14	255925.005	1174374.364
15	255918.298	1175221.160
16	255874.430	1177079.664

DISTANCE RESIDUALS

DISTANCE		RESIDUAL
1	- 1000	.000
1	- 2	.000
2	- 3	-.348
3	- 4	-.255
4	- 5	-.361
5	- 6	-.529
6	- 7	-.059
7	- 8	-.223
8	- 9	-.317
9	- 10	-.048
10	- 11	-.345
11	- 12	-.142
12	- 13	-.241
13	- 14	-.184
14	- 15	-.169
15	- 16	-.370
16	- 1	.007

ANGLE RESIDUALS

ANGLE			RESIDUAL (SEC)
2	- 1	- 1000	.0
1	- 2	- 3	199.3
2	- 3	- 4	.5
3	- 4	- 5	-.9
4	- 5	- 6	-5.4
7	- 6	- 5	-4.1
6	- 7	- 8	-4.1
7	- 8	- 9	-.1
8	- 9	- 10	.3
9	- 10	- 11	5.4
10	- 11	- 12	-1.3
11	- 12	- 13	.4
12	- 13	- 14	-.3
13	- 14	- 15	6.0
14	- 15	- 16	.0
15	- 16	- 1	.0
16	- 1	- 2	-194.9

AZIMUTH RESIDUALS

AZIMUTH		RESIDUAL (SEC)
1	- 1000	.0

Notice that the report shows the same things we had on screen output followed by what **GENER** came up with for residuals, at this point these don't mean much.

A residual is the difference between the measurement and the adjusted value.

The angle residuals at point 1 and 2 represent the quick and dirty way that **GENER** used to get the coordinates. Remember though that **GENER**'s goal is just to produce approximate coordinates for **LSAQ**. Our error estimates, the ones that represent our judgement come next.

Next we will go ahead and run a least squares analysis just for fun.

Running the Least Squares Analysis

1) At the Main CMM Menu select the A option with either the light bar and (enter) or by just typing:

A

2) You should now get the screen shown in Figure 6. This is a screen that allows you to enter your error estimates and other data that controls how the analysis and adjustment will be performed.

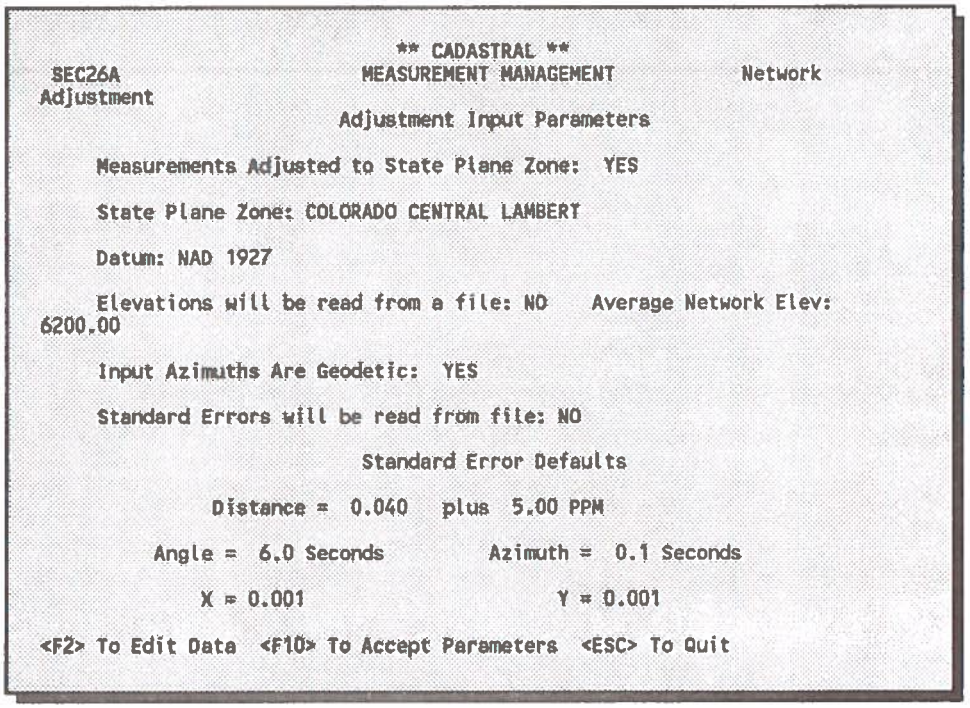


Figure 6 - Least Squares Parameter Entry Screen #1

The top portion of this screen should reflect the same project data you entered before in Figure 5. What you now need to define are the items shown at the bottom of the screen as show here in Figure 7.

To edit these items, hit the **<F2>** key as instructed at the bottom of the screen. If you now hit enter, you will have to go through all the parameters at the top of the screen again. These seldom change. You can avoid that by hitting the up arrow on your cursor pad instead. You can then move up to the entries shown, that we are interested in.

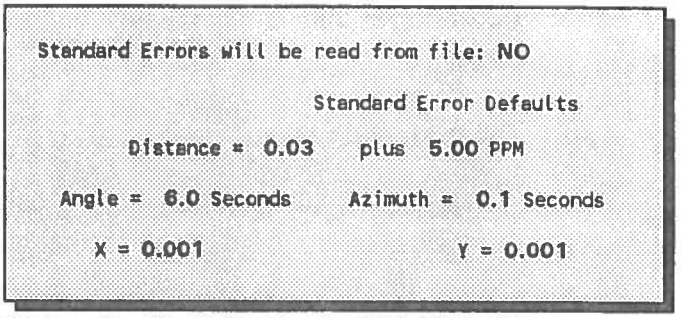


Figure 7 - Error estimate definition

3) The first new question here is at the top:

Standard errors will be read from file: ***NO***

At this time ***N*** for No is the best answer. The choice here is between supplying general error estimates that are going to apply to all of you angles, distances, etc.. If you answered ***yes*** here the rest of the screen below will disappear since the defaults are no longer needed. To define individual errors another file has to exist that contains the individual error numbers. That file is produced by a program called **SD**. We will experiment with that later.

4) Now you are into the actual error estimate screen, you can select each prompt in turn. Remember these are default values that will be applied to all such measurements in this project.

Distance = ***0.03*** plus ***5.00*** PPM

The distance error is not too difficult to come up with in EDM work. This estimate assumes a normal EDM error specification. Note that the units here are in feet. If you were in a metre based NAD83 SP Zone it would be metres. If you know you have large setup error, and you only guess at the EDM's environmental PPM correction, or have plumbing error or use a hand held prism, you would be wise to make this value a little higher. It is just a reasonable judgement by you of how good you think your measurements are. The distance error is in 2 parts as you see, a base absolute error plus a Parts per Million (PPM) portion. This will make the final error estimate over a long line larger than a short line.

5)

Angle = ***6.0*** Seconds

This estimate represents how good you think your angles are on the average. In this case I have a feeling that I can turn pretty good angles, most of the setups are good, and we have long enough sights, and the instrument is of the typical Total Station T1 class.

6) The next value is:

Azimuth = ***0.1*** Seconds

This is the estimate for all your Azimuth determinations, such as Solars, Polaris observations, etc. There are two ways to handle this. You can put in a realistic estimate. For example, the average solar is probably in the 15-20 second range, but if we only have 1 observation setting the error to 0.1 (you can't set these to zero) will essentially hold all the Solars. You may want to experiment with both approaches. Because this job only has one Solar it will be held no matter what. The most logical approach from a statistical approach is to put in the most realistic value. The least squares will then use it to the degree it merits 'averaging' the effect of all your observations.

7) The next values represent the positional error estimates that apply to your control points. They also are in the base units for the projection you are using, in this case feet. The 0.001 values mean hold the control (so it can't move). Remember that you can have more than one control point in a job and if you choose, you can set weights on them. This may seem a little odd at first. Usually we think of control as absolute and always hold it as the truth, but this is not always justified. Errors and distortion in the NAD27 network are frequently greater than common modern survey practice. Thus holding such points fixed could distort your measurements to an unacceptable degree. Other control that can be weighted would be some GPS and doppler positions.

Since we only have one control point, it doesn't matter.

X = ***0.001*** Y = ***0.001***

8) Hitting the ***<F10>*** key accepts the data on this input screen and takes you to another. This screen should look like Figure 8 which follows on the next page. These parameters control what kind of output you will get from the Least Squares process. The first prompt:

Error Analysis: ***NO***

This prompt could be confusing. It is NOT asking if you want error analysis *period*, but what it defines is whether you want the program to compute error ellipses. Error ellipses describe positional error information rather than measurement error

information. There are 2 reasons to say "NO" to this. First of all, error ellipses give you information about absolute position error, and do not tell you much about relative measurement accuracy. In other words for what we want to do, they do not help much. Error ellipse information is always larger the farther away you go from your control. The second reason, is that this computation is intense, takes extra time and resources. **LSAQ** will give up even trying to compute it on large networks, and it won't be computed anyway.

9) Next we have:

Residual Printout Limits:

Distance = ***0.000***

Angle = ***0.000***

Azimuth = ***0.000***

taking these together. The program prints out a list of the residuals, again this is the difference between your measurement and the value that came out of the adjustment. In a large job there can be a lot of these, possibly thousands. You are generally only concerned with values that are large where the least squares is telling you something bad may be happening. These limits are a way to limit output to only residuals over what you set. For example, I could say I really don't care about residuals where the adjustment was less that 0.01 ft., and 1 second in angle and 2 seconds in azimuth. Leaving these at Zero's will print all residuals

10) Next prompt is:

List Adjusted Bearings & Distances: ***NO***

Determines whether the output reports all the bearings and distances after the adjustment. We usually say NO because the values are in GRID and don't mean that much to us anyway, besides taking up even more room on the disk.

11) Next prompt:

Update Coordinate File: ***YES***

Normally this is what you want to do, the goal of this process is to end up with the best coordinate values for the measurements you put in. Some times you may just be experimenting, adjusting weights, or looking for errors, and you already have an acceptable coordinate file. Saying NO would allow you to perform the computation and get the results of the analysis, but the *ANSWERS* will not be written to you official coordinate .COR file.

12) Last prompt is:

Readjust With Robusted Error Estimates: ***NO***

This can be important and you may select Yes or No. We will go through a YES session later. Also see a discussion of Robusting in Ray's explanation, and in the extra documentation in the Reference Section. This is one of the many error and small blunder detection techniques contained in CMM. For this run, we will say NO. If we say yes all that will happen is we will get asked a question about re-adjusting with new weights after the program has made its first run. We can still say No there.

13) We are now ready to proceed with the Least Squares Stuff. As soon as you hit the ***<F10>*** key the program **LSAQ** will run using the project parameters that are stored in the SEC26A.DEF file and the measurement data stored in the SEC26A.LSA file. The annotated screen I/O follows. **LSAQ** creates a complete report file with the ADJ extension, and the listing from it follow the screen dump.

```
COMPUTER PROGRAM LSAQ        VERSION 9-5-90

         PROJECT NAME IS SEC26A

ALL OBSERVATIONS ARE REDUCED TO THE NAD 27 DATUM
ALL LISTED MEASUREMENTS HAVE BEEN REDUCED TO GRID
61 COLORADO CENTRAL LAMBERT
INPUT NETWORK ELEVATION IS      6200.00 FT.

NUMBER OF CONTROL STATIONS =    1
NUMBER OF DISTANCES =   17
NUMBER OF ANGLES =   17
NUMBER OF AZIMUTHS =    1
TOTAL NUMBER OF STATIONS =   17

BANDWIDTH IS     5 STATIONS
BAND IS   5 STATIONS
NUMBER OF REQUIRED TERMS IN NORMAL EQUATIONS IS     397

RESULTS OF ITERATION  1

STATION          NORTHING (Y) UPDATE    EASTING (X) UPDATE
5                         -1.128               4.105
6                          1.398               4.398
4                          -.812               2.542
1000                       -.011                .001
3                          -.405               1.484
7                          1.408               4.651
8                          2.381               4.979
2                           .005                .001
1                           .000                .000
9                          3.808               5.259
10                         4.033               5.231
16                         2.432                .106
15                         4.134                .505
11                         4.128               3.448
12                         4.347               2.758
13                         4.630               1.565
14                         4.909                .670

STANDARD ERROR OF UNIT WEIGHT=    29.727
```

Tells you your project definition

See Ray's explanation to understand this

These are the coordinate residuals for the first iteration. These are as large as they are because GENER's estimates are crude.

```
RESULTS OF ITERATION  2

STATION          NORTHING (Y) UPDATE    EASTING (X) UPDATE
5                        -.002                  -.001
6                        -.002                   .000
4                        -.001                  -.001
1000                      .000                   .000
3                        -.001                   .000
7                        -.002                   .000
8                        -.003                   .001
2                         .000                   .000
1                         .000                   .000
9                        -.003                   .001
10                       -.003                   .002
16                        .000                   .001
15                        .000                   .002
11                       -.002                   .002
12                       -.002                   .002
13                       -.001                   .002
14                       -.001                   .002

STANDARD ERROR OF UNIT WEIGHT=      .988

DISTANCE RMS ERROR =       .009
MAXIMUM DISTANCE RESIDUAL 5               - 6
OF       .015

ANGLE RMS ERROR =        2.2 SECONDS
MAXIMUM ANGLE RESIDUAL 9               - 10
OF     3.9 SEC.

AZIMUTH RMS ERROR =         .0 SECONDS
MAXIMUM AZIMUTH RESIDUAL 1              - 1000
OF       .0 SEC.
UPDATING APPROXIMATE COORDINATES IN .LSA FILE
```

This indicates our estimates were reasonable, Values between 0.7 and 2.3 usually okay. On the average distances only had to change this much, looks pretty good. More info in file.

Average angle change, pretty good huh!

Azimuth is zero because we held it and only 1

Now let's look at the SEC26A.ADJ file. It has all the important information. Do not worry about missing anything that flies by when **GENER** or **LSAQ** run, it will be in the appropriate output file.

<File SEC26A.ADJ>

```
          PROJECT NAME IS SEC26A
     PARAMETRIC LEAST SQUARES ADJUSTMENT

 ALL OBSERVATIONS ARE REDUCED TO THE NAD 27 DATUM
 ALL LISTED MEASUREMENTS HAVE BEEN REDUCED TO GRID
 61 COLORADO CENTRAL LAMBERT

 INPUT NETWORK ELEVATION IS       6200.00 FT.

 NUMBER OF CONTROL STATIONS =     1
 NUMBER OF DISTANCES =    17
 NUMBER OF ANGLES =    17
 NUMBER OF AZIMUTHS =     1
 TOTAL NUMBER OF STATIONS =    17

                        RESULTS OF ADJUSTMENT

                                                STANDARD ERRORS   ERROR ELLIPSE INFO.
 STATION              ADJ. N (Y)    ADJ. E (X)    IN N    IN E     SU      SV      T

 5                    261071.178   1179827.577
 6                    260812.600   1177232.857
 .
 .
 .
 13                   256963.717   1174477.131
 14                   255929.896   1174375.051
```

RESIDUALS IN THE OBSERVATIONS

CONTROL POINT COORDINATES

STATION	NORTHING (Y) RESIDUAL	NORTHING (Y) EST. ERROR	EASTING (X) RESIDUAL	EASTING (X) EST. ERROR
1	.000	.001	.000	.001

MINIMUM DISTANCE RESIDUAL PRINTOUT = .000

DISTANCES

OCCUPIED STATION	SIGHTED STATION	DISTANCE	RESIDUAL	EST. ERROR
1	1000	6597.904	.000	.050
1	2	1118.423	-.003	.033
2	3	1531.390	-.004	.035
3	4	1120.731	-.004	.033
4	5	1579.817	-.004	.035
5	6	2607.581	.008	.038
6	7	256.199	-.001	.031
7	8	1073.885	.006	.033
8	9	1546.233	.007	.035
9	10	243.795	.006	.031
10	11	1931.159	.003	.036
11	12	795.320	.004	.032
12	13	1356.082	.004	.034
13	14	1038.852	.004	.033
14	15	846.653	-.006	.033
15	16	1858.651	-.007	.036
16	1	2618.079	-.008	.038

DISTANCE RMS ERROR = .005
MAXIMUM DISTANCE RESIDUAL 5 - 6 OF .008

MINIMUM ANGLE RESIDUAL PRINTOUT = .0 SECONDS

ANGLES

BACKSIGHT STATION	OCCUPIED STATION	FORESIGHT STATION	MEAS.	RESIDUAL (SECONDS)	EST. ERROR (SECONDS)
2	1	1000	16-26-59.9	.0	6.0
1	2	3	186- 2-12.0	-2.8	6.0
2	3	4	185-45- .0	-1.3	6.0
3	4	5	170-10-36.0	-.3	6.0
4	5	6	85-41-12.1	1.3	6.0
7	6	5	99-24- 2.9	-2.4	6.0
6	7	8	110-40-54.1	2.8	6.0
7	8	9	172-29-24.1	3.4	6.0
8	9	10	160- 0-54.1	4.2	6.0
9	10	11	103-43- 6.0	4.2	6.0
10	11	12	194- 5-12.0	2.2	6.0
11	12	13	175-53-18.0	1.4	6.0
12	13	14	183-51-24.0	.1	6.0
13	14	15	84-52- .0	-.8	6.0
14	15	16	180-53-53.9	-1.3	6.0
15	16	1	181-39-23.8	-2.4	6.0
16	1	2	83-35-41.9	-4.0	6.0

ANGLE RMS ERROR = 2.5 SECONDS
MAXIMUM ANGLE RESIDUAL 9 - 10 - 11
OF 4.2 SEC.
MINIMUM AZIMUTH RESIDUAL PRINTOUT = .0 SECONDS

```
                        AZIMUTHS

OCCUPIED          SIGHTED                MEASUREMENT    RESIDUAL  ERROR EST.
STATION           STATION                               (SECONDS) (SECONDS)

1                 1000                    13- 6-28.8        .0        .1

AZIMUTH RMS ERROR =          .0 SECONDS
MAXIMUM AZIMUTH RESIDUAL 1                    - 1000              OF       .0 SEC.


     STANDARD ERROR OF UNIT WEIGHT IS       1.039
      WITH     3 DEGREES OF FREEDOM

                              ** ** ** ** ** **
```

There is a lot of valuable information in this report.

* The Distance Residual list shows you how much the adjustment had to change each distance measurement. You can see for this good set, they are all less then the estimate that is next to them.

* The Angle residual list is similar. This data is not unusual. If you take a look at the paper in Appendix II, you will see the results from actual large Cadastral Surveys.

One of the reasons for considering this as a *non-adjustment* or a *User Accountable* adjustment is this habit it has of not changing the measurements in an unacceptable way. If the network can be solved for all it's conditions in such a way that no distance, angle azimuth etc. changed by more than what we thought was a reasonable estimate. This of course will not always be true, and it can tell you where you might have problems.

This is a simple loop, there is minimal redundancy, so there is minimal information available to help you locate errors, nevertheless let's introduce a large distance error into the file and see if we can find it.

Let's add 1 chain to the distance on line from station 10 to 11 making it 28.269 chains.

To do that we will use **GENER**, although if you are comfortable with an editor you may make the modification directly to the SEC26A.LSA file. The problem with that is that this file has to have everything in the right place. If it doesn't or a stray character gets into it, **GENER** will not like it. There is a solution to this you should be aware of, that is a program called **SETUP**. **SETUP** can be accessed through the Utilities Menu. It's purpose is to take a messed up .LSA file and reconstruct it into a proper format for **GENER**.

To do this it is easiest to use the editing capabilities in **GENER**. Select ***G*** from the Main Menu. The process is outlined on the following page.

```
COMPUTER PROGRAM GENER      VERSION 9-5-90

          PROJECT NAME IS SEC26A

DO YOU WANT TO INPUT NEW DATA OR EDIT EXISTING DATA? (Y/N):
Y                                                    Yes we are going to edit a line.

1-INPUT OR DELETE CONTROL POINTS
2-INPUT OR DELETE DISTANCES
3-INPUT OR DELETE ANGLES/ DISTANCES
4-INPUT OR DELETE AZIMUTHS OR BEARINGS
5-LIST CONTROL STATIONS AND COORDINATES
6-LIST DISTANCES
7-LIST ANGLES AND DISTANCES
8-LIST AZIMUTHS
9-VIEW/CHANGE CURRENT DISTANCE ENTRY/EDIT UNITS
10-CHANGE (EDIT) EXISTING DATA
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #
9                                                    Make sure to select units so we can
                                                     tell what we are looking at.

DISTANCE ENTRY/DISPLAY UNIT IS FEET

CHANGE UNITS (Y/N) ?
Y
DO YOU WANT DISTANCE ENTRY/DISPLAY UNIT TO BE
(1) FEET
(2) CHAINS
(3) METERS
PICK A #
2

DISTANCE ENTRY/DISPLAY UNIT IS CHAINS

1-INPUT OR DELETE CONTROL POINTS
2-INPUT OR DELETE DISTANCES
3-INPUT OR DELETE ANGLES/ DISTANCES
4-INPUT OR DELETE AZIMUTHS OR BEARINGS
5-LIST CONTROL STATIONS AND COORDINATES
6-LIST DISTANCES
7-LIST ANGLES AND DISTANCES
8-LIST AZIMUTHS
9-VIEW/CHANGE CURRENT DISTANCE ENTRY/EDIT UNITS
10-CHANGE (EDIT) EXISTING DATA                       This entry is good for almost every change
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #
10
(1) CHANGE CONTROL INFORMATION
(2) CHANGE DISTANCE INFORMATION
(3) CHANGE ANGLE AND DISTANCE INFORMATION
(4) CHANGE AZIMUTH INFORMATION
(5) QUIT
SELECT A #
2
DO YOU WANT TO LIST INFORMATION (Y/N)                List to find the data, guess where it is.
Y
TOTAL NUMBER OF THIS MEASUREMENT TYPE IS    17
INPUT MINIMUM LIST #
8
INPUT MAXIMUM LIST #
12

NUMBER OF DISTANCES IS  17

LIST#       OCCUPIED              SIGHTED              DISTANCE
   8    7                     8                        16.276
   9    8                     9                        23.435
  10    9                     10                        3.695
  11    10                    11                       29.269    <<-This is it distance #11.
  12    11                    12                       12.054
PRESS ENTER TO CONTINUE
```

```
INPUT LIST # TO EDIT (ZERO IF FINISHED WITH EDIT OPTION):
11                                                    Select distance #11 to change
(1) OCCUPIED STATION = 10                             Program shows us each part
(2) SIGHTED STATION = 11
(3) DISTANCE =        29.269
(4) QUIT
SELECT A #
3
INPUT NEW DISTANCE (ZERO IF NO CHANGE)
28.269                                                Change it! This could have been used to fix
(1) OCCUPIED STATION = 10                             this as well as mess it up.
(2) SIGHTED STATION = 11
(3) DISTANCE =        28.269
(4) QUIT
SELECT A #
4
DO YOU WANT TO LIST INFORMATION (Y/N)
N
INPUT LIST # TO EDIT (ZERO IF FINISHED WITH EDIT OPTION):
0                                                     Now, we just get out of here and run the file.
(1) CHANGE CONTROL INFORMATION
(2) CHANGE DISTANCE INFORMATION
(3) CHANGE ANGLE AND DISTANCE INFORMATION
(4) CHANGE AZIMUTH INFORMATION
(5) QUIT
SELECT A #
5

1-INPUT OR DELETE CONTROL POINTS
2-INPUT OR DELETE DISTANCES
3-INPUT OR DELETE ANGLES/ DISTANCES
4-INPUT OR DELETE AZIMUTHS OR BEARINGS
5-LIST CONTROL STATIONS AND COORDINATES
6-LIST DISTANCES
7-LIST ANGLES AND DISTANCES
8-LIST AZIMUTHS
9-VIEW/CHANGE CURRENT DISTANCE ENTRY/EDIT UNITS
10-CHANGE (EDIT) EXISTING DATA
11-QUIT DATA ENTRY AND GENERATE APPROXIMATE COORDINATES
CHOOSE A #
11
DO YOU WANT TO USE EXISTING COORDINATES (Y/N)?
N

STATION  2              HAS COORDINATES GENERATED BY ANGLE    AND DISTANCE
FROM KNOWN BACKSIGHT
NORTHING (Y) =    256809.652 EASTING (X) =   1179377.412

TRAVERSE CLOSURE REPORT                               Closure now shows up not so good!
ERROR IN NORTHING =   62.551 ERROR IN EASTING =   -18.469

LINEAR ERROR OF CLOSURE IS       65.220 FT.

PRECISION IS 1/         312.

ANGULAR CLOSURE IS         9. SECONDS
CLOSURES REFLECT ANGULAR ADJUSTMENT

STATION            NORTHING (Y)      EASTING (X)
1                     255737.008     1179694.126
.
.(we won't waste space showing bad coordinates)
.
2                     256809.652     1179377.412
DIRECTION ASSUMPTION HAS BEEN CORRECTED
```

```
<File SEC26A.GEN>
          PROJECT NAME IS SEC26A

 STATION  2                HAS COORDINATES GENERATED BY ANGLE    AND DISTANCE
 FROM KNOWN BACKSIGHT
 NORTHING (Y) =    256809.652 EASTING (X) =   1179377.412

 TRAVERSE CLOSURE REPORT
 ERROR IN NORTHING =   62.551 ERROR IN EASTING =   -18.469

 LINEAR ERROR OF CLOSURE IS       65.220 FT.

 PRECISION IS 1/         312.

 ANGULAR CLOSURE IS         9. SECONDS
 CLOSURES REFLECT ANGULAR ADJUSTMENT

 STATION            NORTHING (Y)      EASTING (X)
 1                     255737.008     1179694.126
 16                    255272.246     1177116.718
 .(we won't waste space showing bad coordinates)
 .
 2                     256809.652     1179377.412

 FINAL GENERATED COORDINATES
 STATION               NORTHING (Y)     EASTING (X)
 1                       255737.008     1179694.126
 1000                    262163.010     1181190.447
 2                       256853.530     1179628.926
 .
 .(we won't waste space showing bad coordinates)
 16                      255868.878     1177078.472

 DISTANCE RESIDUALS
            DISTANCE                    RESIDUAL

 1                - 1000                   .000
 1                - 2                      .000
 2                - 3                     4.578
 3                - 4                     3.295
 4                - 5                     4.743
 5                - 6                     -.941
 6                - 7                      .751
 7                - 8                      .289
 8                - 9                     -.232
 9                - 10                    -.304
 10               - 11                   -6.337
 11               - 12                   -2.682
 12               - 13                   -4.609
 13               - 14                   -3.504
 14               - 15                    -.340
 15               - 16                    -.840
 16               - 1                     -.897

 ANGLE RESIDUALS
                    ANGLE                                RESIDUAL (SEC)
 2                - 1                - 1000                      .0
 1                - 2                - 3                      1237.4
 2                - 3                - 4                       -65.8
 3                - 4                - 5                       112.9
 4                - 5                - 6                       679.0
 7                - 6                - 5                       521.3
 6                - 7                - 8                       515.0
 7                - 8                - 9                         7.0
```

```
8                - 9              - 10                -36.3
9                - 10             - 11               -684.8
10               - 11             - 12                161.6
11               - 12             - 13                -47.0
12               - 13             - 14                 44.1
13               - 14             - 15               -758.8
14               - 15             - 16                   .7
15               - 16             - 1                   1.8
16               - 1              - 2                -636.5

AZIMUTH RESIDUALS
          AZIMUTH                          RESIDUAL (SEC)
1                - 1000                           .0
```

As you can see the GENER residuals have started to go bananas, there is some very small indication that there may be a problem as the worst residual is on the distance where we messed things up, but there is nothing definitive here, we could just as well have some angle errors. Lets go ahead and try an adjustment to see if that analysis will tell us any more.

```
<File SEC26A.ADJ>
          PROJECT NAME IS SEC26A

     PARAMETRIC LEAST SQUARES ADJUSTMENT

 ALL OBSERVATIONS ARE REDUCED TO THE NAD 27 DATUM
 ALL LISTED MEASUREMENTS HAVE BEEN REDUCED TO GRID
 61 COLORADO CENTRAL LAMBERT

 INPUT NETWORK ELEVATION IS       6200.00 FT.

 NUMBER OF CONTROL STATIONS =     1
 NUMBER OF DISTANCES =    17
 NUMBER OF ANGLES =    17
 NUMBER OF AZIMUTHS =     1
 TOTAL NUMBER OF STATIONS =    17

                      RESULTS OF ADJUSTMENT

                                                STANDARD ERRORS  ERROR ELLIPSE INFO.
 STATION            ADJ. N (Y)    ADJ. E (X)    IN N    IN E    SU      SV      T

 5                  261065.065  1179812.301
 6                  260786.196  1177219.873
 4                  259487.689  1179859.020
 1000               262162.999  1181190.448
 3                  258380.047  1179698.483
 7                  261031.723  1177151.445
 8                  261126.712  1176082.223
 2                  256851.940  1179629.020
 1                  255737.008  1179694.126
 9                  261061.262  1174537.650
 10                 260968.471  1174311.934
 16                 255880.867  1177079.455
 15                 255929.005  1175221.009
 11                 259122.190  1174589.707
 12                 258329.252  1174511.859
 13                 256972.037  1174474.406
 14                 255936.522  1174374.078
```

RESIDUALS IN THE OBSERVATIONS

CONTROL POINT COORDINATES

STATION	NORTHING (Y) RESIDUAL	NORTHING (Y) EST. ERROR	EASTING (X) RESIDUAL	EASTING (X) EST. ERROR
1	.000	.001	.000	.001

MINIMUM DISTANCE RESIDUAL PRINTOUT = .000

DISTANCES

OCCUPIED STATION	SIGHTED STATION	DISTANCE	RESIDUAL	EST. ERROR
1	1000	6597.904	.000	.073
1	2	1118.423	1.592	.046
2	3	1531.390	1.705	.048
3	4	1120.731	1.516	.046
4	5	1579.817	1.750	.048
5	6	2607.581	.198	.053
6	7	256.199	1.315	.041
7	8	1073.885	.451	.045
8	9	1546.233	.274	.048
9	10	243.795	-.250	.041
10	11	1865.179	-1.880	.049
11	12	795.320	-1.431	.044
12	13	1356.082	-1.650	.047
13	14	1038.852	-1.512	.045
14	15	846.653	-.312	.044
15	16	1858.651	-.418	.049
16	1	2618.079	-.547	.053

DISTANCE RMS ERROR = 1.190
MAXIMUM DISTANCE RESIDUAL 10 - 11 OF 1.880

MINIMUM ANGLE RESIDUAL PRINTOUT = .0 SECONDS

ANGLES

BACKSIGHT STATION	OCCUPIED STATION	FORESIGHT STATION	MEAS.	RESIDUAL (SECONDS)	EST. ERROR (SECONDS)
2	1	1000	16-26-59.9	.0	6.0
1	2	3	186- 2-12.0	331.3	6.0
2	3	4	185-45- .0	381.2	6.0
3	4	5	170-10-36.0	431.9	6.0
4	5	6	85-41-12.1	467.7	6.0
7	6	5	99-24- 2.9	-117.1	6.0
6	7	8	110-40-54.1	114.6	6.0
7	8	9	172-29-24.1	-24.4	6.0
8	9	10	160- 0-54.1	-230.6	6.0
9	10	11	103-43- 6.0	-262.9	6.0
10	11	12	194- 5-12.0	-275.3	6.0
11	12	13	175-53-18.0	-306.7	6.0
12	13	14	183-51-24.0	-347.8	6.0
13	14	15	84-52- .0	-388.6	6.0
14	15	16	180-53-53.9	-276.7	6.0
15	16	1	181-39-23.8	-32.0	6.0
16	1	2	83-35-41.9	310.2	6.0

```
ANGLE RMS ERROR =      289.6 SECONDS
MAXIMUM ANGLE RESIDUAL 4                  - 5                  - 6
OF   467.7 SEC.

MINIMUM AZIMUTH RESIDUAL PRINTOUT =          .0 SECONDS

                         AZIMUTHS

OCCUPIED          SIGHTED                MEASUREMENT    RESIDUAL  ERROR EST.
STATION           STATION                               (SECONDS) (SECONDS)

1                 1000                    13- 6-28.8         .0        .1

AZIMUTH RMS ERROR =          .0 SECONDS
MAXIMUM AZIMUTH RESIDUAL 1                   - 1000               OF      .0 SEC.


    STANDARD ERROR OF UNIT WEIGHT IS     130.180
     WITH     3 DEGREES OF FREEDOM
```

Note again that the residual on the bad distance is the worst, but we also have some real bad angle residuals. What is happening is that the traverse is being warped all over the place by the distance blunder, but we know we have a blunder and we see from the out put report on the next page that we can't really tell much about where the error is. The reason for this is that we have just a simple loop with very little redundancy. In other words there is not enough information to definitively find the error. We will try a few other of the tools in the system, but in this case we will not find much.

There are many other tricks that can be used to find errors in the data. Some of these we will look at later when we have enough redundancy to make it worthwhile. The best solution, if you cannot find the error by going over your field data, is to get more measurements, run more line, take more Solars or something.

One program in the system which is designed to find BIG errors (blunders) in LSA files is called **BLUNDER**. This program applies several methods to locate large distance or angle errors in loops. In the future, additional blunder detection methods will be added to this program, for now the distance routine has trouble on cardinal sided loops. If you have a lot of north-south lines and a distance error on one of them the program has difficulty determining which one. The **BLUNDER** program is run from the ***Utilities Menu***. This menu is user (you) customizable, so the items may appear in different order than shown here.

1) Select the Utilities Menu from the Main Menu with ***U***.

2) Select **BLUNDER** from the Utilities menu by finding it's listing either with the light bar and (enter) or by typing the menu letter next to it.

```
COMPUTER PROGRAM BLUNDER - VERSION 8-2-1990

          PROJECT NAME IS SEC26A

INPUT INITIAL STATION (ZERO IF FINISHED)
1
POSSIBLE NEXT STATIONS
  1)  1000
  2)  2
  3)  16
PICK THE # ASSOCIATED WITH THE NEXT STATION (ZERO TO QUIT)
2
NEXT STATION IS 2
NEXT STATION IS 3
NEXT STATION IS 4
NEXT STATION IS 5
NEXT STATION IS 6
.
.
.
NEXT STATION IS 16
NEXT STATION IS 1

ANGLE BLUNDER DETECTION
ANGLE NOT USED AT STA.       RESULTING LINEAR CLOSURE
1                                  65.702
2                                  65.697
3                                  65.684
4                                  65.670
5                                  65.661
6                                  65.775
7                                  65.776
8                                  65.822
9                                  65.889
10                                 65.899
11                                 65.900
12                                 65.908
13                                 65.919
14                                 65.930
15                                 65.894
16                                 65.814

WITH ANGLE AT STATION 5
NOT USED PRECISION IS 1/         326

WITH ANGLE AT STATION 4
NOT USED PRECISION IS 1/         326

THESE ARE THE TWO BEST PRECISIONS
INDICATES NO ANGLE BLUNDER ISOLATED

DISTANCE BLUNDER DETECTION
        DISTANCE                    CLOSURE
8               -9                  187.480
9               -10                 191.505

9               -10                   .329
10              -11                 65.976 <--

10              -11                 67.509 <--
11              -12                   1.660

11              -12                 165.094
12              -13                 229.504

12              -13                 241.570
13              -14                 177.136

13              -14                  65.351
14              -15                  16.351
```

We have to define a loop, we only have one here
Any point would do in this case.
The program is helping us define the loops
by showing what points connect to 1
We decide to go north

The program finds the traverse and will only stop and give you choices if there is a branch to go two ways. So this single loop just zips through.

The program then figures closures by holding out 1 angle each in turn

The fact that these are all the same indicates that we do not have any significant angle error, it's distance.

Now the program goes around the loop holding out a couple of distances and doing an bearing-bearing intersection to the point

Look for errors of the loop closure magnitude where the two adjacent sets give about the same magnitude for the same line.
Like here!!

This won't always work and the program doesn't see it.

```
14              -15                2455.866
15              -16                4160.703

15              -16                1486.192
16              -1                 2244.706

16              -1                    6.168
1               -2                   64.727

1               -2                  122.964
2               -3                   57.870

2               -3                  192.202
3               -4                  128.436

3               -4                   48.069
4               -5                  112.519

4               -5                   65.769
5               -6                    8.160

5               -6                    7.666
6               -7                   66.591   <--  This could have been it too!

6               -7                   68.197   <--
7               -8                    8.093

7               -8                  500.160
8               -9                  488.359

NO DISTANCE BLUNDER ISOLATED
                SMALLEST CLOSURES
     DISTANCE                       CLOSURE
8               -9                  488.359
7               -8                  500.160
7               -8                    8.093

INPUT INITIAL STATION (ZERO IF FINISHED)
0
```

BLUNDER tells us a little, but is not definitive. It looks like we have a distance error and it could be at line 10-11 or maybe line 6-7. Another way to try to find this error is to use **LSAQ**. We already ran it a while ago, but what happened is that we had a distance error estimate that was very tight (0.03') and the adjustment attempted to maintain that rigidity and warped the angles because they were not estimated as rigid. Let's change that and see what happens. This is ONLY for error detection. It is not valid to make incorrect estimates for your final work, and the Least Squares will tell us we made bad estimates.

Make the ***A (Adjust LSAQ)*** selection from the Main Menu.

To change the distance error estimate: hit ***<F2>*** at the adjustment parameter screen. Move the cursor up to the Distance error estimate prompt and enter:

0.5

Then exit with ***<F10>*** through the next screen to run LSAQ.

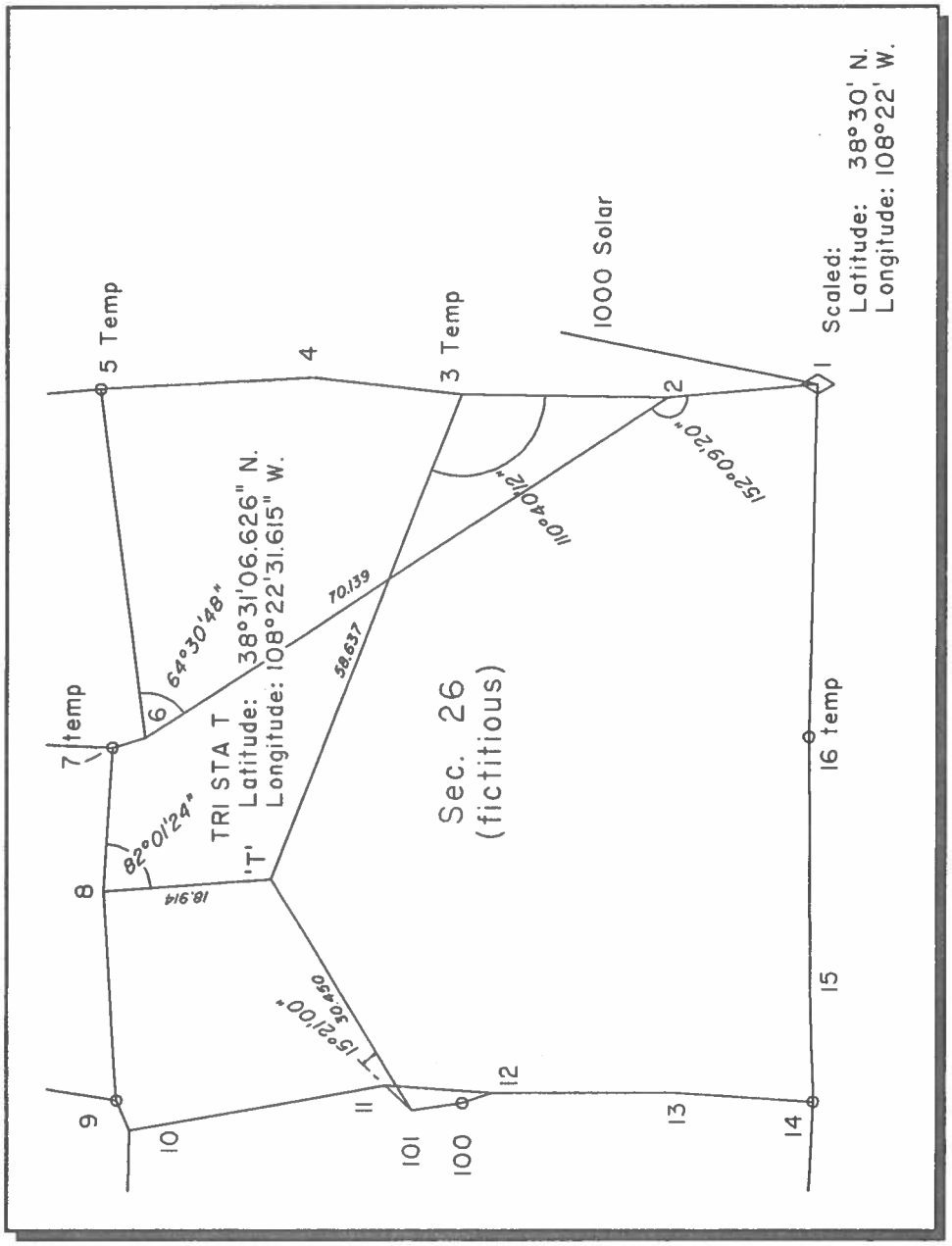
Now let's look at the output file:

```
<File: Sec26A.ADJ>
          PROJECT NAME IS SEC26A
     PARAMETRIC LEAST SQUARES ADJUSTMENT

 ALL OBSERVATIONS ARE REDUCED TO THE NAD 27 DATUM
 ALL LISTED MEASUREMENTS HAVE BEEN REDUCED TO GRID
 61 COLORADO CENTRAL LAMBERT

 INPUT NETWORK ELEVATION IS       6200.00 FT.

 NUMBER OF CONTROL STATIONS =     1
 NUMBER OF DISTANCES =    17
 NUMBER OF ANGLES =    17
 NUMBER OF AZIMUTHS =     1
 TOTAL NUMBER OF STATIONS =    17

                          RESULTS OF ADJUSTMENT
                                                STANDARD ERRORS  ERROR ELLIPSE INFO.
 STATION              ADJ. N (Y)    ADJ. E (X)    IN N    IN E    SU      SV      T

 5                    261043.281  1179826.208
 .
 .
 14                   255930.443  1174369.641


                          RESIDUALS IN THE OBSERVATIONS

                          CONTROL POINT COORDINATES

  STATION             NORTHING (Y)  NORTHING (Y)  EASTING (X)  EASTING (X)
                       RESIDUAL     EST. ERROR     RESIDUAL     EST. ERROR

 1                        .000          .001           .000          .001

 MINIMUM DISTANCE RESIDUAL PRINTOUT =        .000

                          DISTANCES

   OCCUPIED              SIGHTED               DISTANCE    RESIDUAL  EST. ERROR
   STATION               STATION

     1                   1000                 6597.904        .000      .533
     1                   2                    1118.423       7.118      .506
     2                   3                    1531.390       7.012      .508
     3                   4                    1120.731       6.729      .506
     4                   5                    1579.817       7.139      .508
     5                   6                    2607.581        .907      .513
     6                   7                     256.199       7.086      .501
     7                   8                    1073.885       2.262      .505
     8                   9                    1546.233       1.361      .508
     9                   10                    243.795      -1.134      .501
     10                  11                   1865.179      -7.299      .509
     11                  12                    795.319      -6.794      .504
     12                  13                   1356.082      -7.018      .507
     13                  14                   1038.852      -6.837      .505
     14                  15                    846.653      -1.642      .504
     15                  16                   1858.651      -1.787      .509
     16                  1                    2618.079      -2.021      .513

 DISTANCE RMS ERROR =      5.206
 MAXIMUM DISTANCE RESIDUAL 10               - 11              OF      7.299

 MINIMUM ANGLE RESIDUAL PRINTOUT =        .0 SECONDS
```

```
                              ANGLES

BACKSIGHT        OCCUPIED         FORESIGHT        MEAS.    RESIDUAL  EST. ERROR
STATION          STATION          STATION                   (SECONDS)  (SECONDS)

 2                1                1000             16-26-59.9     .0     6.0
 1                2                3               186- 2-12.0    12.3    6.0
 2                3                4               185-45-  .0    14.3    6.0
 3                4                5               170-10-36.0    16.3    6.0
 4                5                6                85-41-12.1    17.8    6.0
 7                6                5                99-24- 2.9    -5.1    6.0
 6                7                8               110-40-54.1     5.0    6.0
 7                8                9               172-29-24.1     .0     6.0
 8                9                10              160- 0-54.1    -7.5    6.0
 9                10               11              103-43- 6.0    -8.7    6.0
 10               11               12              194- 5-12.0    -9.4    6.0
 11               12               13              175-53-18.0   -10.6    6.0
 12               13               14              183-51-24.0   -12.3    6.0
 13               14               15               84-52-  .0   -13.9    6.0
 14               15               16              180-53-53.9    -9.9    6.0
 15               16               1               181-39-23.8    -1.0    6.0
 16               1                2                83-35-41.9    11.4    6.0

ANGLE RMS ERROR =       10.6 SECONDS
MAXIMUM ANGLE RESIDUAL 4                - 5                - 6
OF    17.8 SEC.

MINIMUM AZIMUTH RESIDUAL PRINTOUT =         .0 SECONDS

                            AZIMUTHS

OCCUPIED         SIGHTED              MEASUREMENT   RESIDUAL  ERROR EST.
STATION          STATION                            (SECONDS) (SECONDS)

1                1000                 13- 6-28.8        .0        .1

AZIMUTH RMS ERROR =         .0 SECONDS
MAXIMUM AZIMUTH RESIDUAL 1                - 1000             OF      .0 SEC.


    STANDARD ERROR OF UNIT WEIGHT IS     24.846
     WITH    3 DEGREES OF FREEDOM
```

Well what does that show? First is last, the angle residuals are looking better, and we see all the distance error being put on the N-S lines the most being on the line where the error occurred.

Now let's add more measurements to the loop, adding redundancy by sighting a tri station from several points, as well as turning in some intervisible points. The additional things we want to add are shown on the figure on the next page. This could just as easily be subdivision of section or other survey lines.



Additional measurements for Example 1

Note: this is the end of the dialog on the tutorial for Example 1, as of this Release.

Next, enter the additional data shown, rerun GENER, look at it's loop closures, run blunder with additional loops, run LSAQ with the 0.5 ft. distance float.

See if the additional traverse links and observations help locate our error. After LSAQ run the CHECKER program holding each 'corner' of the square to see if the area of the distance blunder starts to become more obvious.

You should also delete the original scaled control on station 1 and add the tri station values with GENER.

Chapter 6 - Reference

ADJUST

The purpose of **ADJUST** is to provide the Cadastral Surveyor with a comprehensive set of tools specifically for the "special case" adjustments often found in the PLSS. ***The Manual of Surveying Instructions, 1973*** describes a number of unusual boundary determination adjustment procedures that are not usually used in private sector work or dealt with in textbooks or available software. **ADJUST** provides solution for these methods, and another feature is the ability to manually perform single and double proportions which are also available in **PROPORT** and **AUTOPROP**. This is useful for simple one-shot computations, or unusual situations which do not lend themselves to the automated capabilities of the other programs. The functionality of **ADJUST** is analogous to that of **CSTUF** or **PROPORT**. The user interface and method of operation has been intentionally kept similar to maintain consistency where possible.

The routines in **ADJUST** have been designed to provide the maximum flexibility to the user while strictly conforming the guidelines set forth in ***The Manual of Surveying Instructions, 1973***. For example, the user is only allowed to perform double proportions geodetically; the '*Manual*' process requires proper allowance for cardinal equivalents of the record and cardinal offsets to determine the true position. These can only be performed within a geodetic or true bearing frame of reference.

There is no substitute for user accountability when using this program or any other program in the CMM software package. The user is also reminded to be aware of the approriate section of the *'Manual'*. For example:

> **5-21.** The rules for the restoration of lost corners should not be applied until all original and collateral evidence has been developed. When these means have been exhausted, the surveyor will turn to proportionate measurement, which harmonizes surveying practice with legal and equitable considerations. This plan of relocating a lost corner is always employed unless outweighed by conclusive evidence of the original survey.

ADJUST - AT A GLANCE

Program Function:
Miscellaneous PLSS Adjustment Routines

Computational Ability:
Geodetic and Plane

Routines:
North/South Single Proportion, East/West Single Proportion, Double Proportion, One Point Control, Two Point Control, Three Point Control, Irregular Boundary Adjustment, Grant Boundary Adjustment, Compass Rule Adjustment

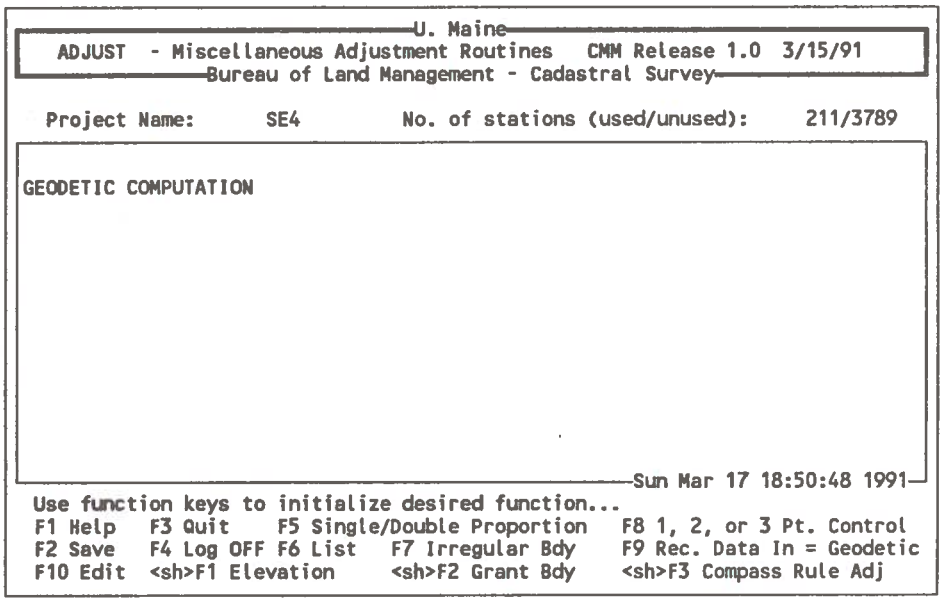


Figure 7.1 - ADJUST Main Screen

Function Keys and Operations:

HELP - F1:

Pressing the F1 key invokes the HELP screens for adjust. The user can then scan the various help screens by pressing the <Page Up> or <Page Dn> keys to find the desired topics. <Esc> exits from HELP and back to the operation where the user left off.

SAVE - F2:

By pressing the F2 key, the user will save all previously computed coordinates to the **.COR** file of the current job.

EXIT - F3:

Pressing the F3 key gives the user three options.

1) Quit <u>without</u> saving newly computed coordinates to the **.COR** file.

2) Quit <u>with</u> saving all newly computed coordinates to the current **.COR** file.

3) Cancel and return to **ADJUST**.

LOG ON/OFF - F4:

Pressing the F4 key allows the user to open a logfile for the purpose of providing a "hard copy" record of all operations performed and the results of these operations. The logfile is simply a DOS text file that all screen output is echoed to. The default logfile for **ADJUST** operations has the name 'Project.AJL' where 'Project' is the currently defined project name. If the user desires to write to this file, just hit <Enter> at the prompt. Otherwise the user may specify his or her own logfile name. If the logfile opened already exists, new output will be appended to it, existing data will not be overwritten.

SINGLE/DOUBLE PROPORTIONING - F5:

F5 will invoke the proportioning routines.

SINGLE PROPORTION - (*Manual* Section 5-30) Can be performed both geodetically and plane. The control points used must exist in the **.COR** file. Only one record distance is allowed from each control station to the reestablished point.

DOUBLE PROPORTION - (*Manual* Section 5-25) Can only be performed in geodetic mode. The four control points used must exist in the **.COR** file. Multiple record courses from each control point are allowed. To enter the record courses for each control leg, input the information asked for at the prompts. To end record input for any leg, enter the identification of the point being recovered that was previously input. **ADJUST** will then prompt for records for the next leg.

LIST - F6:

The F6 function key invokes the list routine. This allows the user to list the coordinates of points in the **.COR** file by either individual names or all the points between a certain pair of points. If geodetic mode is in effect, screen output will be in spherical coordinates (Latitude and Longitude) otherwise output will be in State Plane. If the logfile is active, all listed coordinates will be output to it. To list all points in a **.COR** file, use 0 and z as upper and lower limits respectively of the range.

IRREGULAR BOUNDARY ADJUSTMENT - F7:

Manual Section 5-36 describes an unusual adjustment process that is used to restore lost corners on irregular rectangular exteriors. It is in effect 2 adjustment procedures, 1 for E-W lines and 1 for N-S lines. F7 invokes the Irregular Boundary Adjustment. To begin, enter the starting and terminating control points of the adjustment (they must be resident in the **.COR** file). The record course data is then entered at the appropriate prompts. To end record input, enter the name of the terminating control station at the "To Station ?..." prompt. The adjustment will then proceed automatically. The first thing the user will see is a report of misclosure similar to the below. The program determines which of methodology to use based on the direction of the input record lines.

Report of Record Traverse Misclosure

Mean Geodetic Bearing to Closing Station: S 2°33'57" W
Ground Distance to Closing Station: 231.6252 Ft. at 1100 Ft. Elv.
Error in Latitude: 0° 0' 2.2840"
Error in Longitude: - 0° 0'.1489"
Error in State Plane Northing: 231.4168
Error in State Plane Easting: 9.3592

The misclosure statement gives the user a measure of how good (or bad) a record traverse was. The bearing and distance to the closing station is the direction and distance from the end of the record traverse and the terminating station it was supposed to end up on.

The rest of the information is the difference between the end of the traverse and the terminating control point in both spherical coordinates and State Plane Coordinates.

* The last thing output will be the adjusted record courses.

* The coordinates of the starting and terminating stations will not be altered.

ONE, TWO, and THREE POINT ADJUSTMENTS - F8:

To invoke either ONE, TWO, or THREE point adjustment routines simply hit <F8> and enter the required control points at the prompt '*Control Station #x*'. If no morecontrol points are needed, hit <Enter> at this prompt and the adjustment will begin to prompt you for record data.

ONE POINT CONTROL: One point control a method of restoration where the record from only one direction is used. (see *Manual* Section 5-45). **ADJUST** provides a traversing routine where an "index correction" may be applied to either the bearing and/or the distance of the records entered. Index corrections are rarely applied unless it is clear from the retracement of many other lines that there is a consistent bias to the original record. The bearing index correction is a value added or subtracted to the bearing of a record course. The distance index correction is a scale factor that is multiplied to the distance of a record course. This is accomplished by entering an @ symbol at either the *'Bearing From < ?> ?...'* prompt or the *'Distance from < ?> ?...'*. The adjustment will then prompt the user to input a proper correction value. This correction factor will be echoed at the top of the screen and applied to all successive record courses. If the user desires to negate the effects of the index correction, use the @ symbol at the aforementioned prompts and enter 0 to negate the bearing index correction and enter 1.0 to negate the distance correction factor.

NOTE: The index correction function is available for use in all routines.

TWO POINT CONTROL: (Refer to Section 5-29 of the *Manual*) Two point control is invoked by pressing <F8>, entering two control points at the appropriate prompts, and hitting <Enter> at the prompt for the third control point. After the ID of the position to be reestablished is entered, the routine will prompt for record traverse courses from each control point. To end record input for each traverse leg, enter the ID of the position to be reestablished at the station input prompt. After all record data is input, the adjustment will proceed automatically. All intermediate traverse stations (stations between each control point and the reestablished position) will not be saved in the **.COR** file.

THREE POINT CONTROL: (Refer to Section 5-29 of the *Manual*) Three point control is invoked by pressing <F8> and entering all three control points in any order. The program will automatically determines which two control points are proportioned from and which control point is traversed from. This is accomplished by examining the azimuths between the three control points. The control points with an azimuth that is $\pm 20°$ of a cardinal direction are the points used for proportioning. The third control is traversed from. If there exists no azimuth that is $\pm 20°$ of a cardinal direction, the three point routine will cease with an error message. The three point routine will then prompt for record data from the two proportioning control points. Multiple record courses are

allowed for the single proportion. To end record input for the proportioning, enter the ID of the position to be reestablished. The intermediate proportioned points coordinates will then appear on the screen and the record traverse data will be prompted for from the third control point. Again, to end record input, enter the ID of the position that is being reestablished. No intermediate record traverse or proportion station coordinates will be saved to the **.COR** file.

GEODETIC/PLANE - F9:

The F9 key brings up a menu that allows the user to change the type of record data being input between GEODETIC record data and PLANE record data. When you first start **ADJUST**, the default mode is GEODETIC.

EDIT - F10:

This function is not available for CMM release 1.0. When it does become available, it will allow the user to edit record courses in the middle of an adjustment without having to reenter the whole record.

ELEVATION - <SHIFT>F1:

The default elevation for a project is defined in the **.DEF** file. During the course of running adjustment, it may be desirable to change the mean project elevation. The is accomplished by pressing the <SHIFT> and the F1 keys simultaneously. This will change the project elevation for the rest of the **ADJUST** session but will not change the mean project elevation in the **.DEF** file. The mean elevation cannot be changed in the middle of an **ADJUST** procedure. It must be done before the adjustment is started.

GRANT BOUNDARY ADJUSTMENT - <SHIFT>F2:

The grant boundary adjustment (*Manual* Section 5-44) can be invoked by pressing the <SHIFT> and the F2 keys simultaneously. The record data is then input identically to the irregular boundary adjustment. To end traversing, enter the ID of the terminating station. The first thing the user will see is the following misclosure report. The Grant boundary adjustment is designed to preserve the angles at each angle point in the boundary and a uniform scale factor is applied to all record distances to reach the found control point.

Report of Record Traverse Misclosure

Angular Correction to Record Bearings: - 0° 7' 4"
Scale Factor Applied to Record Distances: 0.956137
Error in Latitude: 0° 0' 2.2860"
Error in Longitude: - 0° 0'.1489"
Error in State Plane Northing: 231.2341 Ft.
Error in State Plane Easting: 9.3615 Ft.

The angular correction and the scale factor listed above are adjustment factors applied to each record bearing and distance. The rest of the misclosure listing is the difference between the ending point of the record traverse and the terminating station in both spherical and State Plane coordinates. The adjusted record courses are output to the screen immediately following this misclosure report.

COMPASS RULE ADJUSTMENT - <SHIFT> F3:

Manual Sections 5-43 describes a special adjustment which is labelled as the "Nonriparian meander line adjustement." As described it is the familiar compass rule. By pressing <SHIFT> and F3 simultaneously, the user can perform a compass rule adjustment. The input of record is made in and identical way as that in the Irregular Boundary and Grant Boundary adjustments.

Record traverse is performed between the starting and terminating control points input. For a closed traverse compass rule adjustment, enter the starting (and terminating) as the same point ID. The first thing output to the screen will be the report of record traverse misclosure similar to the one below.

Report of Record Traverse Misclosure

Mean Geodetic Bearing to Closing Station: N 37°50'17" W
Ground Distance to Closing Station: 0.8918 Ft. at 1100 Ft. Elv.
Sum of Record Traverse Distance: 2466.0500
Relative Error of Closure: 1:2765
Error In Latitude: - 0° 0' 0.0070"
Error In Longitude: - 0° 0' 0.0079"
Error In State Plane Northing: -0.7015 Ft.
Error In State Plane Easting: 0.5504 Ft.

The misclosure statement gives the user a measure of how good (or bad) a record traverse was. The bearing and distance to the closing station is the direction and distance from the end of the record traverse and the terminating station it was supposed to end up on.

The sum of the record traverse distance is the total of all record distances traversed for the adjustment in question. The relative error of closure is a general indicator of "how good a traverse closed". The smaller the number, the better the traverse fits the control. The rest of the information is the difference between the end of the traverse and the terminating control point in both spherical coordinates and State Plane Coordinates. Following the Report of Record Traverse Misclosure, is the summary of adjusted record courses based on the adjusted coordinates. The coordinates of the starting and terminating stations will not be altered.

ADDITIONAL KEYS:

PAGE DOWN - Allows the user to review past screen output one screen at a time

PAGE UP - Allows the user to move forward in screen output one screen at a time

UP ARROW - Allows the user to review past screen output one line at a time.

DOWN ARROW Allows the user to move forward in screen output one line at a time.

BACKSPACE - Allows the user to revise input before entering

GENERAL:

Distances can be entered in **ADJUST** in either units of chains or units of feet. To switch between the two units, inserting an f (or x after the record distance to change units from chains to feet or a c (or C) after the record distance to change units from feet to chains. This change is permanent until changed again and is reflected in the distance input prompts.

EXAMPLES: Following are example logfile outputs from **ADJUST** operations.

Double Proportion:

Scenario - Double proportion to reestablish corner 500600. Control station 500700 is controlling corner to the North, station 500500 is controlling corner to the South, station 600600 is controlling station to the East, and station 400600 is controlling corner to the west.

```
GEODETIC COMPUTATION

Single or Double Proportionment
At Elevation:     1100.00

Double  Proportion

500700
   (forward)        S  0° 0' 0" E
   (mean)           S  0° 0' 0" E      1320.0000 ft.       20.00000 ch.
   (reverse)        N  0° 0' 0" E
A
   (forward)        S  0° 1' 0" E
   (mean)           S  0° 1' 0" E      1320.0000 ft.       20.00000 ch.
   (reverse)        N  0° 1' 0" W
B
   (forward)        S  0° 1' 5" W
   (mean)           S  0° 1' 5" W      1320.0000 ft.       20.00000 ch.
   (reverse)        N  0° 1' 5" E
C
   (forward)        S  0° 0' 3" E
   (mean)           S  0° 0' 3" E      1320.0000 ft.       20.00000 ch.
   (reverse)        N  0° 0' 3" W
500600

500500
   (forward)        N  0° 0' 0" E
   (mean)           N  0° 0' 0" E      2640.0000 ft.       40.00000 ch.
   (reverse)        S  0° 0' 0" E
A
   (forward)        N  0° 0' 0" E
   (mean)           N  0° 0' 0" E      2640.0000 ft.       40.00000 ch.
   (reverse)        S  0° 0' 0" E
500600

600600
   (forward)        N 89°59'53" W
   (mean)           S 90° 0' 0" W      1320.0000 ft.       20.00000 ch.
   (reverse)        N 89°59'53" E
A
   (forward)        N 89°59'53" W
   (mean)           S 90° 0' 0" W      1320.0000 ft.       20.00000 ch.
   (reverse)        N 89°59'53" E
B
   (forward)        N 89°59'53" W
   (mean)           S 90° 0' 0" W      1320.0000 ft.       20.00000 ch.
   (reverse)        N 89°59'53" E
C
   (forward)        N 89°59'55" W
   (mean)           S 89°59'58" W      1320.0000 ft.       20.00000 ch.
   (reverse)        N 89°59'51" E
500600
```

```
400600
   (forward)        N 89°59'46" E
   (mean)           S 90° 0' 0" E      2640.0000 ft.       40.00000 ch.
   (reverse)        N 89°59'46" W
A
   (forward)        N 89°59'46" E
   (mean)           S 90° 0' 0" E      2640.0000 ft.       40.00000 ch.
   (reverse)        N 89°59'46" W
500600
  Record Σ LATs from 500500 to 500700:   160.000 ch.
Measured Σ LATs from 500500 to 500700:   152.982 ch.
  Record Σ DEPs from 400600 to 600600:   160.000 ch.
Measured Σ DEPs from 400600 to 600600:   158.929 ch.

Proportioned Position: 500600
 Latitude:   46°45' 3.2345"
Longitude:   88°24'25.5163"
 Northing:    1914203.9312
  Easting:     585957.5139
```

Two Point Control:

Scenario - Two point control is to be used to reestablish corner 500600. Corner 500500 is the controlling corner to the South and 600600 is the controling corner to the East.

```
GEODETIC COMPUTATION

1, 2, or 3 Point Control Adjustment
At Elevation:     1100.00
Two Point Control
500500
   (forward)        N  1°10' 5" E
   (mean)           N  1°10' 5" E      2640.0000 ft.       40.00000 ch.
   (reverse)        S  1°10' 5" W
A
   (forward)        N  0° 0' 2" E
   (mean)           N  0° 0' 2" E      2640.0000 ft.       40.00000 ch.
   (reverse)        S  0° 0' 2" W
500600

600600
   (forward)        N 89°59'46" W
   (mean)           S 90° 0' 0" W      2640.0000 ft.       40.00000 ch.
   (reverse)        N 89°59'46" E
A
   (forward)        N 89° 2'27" W
   (mean)           N 89° 2'34" W      1320.0000 ft.       20.00000 ch.
   (reverse)        S 89° 2'41" E
B
   (forward)        S 89°57'36" W
   (mean)           S 89°57'29" W      1320.0000 ft.       20.00000 ch.
   (reverse)        N 89°57'22" E
500600

Reestablished Position:  500600
             Latitude:   46°45' 5.4855"
            Longitude:   88°24'25.6743"
             Northing:    1914431.9139
              Easting:     585945.5211
```

Grant Boundary Adjustment:

Scenario - A Grant Boundary adjustment is required for record data between control stations 600400 and 700400.

```
GEODETIC COMPUTATION

Grant Boundary Adjustment
At Elevation:     1100.00
600400
   (forward)        N 80° 1'19" E
   (mean)           N 80° 1'23" E       789.2300 ft.       11.95803 ch.
   (reverse)        S 80° 1'27" W
A
   (forward)        S 75°23'50" E
   (mean)           S 75°23'45" E       924.1100 ft.       14.00167 ch.
   (reverse)        N 75°23'40" W
B
   (forward)        N 89°21'55" E
   (mean)           N 89°22' 1" E      1203.3400 ft.       18.23242 ch.
   (reverse)        S 89°22' 7" W
C
   (forward)        N 68° 1' 0" E
   (mean)           N 68° 1' 1" E       233.2300 ft.        3.53379 ch.
   (reverse)        S 68° 1' 2" W
D
   (forward)        S 75°11' 1" E
   (mean)           S 75°10'55" E      1111.2200 ft.       16.83667 ch.
   (reverse)        N 75°10'49" W
E
   (forward)        N 74°24'54" E
   (mean)           N 74°25' 0" E      1125.0100 ft.       17.04561 ch.
   (reverse)        S 74°25' 6" W
700400

          Report of Record Traverse Misclosure
          ------------------------------------
    Angular Correction to Record Bearings:    0°10'55"
 Scale Factor Applied to Record Distances:    1.000594
                     Error in Latitude:       0° 0' 0.1644"
                    Error in Longitude:       0° 0' 0.0454"
           Error in State Plane Northing:     16.6350 Ft.
            Error in State Plane Easting:     -3.2432 Ft.

Adjusted Courses

600400
   (forward)        N 80°12'13" E
   (mean)           N 80°12'18" E       789.6992 ft.       11.96514 ch.
   (reverse)        S 80°12'22" W
A
   (forward)        S 75°12'55" E
   (mean)           S 75°12'50" E       924.6593 ft.       14.00999 ch.
   (reverse)        N 75°12'46" W
B
   (forward)        N 89°32'49" E
   (mean)           N 89°32'56" E      1204.0553 ft.       18.24326 ch.
   (reverse)        S 89°33' 2" W
C
   (forward)        N 68°11'54" E
   (mean)           N 68°11'56" E       233.3686 ft.        3.53589 ch.
   (reverse)        S 68°11'57" W
D
   (forward)        S 75° 0' 6" E
   (mean)           S 75° 0' 0" E      1111.8805 ft.       16.84667 ch.
   (reverse)        N 74°59'55" W
E
   (forward)        N 74°35'49" E
   (mean)           N 74°35'55" E      1125.6787 ft.       17.05574 ch.
   (reverse)        S 74°36' 0" W
700400
```

Compass Rule Adjustment:

Scenario - A compass rule adjustment is required for a loop traverse starting and terminating at control point 700500

```
GEODETIC COMPUTATION

Compass Rule Adjustment
At Elevation:     1100.00
700500
   (forward)        N 26° 9'59" E
   (mean)           N 26°10' 0" E       285.1000 ft.        4.31970 ch.
   (reverse)        S 26°10' 1" W
A
   (forward)        S 75°25' 3" E
   (mean)           S 75°25' 0" E       610.4500 ft.        9.24924 ch.
   (reverse)        N 75°24'57" W
B
   (forward)        S 15°30' 1" W
   (mean)           S 15°30' 0" W       720.4800 ft.       10.91636 ch.
   (reverse)        N 15°29'59" E
C
   (forward)        N  1°42' 0" W
   (mean)           N  1°42' 0" W       203.0000 ft.        3.07576 ch.
   (reverse)        S  1°42' 0" E
D
   (forward)        N 53° 5'57" W
   (mean)           N 53° 6' 0" W       647.0200 ft.        9.80333 ch.
   (reverse)        S 53° 6' 3" E
700500

                Report of Record Traverse Misclosure
                ------------------------------------
 Mean Geodetic Bearing to Closing Station:    N 37°50'17" W
       Ground Distance to Closing Station:    0.8918 Ft. at 1100 Ft. Elv.
          Sum of Record Traverse Distance:    2466.0500
                Relative Error of Closure:    1:2765
                        Error In Latitude: -  0° 0' 0.0070"
                       Error In Longitude: -  0° 0' 0.0079"
             Error In State Plane Northing:   -0.7015 Ft.
              Error In State Plane Easting:    0.5504 Ft.

Adjusted Courses
700500
   (forward)        N 26° 8'52" E
   (mean)           N 26° 8'53" E       285.1452 ft.        4.32038 ch.
   (reverse)        S 26° 8'54" W
A
   (forward)        S 75°25'49" E
   (mean)           S 75°25'46" E       610.2751 ft.        9.24659 ch.
   (reverse)        N 75°25'42" W
B
   (forward)        S 15°31' 1" W
   (mean)           S 15°31' 0" W       720.3245 ft.       10.91401 ch.
   (reverse)        N 15°30'59" E
C
   (forward)        N  1°42'44" W
   (mean)           N  1°42'44" W       203.0593 ft.        3.07666 ch.
   (reverse)        S  1°42'44" E
D
   (forward)        N 53° 5'38" W
   (mean)           N 53° 5'40" W       647.2458 ft.        9.80676 ch.
   (reverse)        S 53° 5'43" E
700500
```

ARIZONA.EXE

ARIZONA is a basic program designed to convert files collected with the BLM custom CO-OP41 data collection system as designed by Olian Shockley of the Arizona office. This data collection system provides up to 3 files, a coordinate file, an ascii description file and a raw data file. The file of interest here is the 'RAW' data file transfered from the data collector to the PC. This file has a **.41R** extension. The formats are similar to the commercial CO-OP format but are not exactly the same.

File Format

The file that is transferred from the CO-OP41 has the extension **.41R**. This distinguishes it from the coordinate file which has the extension **.41S**. This file is a list of short lines that contain data as indicated by the following:

Typical 41R data file structure:

Line	What it contains
000	Latitude (HMS) for curvature corr.
001	Angle repetitions
002	Initial back azimuth (HR)
003	±Beginning latitude (CH)
004	±Beginning departure (CH)
005	Date (M/D/Y)
006	Sequential point number, X<0 if sideshot
007	Record pointer - matching text file description
008	Horizontal angle right (HR), X<0 if angle is mean of multiple angles.
009	First horizontal angle (HMS), if measured.
010	Last horizontal angle (HMS), if measured.
011	..Horizontal distance (CH)
012	Next sequential point number...

AUTOPROP.EXE

Autoprop is an extremely powerful proportioning program. It requires creation of a REC file with **INREC** and controlling corner to be flagged standard corner names with **WHATIS**.

AUTOPROP is designed to automatically proportion and subdivide a township down to the level of center of quarter sections. The automatic capabilities of **AUTOPROP** are extremely useful in generating search coordinates, final positions for corners which need proportioning, and section subdivision. Unfortunately many jobs have peculiarities which cannot be identified automatically, and **AUTOPROP** could make an incorrect assumption in these situations. For this reason a user will need to use **PROPORT, ADJUST** and **CSTUF** in conjunction with **AUTOPROP**. This is also wise as a check.

While **AUTOPROP** uses only numeric Id's, there is a variety of situations where one can expand beyond Standard Id's. In this situation the user would create an irregular file

(.IRR) using **AUTOPROP**'s built in editor. This irregular file would contain user defined subdivisions which are not standard GCDB format.

AUTOPROP reads the **.DEF**, **.COR**, **.REC**, AND **.IRR** files. The output file is labeled with a **.SUB** file extension. The importance of the **.SUB** file cannot be emphasized enough - it is the surveyor's verification that the proportions and subdivisions were handled in what he or she deems a correct fashion.

AUTOPROP first allows the user to proportion all stations in the **.REC** file based on controlling information in the **.COR** file. If this computation is selected, **AUTOPROP** will single proportion stations on the cardinal exterior lines of the data (not necessarily a township line) in the **.REC** file. The remaining "interior" lines are then used in double proportion, followed by single proportion of anything which cannot be double proportioned. No generation of positions occurs outside of the controlling coordinates in the **.COR** file.

AUTOPROP has a unique fashion for identifying closing corners. Since closing corners are generally not used as controlling for single proportions on a township exterior, **AUTOPROP** will not use any station on the exterior as controlling which has a non-zero unit in the third digit for lines running E-W (199700 would not be used as controlling on a north edge of a township) or in the sixth digit for lines running N-S (100199 would not be used as controlling on a west edge of a township). **AUTOPROP** can handle closing corners on all 4 sides of a township.

To utilize closing corners when appropriate as controlling, **AUTOPROP** always searches for one station beyond a standard Id. on a line. For example, if **AUTOPROP** was computing the 200000 line and the largest station ID. in the line was 200640, the **.REC** file would be scanned for an additional line from 200640 to a station within 45 degrees of cardinal north. This would identify a closing line from 200640 to 199700 (a closing corner). The same methodology can be used on the smallest ID. end of a line. Closing lines to the south and east are also handled.

Once this part of **AUTOPROP** is complete, the user can selectively compute all quarter corners not in the **.REC** file (assumed geodetic midpoint between respective Standard Numbered section corners), center of sections, sixteenth corners on township and section lines, sixteenth corners inside sections, and centers of quarter sections. Again, the computation only proceeds if the appropriate controlling stations exist. When computing sixteenth corners inside sections, parenthetical distances are automatically identified and used by finding a 120xxx, 660xxx, xxx120, or xxx660 in the **.REC** file and traversing until an exterior line is reached. If one controlling parenthetical distance exists in the **.REC** file and the other does not, the non-existent one is assumed to be 20 chains.

In using this automatic subdivision, one can over-ride standard GCDB station ID.'s and define new point ID.'s at a midpoint between two user-defined stations. In utilizing the midpoint override the user inputs the station to be positioned and the two controlling stations. As an example, one could position 100140 between 100101 and 100203, or put in a new station 900900 between 200100 and 301100.

In computation of centers of sections or quarter sections one can substitute controlling

stations. As an example 100142 may be used in place of 100140 in determining 140140.

At the completion of **AUTOPROP**, the user has the option to leave the **.COR** and .GEO files unaltered, append all computed station Id.'s with a "T" (temp), or use the GCDB numbering unaltered. **AUTOPROP** will not use the stations appended with a "T" in a subsequent run.

The following is a sample dialog with **AUTOPROP**. In this sample case the 4 corners of the township have been flagged by **WHATIS** as found controlling corners.

```
VERSION 9-23-1990

THIS VERSION IS SUPPOSEDLY WORKING GEODETICALLY CORRECT ON A PROJECT ELEVATION

THIS VERSION IGNORES CLOSING STATIONS AS CONTROLLING ON TOWNSHIP EXTERIORS
THIS VERSION HANDLES CLOSING CORNERS ON ALL FOUR SIDES OF A TOWNSHIP

THIS VERSION ONLY USES EXTERIORS ON TOWNSHIPS FOR INITIAL SINGLE PROPORTION

THIS VERSION FINDS AND USES PARENTHETICALS IN .REC FILE

THIS VERSION ALLOWS INPUT OF STATION IDS WHICH OVER-RIDE STANDARD IDS IN PROPORTIONING.
YOU CAN ALSO STORE ADDITIONAL GEODETIC MIDPOINTS FOR 1/4 AND 1/16 CORNERS.
THE INPUT OF NON-STANDARD INFO IS STORED IN THE .IRR FILE.
THE INCORRECT TOO AUTOMATIC SINGLE PROPORTIONS ARE ELIMINATED

PRESS THE ENTER KEY TO CONTINUE
PROJECT NAME IS GR1044                                   Project Name is indicated.

ELEVATION USED IN ALL PROPORTIONS IS     3300.0          Project Average Elevation is used.

 168 LINES OF RECORD INFORMATION READ FROM .REC FILE     Be sure you had a .REC file made .
DO YOU WANT TO BYPASS AUTOMATIC PROPORTIONING ON          If you want to perform other
TOWNSHIP AND SECTION LINES BASED ON .REC FILE (Y/N) <N>?  AUTOPROP operations say Y


LINE = 100000
.
.
.
.
LINE =    300                                            Shows lines being computed
                                                         (based on standard numbering)
LINE =    400

LINE =    500

LINE =    600

DO YOU WANT TO                                           This is AUTOPROP's Main Menu
(1) PROPORTION ALL QUARTER CORNERS NOT IN .REC           Will compute all remaining corners
    OR .COR FILES (GEODETIC MIDPOINT)                    as described in the menu item.
(2) COMPUTE ALL CENTERS OF SECTION NOT IN .COR FILE BY PLANE INTERSECTION
(3) COMPUTE ALL SECTION LINE 1/16TH CORNERS NOT IN .REC
    OR .COR FILES (GEODETIC MIDPOINT)
(4) COMPUTE ALL 1/16TH CORNERS INSIDE SECTIONS   ( PLANE MIDPOINT)
(5) COMPUTE ALL CENTERS OF QUARTER SECTIONS BY PLANE INTERSECTION
(6) GEODETIC MIDPOINT                                    Based on individual input.
(7) PLANE MIDPOINT                                       Based on individual input.
(8) PLANE BEARING-BEARING INTERSECTION BY STATION ID
(9) EDIT/INPUT NON-STANDARD SUBDIVISION STATION NAMES    Used to define aliases for non-
(10) QUIT                                                ID's such as corners on min control.
PICK A # <10>                                            DEFAULTS show in < > brackets.
                                                         In this case the work was done
                                                         before I came into the menu so I am DONE!
                                                         I hit (enter)
```

```
DO YOU WANT TO
(1) NOT UPDATE THE .COR AND .GEO FILES                                  1) If you just want out.
(2) UPDATE .COR AND .GEO FILES WITH GENERATED STATIONS AS TEMPS (ALPHA APPENDED)
(3) UPDATE .COR AND .GEO FILES WITH GENERATED STATIONS WITH STANDARD GCDB ID
PICK A # <2>                                                            Select Option 2 temporary
2
INPUT A CAPITAL CHARACTER FOR THE ALPHA EXTENSION <T>                   Select Default CAP T

STATION POSITIONS USED OR GENERATED BY AUTOPROP

STATION        LATITUDE          LONGITUDE                              Outputs all values computed in
100100      35 - 21 -  38.91044     117 - 50 -  33.42993                AUTOPROP
.                                                                       If nothing computed no output
.
700600      35 - 26 -   1.74713     117 - 44 -  17.78367
```

After leaving **AUTOPROP** there are 3 options for saving results.

Option 2) Update the .COR and .GEO files with generated stations as temps
(ALPHA APPENDED)

What this is for is to allow you to save all the corner positions computed as TEMPORARY and non controlling positions only. This is done by flagging them with the standard ID but with a T appended as in 700600T. These points will show up as computed in SECTSHOW. The idea behind this is two-fold. First this computation could be for search area purposes. As more and more retracement data is entered and evidence recovered and tied in. **AUTOPROP** can be rerun to determine better positions. The second use of this option is to explore the effects of different control and the relation to various evidence. Each option can be tagged with a different alpha character such as 500440L for local survey control, etc. These points and their relationships can be evaluated with **VIEW** and distance relationships determined with **CSTUF**.

Option 3) Update **.COR** and **.GEO** files with generated stations with standard GCDB id

This option would be used only in the case that the corner positions you are computing are final values.

The output file for **AUTOPROP** is the **SUB** file. It is wise to examine this file, and never fully trust **AUTOPROP** without verification of it's procedure. It is a very fast and accurate tool if the proper controlling conditions and data were input. For example in the above case:

```
ELEVATION USED IN ALL PROPORTIONS IS      3300.0

 LINE = 100000

 PROPORTION MADE
 100100 CONTROL
 100140 POSITIONED BY SINGLE PROPORTION
 100200 POSITIONED BY SINGLE PROPORTION
 100240 POSITIONED BY SINGLE PROPORTION
 100300 POSITIONED BY SINGLE PROPORTION
 100340 POSITIONED BY SINGLE PROPORTION
 100400 POSITIONED BY SINGLE PROPORTION
 100440 POSITIONED BY SINGLE PROPORTION
 100500 POSITIONED BY SINGLE PROPORTION
 100540 POSITIONED BY SINGLE PROPORTION
 100600 POSITIONED BY SINGLE PROPORTION
 100640 POSITIONED BY SINGLE PROPORTION
 100700 CONTROL                                  That's the West Township Bdy.
```

```
LINE = 700000

PROPORTION MADE
700100 CONTROL
700140 POSITIONED BY SINGLE PROPORTION
700200 POSITIONED BY SINGLE PROPORTION
700240 POSITIONED BY SINGLE PROPORTION
700300 POSITIONED BY SINGLE PROPORTION
.
.  (We'll delete a few here to shorten things.)
.
700640 POSITIONED BY SINGLE PROPORTION
700700 CONTROL                                  That's the East Township Bdy.

LINE =    100

PROPORTION MADE
100100 CONTROL
140100 POSITIONED BY SINGLE PROPORTION
.
.
640100 POSITIONED BY SINGLE PROPORTION
700100 CONTROL                                  That's the South Township Bdy.

LINE =    700

PROPORTION MADE
100700 CONTROL
140700 POSITIONED BY SINGLE PROPORTION
200700 POSITIONED BY SINGLE PROPORTION
.
.
640700 POSITIONED BY SINGLE PROPORTION
700700 CONTROL                                  That's the North Township Bdy.

LINE = 100000

LINE = 700000

LINE =    100

LINE =    700

LINE = 200000

PROPORTION MADE
200100 CONTROL
200140 LATITUDE POSITIONED N-S 1ST PASS     Now doing the N-S part of
200200 LATITUDE POSITIONED N-S 1ST PASS     double proportions
200240 LATITUDE POSITIONED N-S 1ST PASS
.
.
200640 LATITUDE POSITIONED N-S 1ST PASS
200700 CONTROL

LINE = 300000

PROPORTION MADE
300100 CONTROL
.
.
.
.
```

```
 LINE =    200

 PROPORTION MADE                                  Now doing the E-W part of
 100200 CONTROL                                   double proportions finishing
 140200 LONGITUDE POSITIONED E-W 1ST PASS         them.
 200200 POSITIONED BY DOUBLE PROPORTION
 240200 LONGITUDE POSITIONED E-W 1ST PASS
 300200 POSITIONED BY DOUBLE PROPORTION
.
.
 540200 LONGITUDE POSITIONED E-W 1ST PASS
 600200 POSITIONED BY DOUBLE PROPORTION
 640200 LONGITUDE POSITIONED E-W 1ST PASS
 700200 CONTROL
```

etc. etc. Now each 1/4 section corner or 1/16 cor. in the .REC file is solves. The file is too long too show here.

BLUNDER.EXE

Blunder is as it's name implies, a blunder detection program. It searches for distance and angle blunders using some basic loop techniques. The technique for distance blunder detection does not work well with rectangular cardinal course traverses, so do not be surprised if it does not pop out those types of errors. It is one tool that MAY help you find blunders or large errors, but not necessarily so. **BLUNDER** works only on RAW data, and so can be run after **GENER** coordinate generation is complete.

BLUNDER performs 2 basic geometry based blunder detection checks on user-defined loop traverses. Both angle and distance blunder detection are built into this program. Angular blunders are bound in this option by systematically computing a loop closure beginning at different stations on the loop (and not using the angle at the beginning station). One good closure amid a series of bad closures indicates a possible angular blunder at that point. The distance blunder detection is a series of bearing-bearing intersections to generate distances, which are then compared to their measured values.

BLUNDER works on angle closed loops only. It can be used before LSAQ is run and is therefore useful in conjunction with GENER to locate possible data input blunders.

For additional information and use see the use of **BLUNDER** in the Example in Chapter 5.

CHECKER.EXE

CHECKER is a program that generates verification of closure by comparing the final adjusted lines to the original measurements on those lines. In addition by careful use it is one of the most powerful error and blunder detection programs in the system. **CHECKER** uses both the RAW data contained in the **.LSA** file and the adjusted results of **LSAQ** contained in the **.COR** file and thus should be run after **LSAQ** do provide additional information concerning the location of problems and blunders.

This file uses the **.LSA** and **.COR** files to compute automatic post-adjustment closures on routes through a network in the same way that **GENER** finds traverse routes. The user can also input other routes for closure computation. Output is written to a **.CHK** file. State plane reductions utilized are in **LSAQ**.

A user is allowed to input other unknown stations to be "held" for closure computations. This is useful, as an example, if one wanted closures between section corners or other traverse junction points. Holding such points will give closures which indicate how much each traverse *'link'* of the network adjusted. This can point to the link where the blunder occured, as with redunancy it will be the one that adjusted the most.

Closure information includes misclosure in X and Y based on the determined direction for the first line in the route, angular closure based on closure of direction of observed angles with the adjusted closing direction, linear error of closure based on raw traverse length compared to adjusted traverse length, precision based on described X and Y misclosures, and precision based on described linear error of closure (precision after rotation of the traverse).

CHECKER INPUT/OUTPUT

Input a station other than control you wish to hold for closure purposes -

If you want to ensure **CHECKER** reports a closure on a desired section of traverse, input the endpoint stations at this point. **CHECKER** will treat these as "control" and thus will report closures that end at these points.

Closure in northing or easting - CHECKER

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 quares adjusted equivalent to get a latitude or departure closure.

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.

Linear error of closure (after rotation)

This is a comparison of the inverse distances of traverse endpoints (least squares adjusted vs. computed by **CHECKER**). 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.

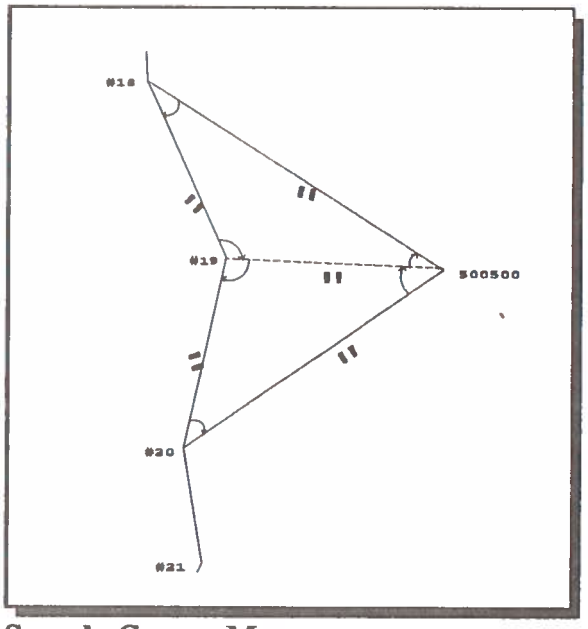
Before rotation precision - based on latitude and departure closures

After rotation precision - based on Linear error of closure (after rotation)

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.

CMOVE.EXE

CMOVE is the corner move program, it also computes offsets for line marking. It is designed to aid the land surveyor in field corner layout. Layout information is provided from three existing points in the form of horizontal angle and ground distance. Common use for the program is in field layout of a lost corner reestablished by PROPORT, **AUTOPROP**, or **CSTUF**.



Sample Corner Move

CMOVE begins with a prompt for a file name to log layout information to. It is this file which the surveyor will copy and take to the field. Next is a prompt for the corner to layout. This corner must exist in the **.COR** file. The program then searches the coordinate file for the nearest three stations. These do not necessarily need to be GCDB ID. points. At this time the user has the option of changing any or all of these stations. Once the move is executed the layout information is displayed on the screen and written to the selected file.

The illustration shows an example of a corner layout. Traverse stations #18, #19, and #20 are found by the program to be the closest stations from which to layout corner 500500. All distances and interior angles are provided by CMOVE. An obstruction of one, or even two of the layout lines will still result in enough information to provide a check in the layout.

COMBIN.EXE

COMBIN is a program that takes two **.LSA** files for **GENER** or **LSAQ** and combines them. Common control stations or observations are only input in the output file once. A series of error messages (same observation - different value, similar coordinates with different station name, same station name with different coordinates, etc.) is output.

Two input file names and one output file name are prompted for.

The program can handle 3000 stations, 4000 angles, 4000 distances, and 3500 azimuths on a PC.

This is useful if a project is worked in small parts, or by different crews, then combined once each data set is evaluated.

COMPAR.EXE

COMPAR is a program that allow you to compare two **.COR** coordinate files. The value of this is as a check to see the absolute and relative effects of different weighting of measurements or the effect of adding new data on resultant coordinates.

CONVERT.EXE

CONVERT Convert allows conversion between state plane and latitude-longitude in NAD 27 and NAD 83 in all zones.

CONVERT can be used for conversion between geodetic and state plane coordinates in either NAD 27 or NAD 83 datums. All state plane zones are included.

CONVERT is completely menu driven. You will be initially prompted for input and output file format names. The input file can be constructed using a word processor.

If you are converting from geodetic coordinates to state plane coordinates each line of your input file should look like this:

Station name	Latitude	Longitude
alphanumeric	degrees minutes seconds	degrees minutes seconds

The station name can be up to 10 characters in length and should contain no blank spaces. Degrees and minutes should not contain decimal points, and seconds can be with or without a decimal point. Any number of spaces is allowed between each entity on a line of input. Spaces must exist between degrees, minutes, and seconds of latitude and longitude (45 23 46.32456 is correct, 452346.32456 is incorrect). The order must be as shown. Any line of input not having this format is ignored.

If you are converting from state plane coordinates to geodetic coordinates each line of your input file should look like this:

Station name	X	Y
alphanumeric	real	real

The station name can be up to 10 characters in length and should contain no blank spaces. The coordinates can be with or without a decimal point. Any number of spaces is allowed between each entity on a line of input. The order must be as shown. Any line of input not having this format is ignored.

In NAD 27 all state plane linear units are assumed to be U.S. survey feet.
For NAD 83, you will be asked if input state plane coordinates are metric, U.S. survey feet, or international feet. Output state plane coordinates in NAD 83 will always be metric, and the user has the option of also outputting either or both English equivalents of the coordinates.

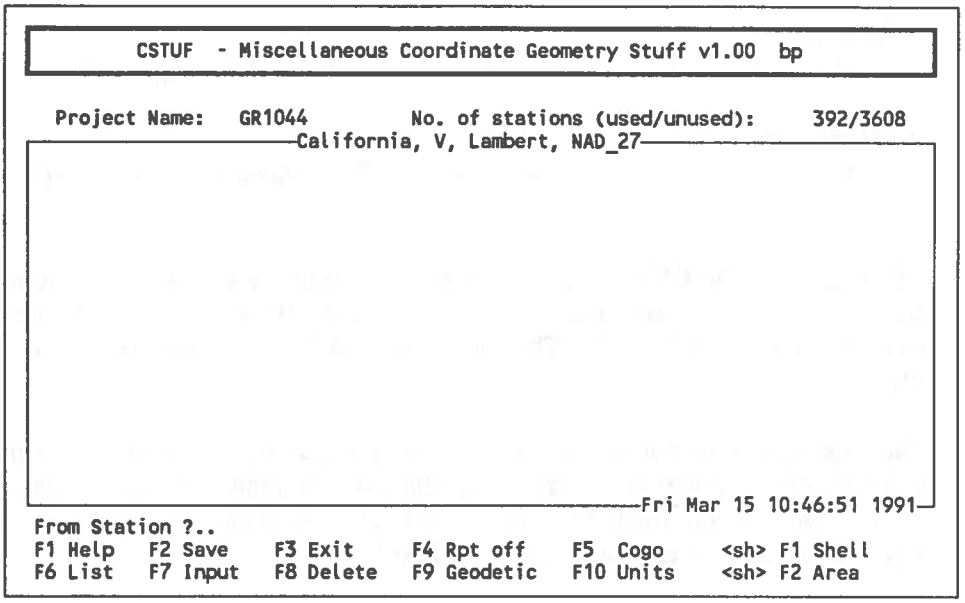
CONVERT requires four files for operation:

(1) NAD83.CON
(2) NAD27.CON
(3) TABLE.DAT
(4) ZONE.DAT

These 4 files must exist in the directory **CONVERT** is being run from.

CSTUF - *The MEAN Machine*

CSTUF is the primary geometric computation tool within CMM. It provides many tools for handling points in the **.COR** file, as well as performing geodetic or state plane computations, traverses, inverses, intersections etc. It has the ability to work with Forward or MEAN geodetic bearings.



Program Function:

Miscellaneous Coordinate Geometry Stuff

Computations:

Geodetic and Plane

Routines:

Traverse, Intersection, Inverse, Area, Point Input, Point Deletion, Point List

Function Keys:

F1: HELP:	Press F1 to view the help file, PGUP or PGDN to the required screen.
F2: SAVE	
F3: EXIT	Choices: to exit with save, exit without save, or return to **CSTUF**.
F4: Report ON/OFF	Press F4 to open/close DOS report log file.
F5: COGO	Press F5 to activate Coordinate Geometry routines.

F6: LIST Press F6 to list points by name.

F7: INPUT Press F7 to input points.

F8: DELETE Press F8 to delete points by name or range.

F9: GEODETIC/PLANE Press F9 to allow change between Geodetic and Plane mode.

F10: Units Press F10 to display units selection window.

<SHIFT>F1:
ELEVATION Press <sh>F1 to shell to DOS temporarily.

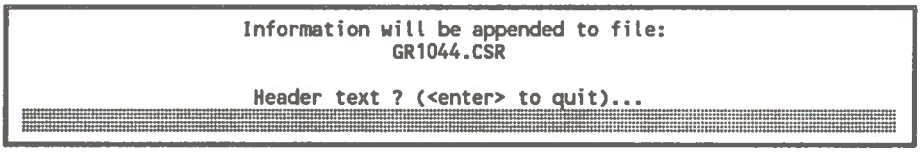
<SHIFT>F2:
AREA Press <sh>F2 to activate area computation routine.

CSTUF- Once the **CSTUF** option has been selected the user is given the power of intricate coordinate geometry routines with swiftness and efficiency. Coordinates are loaded into memory from the **.COR** file. The amount of time taken depends on the size of the coordinate file.

The headings of this menu are mostly self explanatory. The project name is the project selected. The number of stations used refers to the number of points, loaded into memory, from the project coordinate file. The number of stations unused refers to the number of points which will yet fit in computer memory (RAM).

The work screen is the center shaded area. This screen is able to hold up to 500 lines of display. Any activity within **CSTUF**, which causes a screen display, is stored in memory. Previous work during the same session may be scanned using the up/down arrow keys as well as Page Up and Page Down keys.

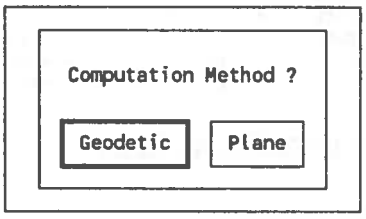
This display may also be logged to a DOS file for future records. Press F4 to allow the opening the **CSTUF** report file 'project.CSR' The following screen is displayed each time the file is opened:



Once a file has been opened any subsequent data which is displayed on the work screen is also sent to the report file. This file may be closed by again pressing F4 and selecting 'Close' or is automatically closed at the termination of **CSTUF**.

The major intended use of **CSTUF** is in coordinate geometry routines, including area. Therefore, the default mode for the program is 'F5 Cogo'.

The default mode of computation is geodetic. This mode may be changed by pressing F9 and selecting from the dialog box:



The default elevation is as listed in the **.DEF** file. When **CSTUF** is initiated it checks to see if an elevation file 'project.LEV' exists. If it does it opens it for use, if not one is created. Any time a new point is computed or input in **CSTUF** an elevation is prompted for and added to the .LEV file. All points are assigned the default elevation if no other is provided.

The four coordinate routines available to the user are: traverse, inverse, intersection, and area. Information is entered by the user at the command prompt line beginning with the 'From Station'. The next requested information is bearing code and bearing. Bearing codes refer to quadrant of bearing. Bearings are entered in HP format ddd.mmssssss. The next requested information is distance. The units used should match the selected units in the **.DEF** file.

The type of routine activated by **CSTUF** is dependant on the information provided by the user.

Traverse may be activated in either geodetic or plane mode. In geodetic mode there is the option of mean bearing or forward bearing. At the command prompt line enter the station, bearing, and distance. **CSTUF** automatically selects traverse mode and prompts the user for the new station name. To end the traverse routine press F5.

Inverse is the same in both plane and geodetic mode with the exception of the output. Geodetic mode causes the display to reveal forward, mean, and back bearings from the first listed station. While in the required mode enter the 'From Station' at the command line prompt. Press 'Enter' for 'Bearing' and 'Distance'. **CSTUF** automatically selects inverse and prompts the user for the 'From Station 2'.

Intersections may be of the type bearing/bearing, bearing/distance, or distance/distance. Again geodetic mode offers the option of forward or mean bearing. While in the required mode enter the 'From Station' at the command line prompt. For bearing/bearing omit distances from the command line prompt. For bearing/distance omit the first distance and the second bearing. For distance/distance omit bearings from the command line prompt. Again, any distances entered should be in the selected units. In geodetic mode the forward or mean bearing option is given.

Area is available in plane mode. After selecting plane mode, begin the area function by pressing <shift>F2. At the command prompt line enter the points enclosing the required area. Press 'Enter' with no point (or the first point listed) to execute the area computation. It is not necessary, however, to re-enter the first point as the area function automatically closes back on the first listed point.

CSTUF will automatically select the required routine based on the presence or absence of input at the prompts.

First Course Bng.	Dist.	InterSect Station	Second Course Bng.	Dist.	Type of Computation
N	Y	prompts	N	Y	Distance Distance Intersect
N	Y	prompts	Y	N	Bearing Distance Intersect
Y	N	prompts	N	Y	" " "
Y	N	prompts	Y	N	Bearing Bearing Intersect
N	N	no	no		Inverse or MidPoint Comp
Y	Y	no	no		Traverse Mean or Forward

Input Distance and Bearing Syntax Rules

Input Distance Syntax:

Generally, when **CSTUF** asks the user for a 'linear' quantity (distance, elevation, coordinate, etc.), users are able to use 'inverse data', default values, or change units (if applicable to the situation). For example, I'll illustrate the example of a cogo traverse, where **CSTUF** is prompting for a distance from station HV_2:

CSTUF prompt: Distance from 'HV_2' ?.. <ft> _

From the prompt, users understand that the program is prompting for a distance from station HV_2, and also that the program is expecting this distance to be in feet (survey feet). At this point, the user has several options; he may type in a distance only (in feet), he may type in an 'inverse distance' only, he may type in a distance and a distance modifier, or he may type in an 'inverse distance' and a distance modifier. Confused ? It's really quite simple once you start using them. In other words, at the distance prompt, users can type in two basic things: a distance and a modifier. Below is a list of acceptable 'distances' and acceptable 'modifiers' that the user may type in at the above prompt:

Example #	User reply
1	2640.66
2	5281.32 /2
3	40.01 ch
4	HV_2:HV_1
5	HV_2:HV_1 /2
6	HV_2:HV_1 +66
7	HV_2:HV_1 if
8	HV_4:HV_9

In the list above, examples #1-3 all produce exactly the same result; an input distance of 2640.66 U.S. Survey Feet. However, example 3 changes the default display units from survey feet to chains. Examples #4-8 show how to use an 'inverse distance'. Basically, this type of distance syntax says the following: Get the coordinates for both stations, inverse between them, and give me back the distance as your input distance. Any two stations can be used as long as they have defined coordinates. Like the examples show, 'inverse distances' can be used stand alone (4 & 9), or with a modifier (5-7). Example #5 says give me the inverse distance between stations HV_2 and HV_1, then divide it by 2 and use the result as input. Example #7 is a little bit deceiving. This syntax says

inverse between HV_2 and HV_1, use this distance as input, and then change the output units to international feet; the 'if' modifier doesn't actually change the 'inverse distance'.

The number of possible input statements for any distance prompt is overwhelming. But as I said earlier, basically there are two components, the 'distance' and the 'modifier'. You must reply with a 'distance', but the modifier is optional. The distance may be either a real number or two station names separated by a colon (:). If you use the 'inverse distance' syntax, you CANNOT use any space characters and you cannot use any colons in the first station name. Below are some input 'distance' examples:

```
GOOD                    BAD
=============================================
HV_2:NEX_S16            HV_2 : NEX_S16
HV_2:NEX_S16            HV_2 :NEX_S16
HV_2:NEX_S16            HV_2: NEX_S16
CORNER_1:CORNER_2       CORNER_1:CORNER 2
HV_2:NEX_S16            HV 2:NEX_S16
CORNER_1:CORNER:2       CORNER:2:CORNER_1
```

Distance Modifier: As you have probably guessed, the modifier portion 'operates' on the distance portion, somehow. Modifiers may be either algebraic, or textual. Legal modifiers always begin with one of the following characters eight characters: {+, -, *, /, m, f, i, c}. As you've probably figured out by now, the algebraic modifiers require another number to follow them. In fact, you MUST supply a number after one of the algebraic modifiers; any old number will do. Then, these modifiers operate on the distance just the way you would expect them to. The modifier /2 will divide the distance portion in two. The modifier +40.1 will add 40.1 (default units) to the distance portion. Etc. Now, the affect of the units modifiers (m, f, i, c) depends on what you supplied for a distance. If you supplied a real number, the units modifier will change the real number into the units specified, and use that number as input (it also changes the default output units). If you supplied an 'inverse distance', the units modifier only changes the default output units; it does not change the 'inverse distance'. Examples of good and bad modifiers are shown below:

```
GOOD            BAD
====================================
+40.1           + 40.1
+40.1           +HV_2:HV_1
/2              /2 ch
ch              acres
chains          rods
ft              survey_feet
ft              sf
m
meters
f
i
if
c
```

These rules make a lot of sense after you think about it for a while. In addition **CSTUF** will tell you if you screw it up.

Input Bearing Syntax:

Like the input distance syntax, **CSTUF** allows you to input 'inverse bearing' and bearing 'modifiers' as input for angular quantities. The rules are, as you might expect, very similar. Bearing input is somewhat simpler than distance input, in that there are no units to mess with (ignoring radians, degrees, grads, north azimuth, south azimuth, etc.).

In response to a prompt for bearing, users may input a bearing code and a bearing, or they may supply an 'inverse bearing' and perhaps a bearing 'modifier'. The 'inverse bearing' syntax is exactly the same as the 'inverse distance' syntax. No problems there. Or are there ? In geodetic mode you've got three azimuths: fwd, back, and mean. No problem. I always use the forward geodetic bearing from the first station to the second station. This makes a lot of sense to me, so I'm imposing this on all of you. It's great playing god.

Bearing modifiers consist only of algebraic modifiers (+, -, *, /). The rules for these algebraic modifiers are the same as before. If you use one of them, you MUST supply a real number afterwards. This real number is interpreted as a HP-format angle (i.e. dd.mmsss), and the appropriate function is applied to the angular portion of the user input. Examples of responses to bearing prompts are shown below:

```
GOOD                    BAD
=============================================
HV_2:HV_1 /2            HV_2:HV_1 / 2
COR_2:COR_1 +45.30      COR_2:COR_1 +COR_3:COR_4
```

Area is listed on the work screen in square feet and acres at grid, sea level (corrected for grid scale factor), and at average terrain elevation (corrected for grid and elevation factors).

A session of **CSTUF** is terminated by pressing F3. At this point the user is given the option to exit with save, exit without save, or return to **CSTUF**.

DXFLSA.BAT
DRAW.EXE

DXFLSA/DRAW DXFLSA is a batch file that first runs the DRAW executable program which takes the appropriate data and generates a portion of a DXF file. A DXF file is a graphic file format developed by AutoDesk for AutoCad and stands for Drawing Exchange Format. Then the batch file adds it to a DXF header file named FRONT.DXF. The executable DRAW uses **.LSA** (must contain approximate coordinates for all unknown stations) and **.COR** (if adjusted coordinates are to be used) to create an AutoCad **.DXF** file labeled **.DXF** which will allow viewing of the network within AutoCad or AutoSketch or any other CAD program that can read DXF format files. Some CAD packages do not provide for sufficient compatibility with AutoCad to accept error ellipses to display, if you selected that option. DXF files may also be converted into WordPerfect **.WPG** files for importing and printing through WordPerfect.

The user will be prompted for text size (station name), unknown station symbol size (circle radius), control station symbol size (triangle side length), and error ellipse magnifier (so you

can see them). All text and symbol sizes are in ground units. When you get into AutoCad, create a new drawing file with your project name. Then type DXFIN LSA to bring in your **.DXF** file. When the prompt reappears (this could take a few minutes) type ZOOM E (for extents) and your network will appear. Data is placed in appropriate layers. Files of line connections (chains) can also be input. The end of a chain string in a file is denoted by a zero.

GENER.EXE

Introduction

There are essentially two methods which can be used to adjust horizontal control networks using least squares: observation equations and condition equations. In the condition equation method the user has to define paths through the networks in such a way that all the redundancy in the network is realized. This is a simple task for a basic loop traverse or a single link traverse and thus most COGO packages which contain least squares use this method since only these simple networks are dealt with. In any traverse network of any complexity finding the proper number of independent conditions is a problem the surveyor should not have to deal with.

In adjustment by least squares by observation equations (also called a parametric adjustment), the user is not required to supply any information concerning routes through the network. This is very advantageous when the networks become very complex and interconnected. The drawback to adjustment of horizontal networks by observation equations is that initial approximations are required for all unknown station coordinates. **GENER** handles this problem automatically for the user.

The requiring of route defining in the condition method and the requiring of initial approximations in the observation equation method has made it difficult for the practicing surveyor to use least squares. Hopefully this problem has now been solved with the use of **GENER** and **LSAQ** within **CMM**.

When <G> is selected from the Main Menu the CMM batch file runs the program called GENER. There are 3 functions of this program:

* Manual Data Entry and editing.

* Preliminary Closure checks for significant blunders.

* Primary ultimate purpose is to GENERate approximate coordinates for all traverse points in your project.

Detailed Explanation:

GENER is an approximate coordinate generator for any integrated form of traverse network. Proper state plane reductions are applied to all measurements if a state plane zone has been selected. **GENER** also provides the user with link closures, angular closures, and other forms of basic pre-adjustment blunder detection. **GENER** also provides full einput and diting capabilities for the data file **.LSA** which also supplies control stations and their coordinates,

measurements, and unknown stations and their approximate coordinates for the least squares adjustment of horizontal survey information. The editor checks for input errors, and is fully explanatory in use.

When using **GENER** it is optimal that all station names should be entered in capital letters as the programs are case sensitive (keep CAPS LOCK on at all times). Towards that end a DOS utility is used to force your keyboard to upper case lock when entering GENER thru CMM. What can happen if you don't use upper case only is confusion that arises between a station named 'a' and station named 'A', for example. These could be considered as one point, or two depending on the concentration of the data entry person. To avoid this problem most (but not all) of the CMM utilities see both these types as the same, therefore the requirement resolves any potential problems. Currently the CMM batch file which invokes GENER uses a utility to set CAPS LOCK On and then off when GENER is exited.

All angular quantities are input in 'HP-format' That is **DD.MMSS** where **DD** is degrees, **MM** is minutes, and **SS** is seconds. Minutes or seconds should not contain any additional decimal points. **GENER** does not generate coordinates for bearing-bearing or distance-distance situations, but it is possible to type approximate coordinates for these situations directly into the **.LSA** file. That is each station located needs to have at least one angle and distance to it, or a coordinate estimate input.

GENER does not require the user to define the traverse routes which enable coordinate generation, as traverse routes are automatically generated. This means the user does not need to order his data in any fashion. If **GENER** finds it cannot generate coordinates for an unknown station due to omission of data or highly unusual network connectivity, this information is output to the user. If the user desires to add information to the **.LSA** file without using **GENER**'s input functions, the structure of the file is easily interpreted and could easily be input using any line or full screen editing package. Caution should be exercised though since the format of the **.LSA** file must be strictly adhered to.

It is recommended that manual data entry be made through **GENER**'S own input editor, as it contains very exclusive data checking capabilities for survey type information which cannot be found in any general editor. Input directly to the .LSA file with an editor or a word processor runs a risk of leaving some improperly formated data. It is almost always wise to then run the utility **SETUP** which checks and formats the data properly for subsequent programs. It is a good idea to input networks a traverse link at a time, then allow **GENER** to check its closure, so that blunders can be systematically eliminated.

GENER can accept any alphanumeric station name up to 16 characters in length. Station names should not contain blank spaces, and should always be input without adding any blank spaces before the actual name.

GENER primarily searches for "link" traverses which connect two distinct stations with known coordinates (control or previously computed by **GENER**). Known coordinates at both ends of the link permit rotation of the link traverse into proper directional orientation. This orientation can only be done on a loop traverse if it has a direction (azimuth) observation on it, or an angle connects it to a line of known orientation.

A network with only one control point and an input direction is handled as a link traverse by assuming a distance connected to the control point as due north (thus making the other station a "pseudo" control point). Once all stations have generated coordinates in this arbitrary system the input direction is used as a basis for rotation of the network into proper orientation.

Closures of link traverses are output as coordinates are being generated. These closures are incredibly helpful in blunder detection. **LSAQ** (the least squares analysis program), **RAW**, **BLUNDER** and **CHECKER** also afford many blunder detection abilities.

In **GENER** traverse computations cease when approximate coordinates for all stations have been generated. It is entirely possible that all traverse closures seem reasonable and yet a blunder still exists. This is because **GENER** uses only the minimal portion of the redundant data set in coordinate generation. These blunders can often be detected in **GENER** after coordinate generation, since **GENER** computes pre-adjustment residuals for all observations. A user should be careful in using this information, since the coordinate generation will force much of the random error into the observations which were not used in the coordinate generation process.

Closures output are always the result of a link traverse between two stations with generated coordinates. The distance between the traverse link end points based on the measurements, compared to the distance computed by inversing between known traverse link end coordinates, represents a closure.

The precision is the closure divided by the sum of the distances in the link traverse, output as the traditional ratio error of closure. It is when a link traverse is found that coordinates of intermediate stations along it can be rotated based on the existing azimuth between end points.

Closures calculated by **GENER** will tend to be larger than those computed if loop closures were computed since closures are often made between end stations whose coordinates were just computed by **GENER**. Since the end station's coordinates are not yet adjusted, and the previous coordinates have misclosure, closing against them will tend to be larger than if adjusted coordinates were known. This will occur in any redundant traverse network. This, of course, would require the subsequent least squares adjustment. If a poor traverse closure is detected, that closure may affect the closure of traverse links computed subsequent to it.

Always look for the blunder in the observations on the first link traverse with a poor closure.

GENER only uses the average project elevation (not a series of elevations as can be used in **LSAQ** with LEV.LSA) in applying the sea level factor, so in rugged terrain this could also slightly affect **GENER**'s closures.

GENER will attempt formation of link traverses followed by closure computation and rotation until all stations have generated coordinates or no more traverse links can be found. If some stations still do not have coordinates, **GENER** will look for an angle-distance combination where one leg of the angle is between stations with coordinates, and the other leg has a distance to a station without coordinates, which will enable calculation of rotated coordinates for the undetermined station.

Often, forgetting to input an angle on a traverse route forces **GENER** to use angle-distance intersection. **GENER** will then reattempt a link traverse generation, with a return to a search for an angle-distance combination if necessary. If all angle-distance possibilities are exhausted, a warning is output to the user indicating which stations could not have coordinates generated for them. This warning can also be a good sign if you have eliminated all observations containing the station from the data. This can happen when you mistakenly name a station in an observation, and later change that station name.

> *It is wise to resolve all such problems before going forward to the Least Squares analysis process. In some cases incomplete data in the .LSA file or incomplete coordinate generation as indicated by GENER will cause LSAQ to fail or even crash.*

When one selects the "quit" option from the editor, **GENER** will regenerate all non-control coordinates. If you are creating a large network you will generally want to input data for a while, then quit the input editor and generate coordinates (and then possibly run **LSAQ**) to see if the data you added is free of problems. If a problem is detected, use the editor to correct it and re-generate all coordinates.

GENER looks for unknown stations which are not on a distance measurement or not on an angle measurement. If such a station exists, it will be impossible for **GENER** to compute coordinates for that station since it is not on an angle-distance combination. This could mean measurements need to be added to the data, or the station is included on a bearing-bearing or distance-distance intersection. If the latter situation is true, approximate coordinates can be input to the .LSA file using a line or full screen editor, followed by execution of program **SETUP** to properly reformat the .LSA file.

If a message appears for a station which was not intended to be deleted from (or added to) the network, it will be necessary to check that all necessary observations have been input relative to that point.

If the editor in **GENER** is not invoked, coordinate generation begins immediately. In the editor one can list control stations, distances, angles, or azimuths (input of bearings is also allowed and they are converted to azimuths); or edit any of those four data types. Data can be added, changed, or deleted. Deleting can be performed by station names or by observation number (ordered # in the file).

After the completion of coordinate generation and pre-adjustment residual calculation, **GENER** automatically updates the **.LSA** file with added observations and generated coordinates. That file is now ready for **LSAQ**.

GENER creates an output file named **.GEN** which will contain all warning messages, all generated traverse links and closure information, a list of generated coordinates, and a list of pre-adjustment residuals. Traverse closure information is also output to the screen as **GENER** is running, but it often whisks by you faster than you can read. The **.GEN** file is useful in blunder detection and checking which observations you have input to the **.LSA** file.

For step by step operation of **GENER** follow the Example contained in Chapter 6.

INREC

Computer program **INREC** is a hard core data entry tool designed to provide any easy way to create the **.REC** (record) file. One can think of the **.REC** record file as a digital file representatio of the record plat bearings and distances.

Record Data: Any measurement management system operates successfully only if blunders in the data being managed do not exist. For this reason it is important that blunders in transcription from paper plat to digital record be kept to a minimum. Record plat data is one of the most important types of data to be entered. Many decisions are based on this information. An example would be a double proportion to locate the legal replacement of a section corner. In this case retracement measurements are related to record plat data. If this digital plat data contains a blunder, the proportioned corner will be positioned incorrectly. Measurement management software has the ability to convert plat data to observation format. This enables the same mathematical checks of integrity to be used on it that are used on survey field data.

One method of record data entry is by measurement management designed software. This software should make use of the township structure from which to base data input. For instance, the eastern boundary of Township 57 South, Range 73 East is designed to have a mean bearing of north, with corners set every 40 chains. The data entry would simply be automated, with the operator needing only to accept the default values of the next bearing and distance. Only in the less common case, where a corner was not set or distance/bearing was irregular, would the user have to override the default values with different input. A secondary benefit of this system is the self-formatting data structure. The software automates the format process with minimal prompts to the user. Many checks can also be incorporated into the data entry which take advantage of the GCDB naming scheme. For example, an entry of south for the direction from 100100 to 100200 can be trapped by software as an entry error.

The alternative method of plat data entry is by a simple text editor. Although this method is straight forward it may often lead to transposed numbers and other transcription errors due to operator fatigue or inattention.

Since **.REC** is a file and not a visually aided graphic representation of the record information, it is required that bearings and distances be defined with a systematic from station and to station designation. Both **INREC** and the proportioning utilities can provide more automated forms of input and computations if a standard numbering scheme is adopted for record information. One can input an entire township's record information not using standard numbering, but it is not conducive to efficient work. **INREC** assumes all station ID's are numeric since that is the essence of the standard numbering system. The numeric names are converted to alphanumeric in subsequent programs. A maximum ID length of 6 numerics is assumed, which is converted to 16 alphanumeric in later programs.

The standard numbering system used in this system is similar in most respects to the GCDB (BLM's Geographic Coordinate Data Base) identification system, but due to application is not as strictly defined. The standard system as defined for use with CMM is described elsewhere in this reference.

If **INREC** is being run for the first time (the **.REC** does not exist or one has erased it for

some logical reason) the user is prompted through the standard numbering for N-S lines (assumed running north) followed by E-W lines (assumed running west). If a user wants southerly or easterly input one must change the initial from designation to 700 instead of 100.

One will have to take time getting used to INREC input. The efficient techniques built into the entry take time to learn. The following items should be noted:

(1) Three numbers of the name are assumed, so the user is only inputting three integers at a time. As the 100xxx line is being input the user only inputs the xxx part. A zero input indicates to the program that the from station should be changed. A zero input at the from station indicates to switch to the next line.

(2) The user has the ability to automatically input series of lines which have common bearings and/or distances. THIS ABILITY IS LIMITED TO GROUPS OF LINES LONGER THAN ONE MILE IN STATION DESIGNATION. As an example if one is starting the 100xxx line (from station is 100100) and the user inputs a 'to' station of 700, 80.02 chains, and due north; if the automatic input option is selected 6 lines: 100100-100200, 100200-100300, ..., 100600-100700 would all be assigned that distance and bearing.

If the distance input was closer to 40 chains all quarter corners would be included. Similarly an input closer to 20 chains would create distances between sixteenth corners. If one input 600 instead of 700 all automatic creation would quit at 5 miles.

One can also select non-automatic line generation, where one would input distances and/or bearings with automatic station numbering.

This input is very powerful but confusing at first. Please take your time in learning it.

(3) All bearing input is checked for proper quadrant and value. One can override the check. All bearing input is N, S, E, or W for cardinal or 1, 2, 3, 4 for quadrant followed by HP time input for value of the bearing. All bearings are assumed to be mean geodetic. All distances are assumed to be input in chains.

(4) THE AUTOMATIC ENTRY WORKS FOR INITIAL ENTRY. Once a **.REC** file is created you automatically move to more manual forms of entry when you run **INREC**.

(5) After automatic entry you have an editor which lets you add more data, list data, delete data, and edit data.

(6) After one quits the editor you asked if you want to create an adjustment data file (.LSA) for adjustment of record. THIS IS ONLY FOR VERIFICATION THAT NO BLUNDERS EXIST IN THE RECORD. If you select this option you are asked to input state plane coordinates for one station (the "control" for the adjustment). This file will not contain any control of have a project .DEF file for it. Therefor copy your projects .DEF file to a new name, for example REC.DEF. Make your .LSA file named REC.LSA, then change to that project with CMM, run GENER and enter a control point in the project area for one of the record corners, of use the LAt/Long off of the plat.

You are required to input a new project name for the .LSA file, or else you could easily be overwriting your field measurement .LSA file. That file is created, and one can now return to project management to change the project name. **GENER** must then be run before a least squares adjustment using **LSAQ** can be performed.

One should remember the **.REC** is the computer version of the record plat. Its correctness is vital to any dependent re-survey, and thus proper use of **INREC** is of vital importance. Examination of a printout of the **.REC** file may help in checking agaionst the plat. I is also possible to **VIEW** the created LSA file once it has been processed thru GENER to see if there are glaring errors and omissions.

LOOPER

LOOPER is a graphics base utility that allows you to cut up a large project into small portions. This can be userful for 2 reasons. First if you are trying to locate errors or blunders within a large data set, this can be very time consuming as each run of GENER, LSAQ take a considerable amount of time. Generally it is very apparent the general location of the problem, and matters can be expedited by 'cutting out' a section of the project surrounding the problem area and working with that as a seperate little project. Thus isolate errors more efficiently by eliminating wasting time reprocessing good data.

LSAQ

LSAQ Detailed Description: This program uses the parametric method, sometimes known as the observation equation method, to obtain the least squares adjustment of a horizontal control network. The adjustment is performed in a planar x,y coordinate system. The program has the ability to reduce distance and azimuth observations to the state plane coordinate system of your choice in either the NAD 1927 or the NAD 1983 datums. The user can also input an average network elevation so the sea level factor used in state plane coordinates can be applied.

If the terrain is fairly undulating, requiring more than one elevation in reduction to datum, station/elevation or X,Y,Z information can be read from a file call 'project.**LEV**' (each line of this file is a station name followed by an elevation or a line of X Y Z). If both end points of a distance are input the mean of the two elevations is applied. If only one end point is used its elevation is used. If neither end point has an elevation, the closest elevation to the midpoint of the line is used for the reduction. All elevation information is assumed to be in feet.

Note: If working in NAD27 state plane coordinates, all coordinate values and distances should be in feet. If you are working in NAD83, you indicate if your coordinates and distances are metric, U.S. Survey Foot or SI International foot for units. If not working in state plane coordinates it does not matter what your linear units are.

Initial approximations are required for all unknown coordinates since the solution uses a Taylor's series expansion in linearization of all observation equations. Initial approximations can be automatically generated for all traverse situations, and are input into the data file, by

using computer program **GENER**. Station names essentially come from **GENER**, and are thus limited to 16 alphanumeric characters.

The program uses Cholesky decomposition in solution of the normal equations. Bandwidth optimization reorders the stationing sequence to fully utilize the sparsity of the normal equations, and only the upper triangular portion of the banded normal equations are stored due to its symmetric nature. In providing error analysis only the diagonal and first off-diagonal terms of the variance-covariance matrix are computed as this is all that is necessary to compte the error ellipse information at a given station.

Output from the program includes all adjusted coordinates with their respective standard errors and error ellipse information if it is desired. This is followed by a list of all observations with their respective residuals and standard error estimates, root-mean-square errors for all observation types, largest residual for all observation types, and the adjustment standard error of unit weight. Adjusted bearings and distances can be computed, adjusted plane and geodetic coordinate files can be created, and the network may be readjusted for blunder detection purposes using new standard error estimates for selected observations, which are computed by very simplistic robustness techniques.

FILE INFORMATION:

The software will read data from a file with the extension **.LSA**. All output will be sent to a file with the extension **.ADJ**. In only very rare circumstances should the **.LSA** file be edited by any fashion other than the editor which is a part of computer program **GENER**. One should be familiar with the basic system file copying, deleting, and renaming commands so that data and output files can be saved. It is also important to know how to display information on the screen (editor or TYPE command) and how to send files to a printer. Important files should always be copied to a secondary storage device (floppy disks) in case anything ever happened to your primary storage device (hard disk).

INPUT DATA FILE STRUCTURE:

The **.LSA** file consists of 5 subgroups. The order of the subgroups cannot be altered. The five groups, in their required order of input, are:

(1) control station coordinate information,

(2) distance measurement information,

(3) angle measurement information,

(4) azimuth measurement information,

(5) unknown station approximate coordinate information.

All data is read in one line at a time by a formatted read, so data not input through **GENER** needs to be formatted using **SETUP**. If the correct number of data strings does not exist on that line, program execution will terminate with output of an appropriate message. One line

of data corresponds to one station or one measurement. Required input for a given line of data must be in a prescribed order. All lines of data are finished with a "0" (zero) or "1" (one). A zero indicates the following line includes data in the same subset. A one indicates the next line includes data which belongs to the next subgroup of data. The last line of input in subgroup five should end with a one, indicating the end of the data file. The zero or one is called a flag, and is always an integer.

Stations can have alphanumeric names up to 16 characters in length. A station name should not have blank spaces in it. All angle and azimuth degrees and minutes should be in integer form, while the seconds can be a real or integer (reals contain decimal points, integers do not). All distances and coordinates should be input as real numbers.

GENER sets up the data file properly for you. Use it and you can ignore all the discussion of data file structure.

> All angles are assumed to be measured clockwise, i.e interior angles right. All azimuths (solars, etc.) are assumed to be measured clockwise from north (north azimuth).
>
> If using state plane coordinates astronomic or geodetic azimuths can be converted to grid azimuths using a program option. All input azimuths must be of one type either all geodetic or all grid.

Coordinates should **not be negative** and should be less than 10,000,000.00 to meet output format restrictions.

If you have negative control coordinates, GENER will be very mad at you.

LSA File Format:

DATA FILE SUBGROUP #1 - CONTROL COORDINATES

All lines in this group have the following form:

station	X coordinate	Y coordinate	flag
(character)	(real)	(real)	(integer)

DATA FILE SUBGROUP #2 - Distance measurements

All lines in this subgroup have the following form:

Occupied Station	Sighted Station	Distance	flag
(character)	(character)	(real)	(integer)

DATE FILE SUBGROUP #3 - ANGLE MEASUREMENTS (Assumed clockwise)

All lines in this subgroup have the following form:

Backsight Station	Occupied Station	Foresight Station	Degrees	Minutes	Seconds	flag
(char)	(char)	(char)	(int)	(int)	(real)	(int)

DATA FILE SUBGROUP #4 - AZIMUTH MEASUREMENTS (assumed from north)

All lines in this subgroup have the following form:

Occupied Station	Sighted Station	Degrees	Minutes	Seconds	flag
(char)	(char)	(int)	(int)	(real)	(int)

```
DATA FILE SUBGROUP #5 - UNKNOWN STATION APPROXIMATE COORDINATES

    All lines in this subgroup have the same format as in subgroup #1.
    If there are no measurements of one type (like azimuths) insert zeroes for a line of a
    subgroup with a flag of one.  For azimuths this would look like: 0  0  0  0  0. 1
```

All estimates of standard errors of observations are generated internally by the program from user input and are thus left out of the data file. The user is given the option of changing the default standard errors, or can input individual standard errors for each observation using computer program **SD**.

The following error estimates are being generated by default:

* Distance error estimate = 0.03 ft. + (3/1,000,000)* distance;

  (the error estimates will be in meters if distances and coordinates are in meters)

* Angle error estimate = 6 seconds;

* Azimuth error estimate = 0.1 seconds;

* X or Y control coordinate error estimate = 0.001 ft.

Note: The actual default values are different than specified here, and depend on whether the job definition file was created with CMM-MANAGE or the stand alone program PROJEC.

The small azimuth default standard error is used because an azimuth is often used to orient a network with only one control station, thus that standard error essentially "holds" that line at that orientation. If control coordinate standard errors are left at their default values it is highly unlikely that any adjustment of their input positions will occur. It is important to get used to the fact that control coordinates contain error, too, so in networks where more than one control station exists (as an example, a township with GPS stations at certain points with redundant traverse in between), it may be justifiable to assign standard errors to the control coordinates which will enable their adjustment along with the rest of the unknown station coordinates.

Before the actual least squares solution begins, a reordering of stations occurs which minimizes the bandwidth of the normal equations so the solution will occur much faster. The iterative solution for the bandwidth will appear on the screen. Larger networks will generally have larger bandwidths, as will networks of high redundancy. Lots of sideshots and open ended traverses make the bandwidth increase dramatically, and thus the solution slows way down. Try to add sideshots and open ended traverse to the network using computer program **SSHOT**.

The solution begins after the minimum bandwidth is found, and each iteration of updates to coordinates will appear on the screen (quickly for small networks, slowly for large networks). A rough estimate of time for an iteration on a 20 mHz PC-AT is 30 seconds for 100 stations, 10 minutes for 500 stations, 30 minutes for 1000 stations, and 1.5 hours for 2000 stations. These times are dependent on the bandwidth of the network, and are based on some "typical" actual survey networks.

The standard error of unit weight for the iteration will appear. This number should go down as iterations occur. If it does not you have blunders in your data. A final standard error of unit weight of close to one (between 0.7 and 2) indicates you did a good job of estimating the random errors in your observations. A final standard error of unit weight of much greater than 2.5 should be considered suspect. If this occurs and you are certain of the estimation of your observation standard errors, and you are certain there are no blunders in your measurements, it usually indicates problems with the control stations in your network. Try changing some of the control points to unknowns, or assign their coordinates larger error estimates, and see if you can isolate the problem.

The number of iterations will usually never exceed 3 since the approximations for unknown coordinates computed by **GENER** are generally fairly reliable. Iteration will quit for one of the following reasons:

(1) The largest coordinate update is less than 0.005 ground units.

(2) The standard error of unit weight is not improving.

(3) 4 iterations have occurred and (1) and (2) are not yet satisfied.

A large increase in the standard error of unit weight usually indicates a blunder is in the data. A very small increase in the standard error of unit weight means the solution has stabilized and iteration should cease since the solution will probably not improve.

After iteration is terminated, error analysis is performed if the user has selected this option. Error analysis means standard errors for all coordinates and error ellipse information for all stations will be computed. In large networks there is a significant amount of computations required for this process, so if the error information is not required you will usually not select this option. If later you needed that information, all you would have to do is run the program again with the error analysis option selected. Very large networks which require temporary storage of the least squares equation coefficients is a file on your hard disk. This file is erased from your hard disk when program execution terminates. In cases where this temporary storage is required (usually 400+ stations) error analysis will not be allowed by the program due to the extensive execution time that would be required for it to complete.

Residuals are now calculated for all observations and written to the **.ADJ** file. Only residuals above user-selected limits are output (inputting a zero means all residuals of that observation type will be output). Remember control coordinates may adjust so they can also have residuals calculated for them. Root-mean-square (RMS) values for all observation types are calculated and the largest residual for each observation type is highlighted. The coordinate output, error analysis, and residual information is not written to the screen (only to the **.ADJ** file) because it moves by your eyes too fast to be interpreted.

LSAQ runs completely without prompts unless the re-weight prompt is selected in project definition. Weights are inversely proportional to standard errors. Re-weighting invokes a tool called robustness which is very useful in blunder detection. In robustness a new standard error is calculated by averaging its original standard error with the absolute value of its post-adjustment residual. This creates a filtering process where observations with low residuals will get lower standard errors, and those with larger residuals will get larger standard errors. This

process can often result in the blunder (or potential blunders) having unusually large residuals in the post-adjustment statistics, thereby isolating the problem.

It is really amazing how successfully this operation can be in blunder isolation even when the network has little redundancy. One should try this tool by inducing a blunder in a network on purpose, and seeing if it will find it. The software gives you the option of re-weighting any type or combination of observations. If the re-weighting algorithm is invoked the software will return to the actual adjustment phase of the software.

If selected in the project definition, the software will next compute adjusted bearings and distances.

The last defined option from project definition of **LSAQ** is the creation of the **.COR** file, which is an ASCII listing of station ID, adjusted X, adjusted Y, point scale factor (no elevation factor), and convergence angle (the last two items are not output if a state plane zone was not selected). If a state plane zone was selected, the **.GEO** is also created which is a list of adjusted latitudes and longitudes. The output file (.ADJ) can now be viewed on the screen or printed.

The creation of the **.COR** file is essential for use of computer program **CHECKER** as it uses the coordinates in this file.

LSAQ is set up to adjust maximums of 3000 stations, 4000 distances, 4000 angles, and 3500 azimuths on an PC-AT with 550 k of available RAM. Bigger networks can be adjusted if a user asks for a larger version (there is a trade-off between larger versions and efficiency of the system).

LSSM

LSAQ is a high performance Least Squares Analysis Program for a PC, and as such it requires approximately 547K of free ram. In many cases such large network solutions are not necessary and sufficient RAM is not available. In that case, a smaller memory model is provided and named LSSM. It can be 'installed' in the system by running the batch file LTLLSAQ. This copies LSSM.EXE to LSAQ.EXE. The batch file BIGLSAQ is provided to restore the original LSAQ.

MANAGE.EXE

MANAGE is the executable portion of a partnership CMM-**MANAGE** that are responsible for the main menu. CMM is a batch file that actually runs each selection after **MANAGE** has exited. The system was designed in this bizarre fashion to make the maximum amount of RAM available to **LSAQ**. With this system **MANAGE** is no longer in memory when the selected programs run. **MANAGE** does contain the project definition screens. You cannot run **MANAGE** as a stand alone program and have it work, it must be called through CMM.BAT.

CMM is used to maintain default parameters for your survey network projects. It also allows you to select appropriate programs, edit files (which also allows one to view files), and change projects.

CMM allows you to directly run **GENER** (approximate coordinate generation), **LSAQ** (adjust network), **CHECKER** (post-adjustment closures), and **DXFLSA** (creation of **.DXF** file of traverse data).

> All of the Cadastral PLSS computation utilities are accessed by selecting the Utilities option.

The G and A options on the Main Menu

Selection of the G (Adjust) option in **CMM** leads you to define 19 parameters for a least squares adjustment of a survey. *Options 1 - 5* pertain to state plane information. If no state plane zone is selected these first five options are ignored. Any state plane zone can be selected in option 1. In option two the user can select NAD 27 or NAD 83. Option 3 has no meaning in NAD 27 as the U.S. Survey Foot is assumed. In NAD 83 the user can select units of meters, U.S. Survey Foot, or U.S. International Foot. All distances and control coordinates must be in the same units.

Option 5 is a project elevation for reduction of distances to a sea level datum. If the terrain is very undulating, the user may want to input a series of elevations into LEV.LSA (option 5, see **LSAQ** user's manual) for a better estimate of elevations at stations. If option 4 is selected (Yes input) one should still input a reasonable project elevation as that quantity is used in elevation reductions in computer program **GENER** and as a default for all utility programs.

Option 6 tells the adjustment programs if the azimuths are geodetic, (Yes) and thus need to be reduced to their state plane grid equivalents, or if the azimuths are already reduced to grid (No).

If a user desires to read individual error estimates from a file a 'Yes' is answered to the standard error question. You must have run **SD** prior to create this file. If a 'No' is answered to the standard error question the user is allowed to edit default error estimates for distances, angles, azimuths, and control coordinates. Control coordinates error estimates should remain at 0.001 unless it is really desired that control coordinates be allowed to adjust.

The next page of **LSAQ** options involve if error analysis (standard errors and ellipse information) is to occur. In large networks a 'Yes' input will be overridden due to the inordinate time required to perform these computations.

The next inputs define limits for residual printout. If the absolute value of a residual is less than the limit it will not be printed. A limit of zero will result in all residuals of that observation type to be printed.

The next option is selected if one desires to print adjusted distances and bearings in the **LSAQ** output file.

The next-to-last option is selected if an ASCII list of adjusted coordinates is desired. This option must be selected if one desires to use computer program **CHECKER** or the Utility programs as it passes adjusted coordinates to these routines.

The final option is selected if one desires to use re-weighting in **LSAQ** in blunder detection. If this option is not selected **LSAQ** runs in a batch mode.

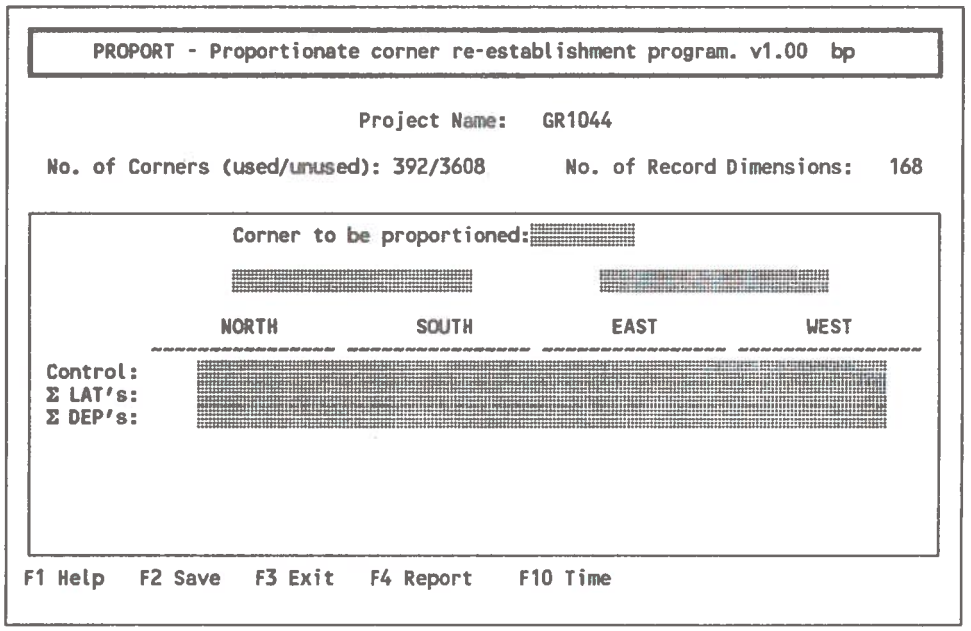
CMM allows one to modify all options, update a project definition file, and select a new project. When a new project is selected the program uses a definition file of that name. If the definition file for the new project does not exist (a new job) the previous project's defaults are used as initial defaults.

PROJEC.EXE

PROJEC is a direct way to create, modify or rename a project .DEF file. It has largely been replaced by data entry thru CMM, but is still useful on occasion as a way to enter trial large error estimates as part of a blunder hunting exercise. CMM limits error estimate entry to reasonable ranges, PROJEC does not. One unusual aspect of PROJECT is that you define the projects parameters, working from the current project as defaults, then change the project name on EXIT from the program.

PROPORT.EXE

PROPORT is a corner by corner single and double proportioning program. It makes significant use of the **.REC** files as created with **INREC**.



Function Key: F2 - Saves all coordinates computed.

Coordinates computed using proportion routines are not automatically saved to disk. They are maintained in memory during the particular **PROPORT** work session. It is a good idea to save your work when you are satisfied that it is correct. You are also prompted to save when you try to exit, but a power outage or reboot will result in unsaved work. If you are experimenting and do NOT want to save points you can Exit without saving.

Function Key: F3 - Allows the user to exit from **PROPORT**.

When executed a dialog box will open giving the user the opportunity to: Exit with save, Exit without save, or Cancel to return to **PROPORT**.

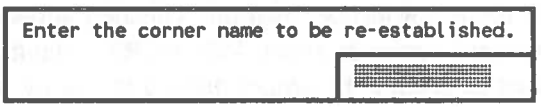
Function Key: F4 - Append report for last computation to Report File.

The report format in **PROPORT** differs from most other CMM routines in that it does not log ongoing operations, but rather the function appends only the last proportion report executed. This allows you to determine the proper proportion method and verify control before logging to the report. Data is logged to **PROPORT** report file 'project.PRR'. An input winndow is opened to allow user notes to go into the file ahead ofthe proportion report data. Each execution of 'F4' appends the last computationn data and closes the report.

The user can move the light bar between a number of special screen windows.

CORNER TO BE PROPORTIONED window:

Moving the cursor to the location and press enter to activate opens a data entry window:



The corner to be proportion is entered in the window. The station name must be in the record file! If NOT an error message will flash. If the station name is a PLSS corner using the standard numbering format **PROPORT** automatically tries to determine the most probable type of proportion and performs the operation.

This **method** selection can be overridden if desired. For non standard station names **PROPORT** defaults to Geodetic Computation and Double Proportion as there is no way for the routine to determine the proper method. IT REMAINS TO THE USER IN BOTH CASES TO CONFIRM THAT THE APPROPRIATE METHOD IS USED.

In some cases the window appears:

This may not exactly be true, but may be an indication that there is insufficient information for **PROPORT** to automatically determine the type of proportion based on the control it finds.

GEODETIC/PLANE COMPUTATION method window:

Once a corner is selected moving the cursor the this window allows toggling between GEODETIC and PLANE Computation if allowed.

The "*Manual of Surveying Instructions*" defines whether a Plane or Geodetic computation is to be used for computing a proportion for a lost PLSS corner. The user is therefore defaulted to a geodetic computation when using the PLSS standard numbering system. In the case where a non-PLSS corner is to be proportioned or conditions dictate the user has the option of changing to Plane computation.

DOUBLE or SINGLE PROPORTION: option window:

After passing through the method window the user may move to this option window and select or overide the method used.

Options are: Double, Single East/West, Single North/South

In some cases the method selected by **PROPORT** when using the standard numbering system will be inappropriate, then this selection allows the user to override the default. If a non-standard corner is given, **PROPORT** defaults to Double Proportion, therefore the user must determine the proper method to use by means of this selection.

While toggling between Double, Single East/West, and Single North/South Proportion, the type of computation (Geodetic vs. Plane) will remain unchanged.

Control Summary windows:

Four windows are presented. Summary control data is shown under the directions control was found. By moving the cursor the appropriate direction and htting (enter) will show the user additional specific information about the controlling courses found and used in the computation.

There must be record (in the REC file) and found corners (as tagged by standard ID's in the COR file by **WHATIS**) within 16 Record legs of the corner to be proportioned!

After a corner has been selected an ERROR message will flash if a valid control corner is not found in the COR file or is not within 16 record legs for each required direction. A WARNING message will flash if record data is missing from the REC file in each required direction.

Background:

In this process record distances are broken into their component latitudes and departures (cardinal equivalents) and proportioned relative to measured distances (methods used vary depending upon corner and situation). Record data is loaded into memory from the **.REC** file and coordinates are loaded into memory from the **.COR** file. The amount of time taken for these steps is based on the computer speed and number of points in the data base.

The number of corners used refers to the number of corner points loaded into memory from the database. The number of corners unused refers to the number of points which will fit in computer memory (RAM). The number of record dimensions refers to the number of courses in the record file.

Single Proportion:

With the selection of single proportion, **PROPORT** searches the record database for the nearest two found PLSS corners (up to a maximum 16 legs in any direction), either north/south or east/west depending on the corner being proportioned. Based on the Manual of Instructions 1973, this proportion is computed in geodetic mode by default but the user may choose to to override this selection by toggling to PLANE mode.

In plane mode the sum of measured latitudes (or departures) is proportioned against the sum of record latitudes (or departures) computed in X, Y cartesian coordinates. In geodetic mode the sum of the measured longitudinal (latitudinal) arcs is proportioned against the sum of the record longitudinal (latitudinal) arcs.

Double Proportion:

When a PLSS corner requires double proportion, as defined by the Manual of Instructions, 1973, **PROPORT** automatically searches the database for the nearest four found PLSS corners, (again, up to a maximum of 16 legs in any direction) in the 4 cardinal directions. In this case the Manual of Instructions, 1973 allows for only a geodetic computation. For the north/south direction the sum of the measured latitudinal arcs is proportioned against the sum of the record latitudinal arcs. For the east/west direction the sum of the measured longitudinal arcs is proportioned against the sum of the record longitudinal arcs.

Cases exist in which the user may use a single proportion in what appears to be a double proportion situation. Two examples would be in the case of fractional townships or in the case of providing search positions. For this reason **PROPORT** is designed so that the user may toggle between solutions. Plane computations cannot properly be used on township or section lines.

SD.EXE

SD This program is an option which sets up a **.SD** file which looks exactly like the **.LSA** file except error estimates replace the corresponding measurements. This is useful when you have surveys of varying accuracy. The **.SD** file is not read fixed format so the user can use a word process or to edit existing standard errors. This is helpful when you only want to change a small number of standard error estimates. **SD** has similar input and editing capability to **GENER** built in.

SECTSHOW.EXE

It is often useful to graphically display a township to identify which PLSS corners exist in the **.COR** database (created with **WHATIS**). For this reason SECTSHOW has been developed. Upon selection from the UTCOMM menu SECTSHOW displays a picture of a standard township on the screen. The main heading includes pertinent information about the project:

- project name,
- project datum and state plane zone,
- number of points within the **.COR** file,
- number of regular PLSS corners, and
- number of temporary PLSS corners.

Regular PLSS section corners are graphically displayed as green squares. Quarter corners are displayed as yellow circles. Sixteenth corners are displayed as red triangles. Temporary PLSS corners are displayed with the same shape in white color. These are the corners tagged with the standard id with a T extension.

SETUP.EXE

SETUP For efficiency, **LSAQ**, **GENER**, **CHECKER**, **SSHOT**, and **DXFLSA** now read formatted data structures in **.LSA**. To convert old data files or ones created using a word processor run **SETUP**. It will prompt you for the file name, and that file will be reformatted. Problems in the old file will be identified. This should only be necessary when you manually edit the **.LSA** file.

SSHOT

This program is for adding sideshots and open ended traverses to a file of coordinates ordered by point ID #s which is generated by **LSAQ**. The reason for using this in lieu of merely keeping the sideshots in the **.LSA** file as maintained by **GENER** and used in **LSAQ** analysis is that the sideshots will greatly slow the overall Least Squares process, and contribute nothing to the analysis as they provide no redundancy. For small jobs this may not matter, but for moderately sized jobs, where you may be waiting for a matter of hours in processing time, removing sideshots may be worthwhile. It has most of the same editing capabilities as **GENER** and uses the state plane scale factor of the station on the main traverse in reducing distances (if state plane coordinates are being used), and uses the same elevation reductions to grid as in **LSAQ**. You can separate sideshots from other stations in the **.COR** file since they will not have convergence angles tagged to them.

Input (data) file is **.SSS**

No output file is created.

SSHOT has a complete but simplified editor.

Allows updating of the **.SSS** and **.COR** files

SSHOT can handle up to 800 stations, 800 angles, and 800 distances.

TDSLSA

TDS is a preliminary program that was designed to convert files collected with the commercial Tripod Data Systems CO-OP41 data collection system.

UTCOMM.EXE

UTCOMM is simply the utilities menu system. It uses the file 'UTCOMM.PRG' for it's definition. Information is available in the installation section and in the UTCOMM.PRG file header concerning how to install programs of your own in the menu system.

VIEW.EXE

VIEW allows screen viewing of a horizontal network. **VIEW** uses the project **.LSA** file. Coordinates are read from the **.LSA** file, so **GENER** must have been executed. **VIEW** allows station name display to be toggled on or off, and allows panning and zooming by input of ground coordinates. **VIEW** requires the provided **MODERN.FON** file to exist, and Microsoft's MSHERC may have to be run to use a Hercules graphics card with CMM.

WHATIS.EXE

Whatis is an extremely important program. It's most important function is to identify which traverse points are to be used as accepted corners used in proportions. The corners thus indentified are recognized by **AUTOPROP** and **PROPORT** as control for proportions. It is also possible to tag each traverse point and/or corner with attributes such as original, local etc. This does not serve any function at present, but may be used in the future to provide symbology with the output graphics.

Computer program **WHATIS** is used to manage your station names and help you keep track of what each station is. After you have run a least squares adjustment of your traverse data you will have created a **.COR** file. This is the least squares adjusted state plane coordinates of your traverse stations.

This tagging can be obtained in one of two ways:

(1) **WHATIS** can be used to give a standard designation to a traverse station. This is the case when evidence in the field is found. In this case the user assigns the traverse coordinates to a new station name (copies the point). The traverse station name is not eliminated.

(2) A coordinate position of a corner is computed using the utilities and identified with a standard corner name. This station will thus appear in the **.COR** file via the utilities and **WHATIS** can be used to assign a properties to that station ID.

The first thing **WHATIS** allows you to do is back up the existing **.COR** file (from the traverse adjustment) into a **.TRA** file. This preserves a copy of the final traverse results. You can assign a traverse designation to all points at this time.

After this is completed, **WHATIS** is capable of assigning coordinates to a new station ID, querying what is the status of a station and updating that status, and listing stations and coordinates.

The following numbering toggles what a station is:

1 - original GLO (found)
2 - original GLO (remonumented)
3 - local (found)
4 - local (remonumented)
5 - temporary
6 - proportioned or set
7 - BLM control
8 - NGS-USGS control
9 - traverse

A station can have any number of these nine designations.

WHATIS also allows the user to query or update the status of a station. By initializing or updating the status of a station the user, and others will have important knowledge of its origination.

Basic WHATIS Dialog

```
WHATIS 2-15-91
WHATIS NOW SAVES YOUR ASSIGNMENT OF COORDINATES (TRAVERSE TO GCDB ID)

YOU HAVE A DEDICATED EDITOR TO MAINTAIN THESE ASSIGNMENTS
ASSIGNMENTS ARE PERFORMED EACH TIME YOU RUN WHATIS

PRESS ENTER TO CONTINUE

WHATIS IS DESIGNED TO ALLOW ONE TO MAINTAIN WHAT A STATION IS
AND COPY TRAVERSE STATION COORDINATES TO OTHER STATION NAMES.
THIS IS THE PROGRAM WHERE YOU WOULD BE ASSIGNING GCDB NAMING CONVENTION
TO FOUND AND/OR SET MONUMENTS.
YOU CAN ADD OR DELETE STATIONS ONLY IN C-STUFF.

THE FOLLOWING NUMBERS DEFINE WHAT A STATION IS

1 - ORIGINAL GLO (FOUND)
2 - ORIGINAL GLO (REMON.)
3 - LOCAL (FOUND)
4 - LOCAL (REMON.)
5 - TEMP.
6 - PROPORTIONED OR SET
7 - BLM CONTROL
8 - NGS-USGS CONTROL
9 - TRAVERSE

        PROJECT NAME IS GR1044
IF THIS IS AN ORIGINAL TRAVERSE .COR FILE YOU MAY WANT TO BACK IT
UP INTO A .TRA FILE                                          This preserves the original data
                                                             the LSAQ run.
DO YOU WISH TO DO THIS (Y/N)? <N>

DO YOU WISH ALL STATIONS IN THE .COR FILE TO RECEIVE
A TRAVERSE STATION LABEL (Y/N)? <N>

(1) ASSIGN COORDINATES (ADD/EDIT/DELETE) MENU                This is how corners are tagged!
(2) WHAT IS ???                                              Query previous flag assignments
(3) LIST STATIONS AND COORDINATES                            List .COR file to see station names
(4) QUIT                                                     The way out.
PICK A # <4>                                                 (default)
1                                                            I select (1) to tag corners.
(1) ASSIGN EXISTING STATION COORDINATES TO A DIFFERENT STATION  Second Menu Option 1 is what I want.
(2) EDIT EXISTING ASSIGNMENTS
(3) DELETE EXISTING ASSIGNMENTS
(4) LIST EXISTING ASSIGNMENTS
(5) RETURN TO WHATIS OPTIONS MENU
PICK A # <5>                                                 (default returns to first menu)
1                                                            Select 1
INPUT NEW STATION NAME: (ENTER IF FINISHED)
700100                                                       SE corner of Township IS:
INPUT EXISTING STATION NAME: (ENTER IF MISTAKE)
16                                                           Traverse Station: 16
STATION 700100          IS


                                                             I set no other flags.
PICK A # OF THE OPTION TO CHANGE: (ENTER IF FINISHED)        (enter)

INPUT NEW STATION NAME: (ENTER IF FINISHED)
700700                                                       NE corner of the Township IS:
INPUT EXISTING STATION NAME: (ENTER IF MISTAKE)
54                                                           Traverse Station: 54
```

```
STATION 700700          IS

PICK A # OF THE OPTION TO CHANGE: (ENTER IF FINISHED)

INPUT NEW STATION NAME: (ENTER IF FINISHED)
100700                                        NW corner of the Township IS:
INPUT EXISTING STATION NAME: (ENTER IF MISTAKE)
84
STATION 100700          IS
.
.
.
```

This process is continued in effect identifying each known corner as such by tagging each traverse point with a standard number.

Appendix I -- Software Installation

Installation Notes -- CMM Version 1.0 Release

Cadastral Survey Measurement Management Software may be contained on differing media. It is distributed on either:

2 - 1.2 Meg 5-1/4" diskette.

or

1 - 1.4M 3.5" diskette.

it can be recopied in a way to be distributed on either

4 - 360K 5-1/4" diskettes.

2 - 720K 3.5" diskettes.

In addition, a hard copy of the documentation should be obtained. It contains a tutorial and other information **ESSENTIAL** for effective operation of the software.

CMM requires a IBM compatible PC with a full 640K base RAM, a hard disk with at least 3MB free space. A math coprocessor is required. An AT 286 or 386 with an EGA or VGA compatible graphics card and monitor, is preferred. We have experienced problems with some portions of CMM on PC's with CGA and monochrome graphics cards. Hercules mono graphics cards can be made to function with most programs if proper emulation routines are run.

Note: If you have your own text compatible (ascii) editor that you would prefer to use with the system, the install process requires that you know it's directory path and name.

What Install does:

The CMM Install process the drive you are installing from and the drive and path you are installing to from the user, then creates that directory, then creates and runs a batch file that manages installing all of the system files and programs. The files are contained in compressed archive format on the installation disk and cannot be run from the floppy, or merely copied to a hard disc and work.

If you do not have sufficient room on the target drive, the install will finish and may appear to complete, but files not fitting will not have been installed. Please be sure you have sufficient space on your disk before proceeding with the installation.

If the source archive file is not found on the selected installation drive, the batch file will prompt you to insert the next diskette. Of course, this will not occur if all the files are on a single source floppy.

When the file installation process is complete (whether or not successfully) the installation resumes by allowing you to specify your own preferred editor or an (enter) will select the default PD editor provided.

The final act of the complete installation process is to create 2 DOS batch files in the root directory of your C: drive. The first of these is critical to the operation of CMM and it is called CMM.BAT. This batch file is the access method to the CMM system and handles CMM's main menu operations. The second batch file created is called GMM.BAT, and it's sole purpose is to allow you to quickly move to the selected CMM drive and directory at the DOS level if you choose.

The second option in the install program can also be used to make a new CMM.BAT whenever necessary, if for example, you move your CMM files to a different drive, directory OR you want to change the default editor choice.

INSTALL STEPS:

1) Place the CMM Beta Release diskette in either drive A or B as appropriate for your system. For the multi disk sets, be sure you inserted disk 1.

2) Log to that drive, for example if drive A: Type:

   a:(enter)

3) then type:

   INSTALL(enter)

4) follow the prompts, and the process is rather straightforward.

   Note: If you have previously installed CMM or MM in the same directory you will be prompted to verify overwriting each file that is installed. Use your judgement about whether this is appropriate or not and answer Y or N accordingly. The install will skip over files that are the same or of later date, so there is no risk of overwriting a later version of a file.

5) After the program exits, you should be able to invoke the system by typing:

   CMM(enter)

   Note: the adjustment portions of CMM require at least 545K of available RAM, therefore it is not advisable to run CMM from many memory resident menu systems. It is best to invoke CMM from the DOS > prompt.

Installing your own editor

Both the Manage 'Main Menu', and the UTCOMM 'Utilities' menu have entries for an editor. The entry on the distribution system is set for a Public Domain editor called TE.

It is expected that people will want to install their own editor, and the system accommodates this. The editor should be an ASCII or TEXT editor, preferrably not a word processing editor. WordPerfect, Wordstar and many other word processors can be used to edit TEXT files if care is taken, but there is also danger that files may be corrupted with special formatting characters used by such systems. One good choice would be WP Library's Program Editor which is a text editor that works a lot like WordPerfect., Norton Editor, PC Write, etc. although the provided PD editor is virtually as powerful. Documentation for the provided editor is installed with the system and is called TE.DOC.

Since the CMM.BAT file is a normal DOS batch file, user's may customize it to some extent so as to exit in a different way. Currently the system returns the user to the C:\ root directory.

UTCOMM - Utilities Menu

Any program may be installed in the Utilities Menu by editing the file UTCOMM.PRG. The program must exist in the DOS path of be in the chosen CMM subdirectory. Batch files will NOT function. Information on how to install programs or otherwise customise UTCOMM.PRG are contained in the header to that file The Version 1.0 release of UTCOMM allows for defining menu colors and defining the menu item 'hot' key with the UTCOMM.PRG file. This is an ASCII file which can be edited by the user.

If you have a program such as AutoSketch that requires a batch file to run in order to install drivers, change directories, etc. Create an appropriate batch file that functions from DOS then compile the batch file with the supplied utility BAT2EXEC. This will then be useable once setup in UTCOMM.PRG.

Deleting or moving CMM

You may encounter difficulties if you attempt to erase CMM, this should only be due to the fact that several of the critical Zone parameter files have been set to DOS's READ-ONLY status. This keeps them from being corrupted inadvertently. There are a number of utilities that can easily remove this flag and allow the files to be deleted, however DOS's ATTRIB command is sufficient. In your CMM directory determine the files that remain undeleted. For example: ZONE.DAT or TABLE.DAT are the offending files:

Type ATTRIB -R *.DAT(enter)

will clear the read-only attribute for those files.

Appendix 2 - Standard Corner Numbering

Many of the proportion routines for rectangular corners in CMM are dependent upon or can perform more automated operations if the standard numbering system is used to identify the controlling or 'found' corners. Those of you familiar with the Bureau of Land Managements Geographic Coordinate Data Base (GCDB) Project will recognize similarities to their system. However the system in use within CMM is simpified and has some significant differences required to meet CMM requirements. *Some places in the documentation do refer to the system as the GCDB system.* Initially it was intended to make CMM independent of the corner identification system, as there are many effective rectangular corner identification systems that have been used throughout the years by different people and agencies. However the improved functionality that accrues in using a specific standard began to emerge as an important attribute. As a result at this point in the system development and use several programs make extensive use of the system:

AUTOPROP for example is dependent upon the system.

INREC's efficient record entry capabilities are only realised when using the standard numbering.

PROPORT is not dependent on the system however it is capable of making a better determination of the proper proportion method when the system is used.

ADJUST is independent of the system.

WHATIS's controlling corner tagging and **SECTSHOW**'s control corner depiction algorythms are dependent upon the system.

For more details see the Reference section documentation for the above programs.

The System

The system consists of a base 6 digit number. The first 3 digits, somewhat like an X coordinate represent corners on the N-S section lines, counting from the West boundary of a standard township. The second 3 digits, similar to a Y coordinate, represent corners located on the the E-W section lines counting from the south. Corners below the section corner level are indicated in approx. chain units i.e. counting from the West and South boundaries of the section. For example the 1/4 corner bet. 20 and 21 is: 300340.

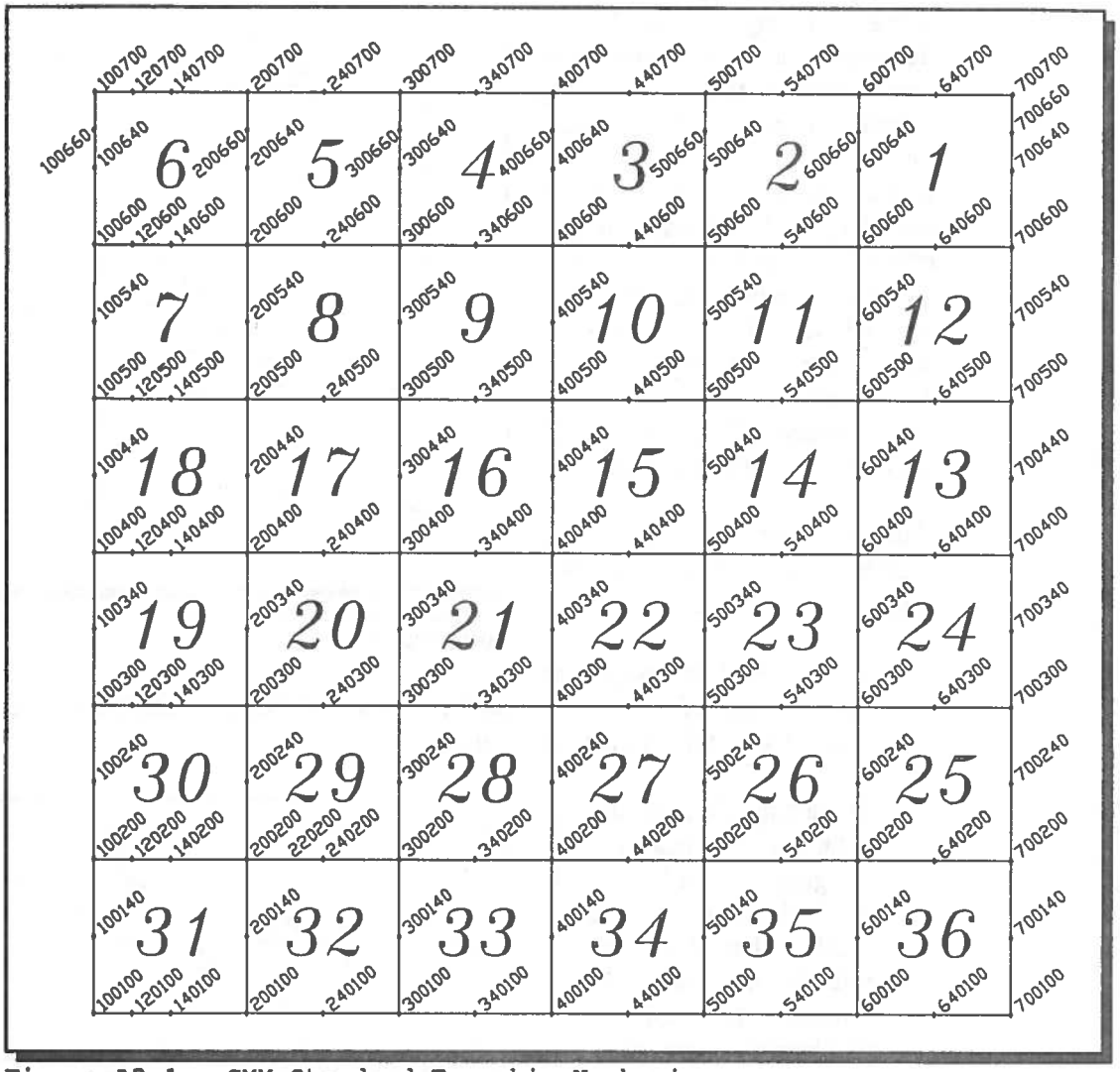


Figure A2.1 - CMM Standard Township Numbering

In the CMM standard system:

* Section corners are characterized by even x00y00 values, like 500300.

* Quarter Section corners are characterized by even 40 chain values like 500340, 540300 or 540340 which is the center 1/4 section corner of section 23.

* Sixteenth Section corners are characterized by even 20 chain values exclusive of the above. Values like 500320, 500360, 560300 (the East 1/16 corner between sections 23 and 26), and 520360 is the SE 1/16 corner of section 23.

* Corners below the 1/16 level are not necessary in the system, that is neither **PROPORT** or **AUTOPROP** compute corners at that level automatically.

* Creativity is required in extended sections. 1/16-80 corners can receive a 400680 designation, but sections elongated beyond 90 chains will require your imagination.

* Witness corners, meander corners, closing corners, etc. are designated at their approximate chain value in the system being careful to avoid EVEN chain increments. For example: a closing corner, CC, on the north boundary of the township that is offset 20 chains from the standard corners might logically be labelled 420700, but since this would indicate a 'regular' 1/16 section corner it should not be used. Instead 419700 or 421700 would be possible selections.

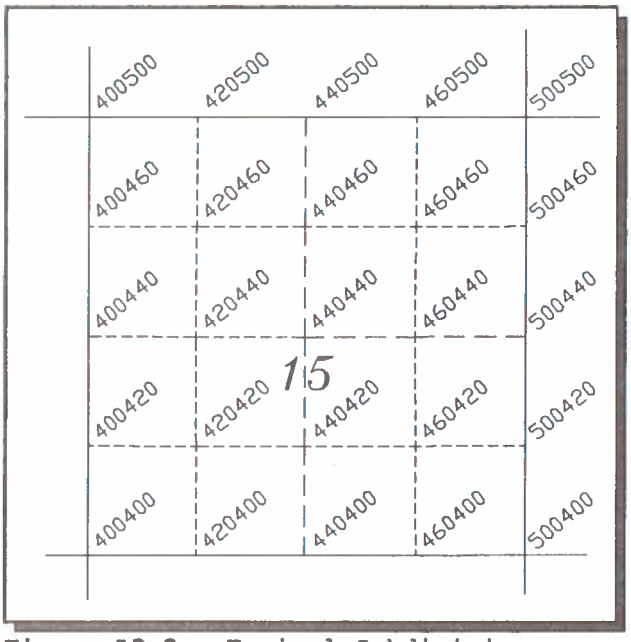


Figure A2.3 - Typical Subdivision Numbering

This is a departure from the GCDB system in at least two ways:

1) In CMM no particular rules are applied to these odd numbered corners, however GCDB rules that do not conflict with this system can be used.

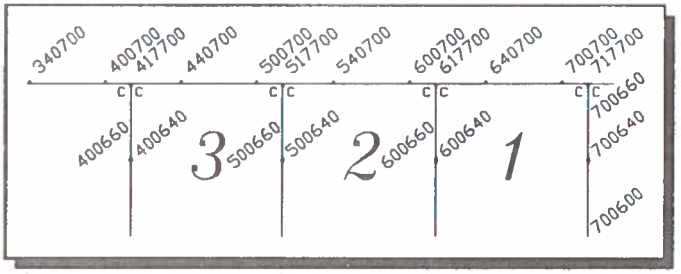


Figure A2.2 - Typical closing corner designation

2) Closing Corners and Standard Corners are designated according to their function in the PLSS rather that their role in the particular township. In GCDB the CC between sections 1 and 2 functions as a section corner and is designated 600700 for the township to the south, but it is not a section corner for the township to the north. In that townhip it would receive an 'odd' designation. In CMM this CC would receive the same first 3 digit designation for both townhips i.e. 617700 for the south township and 617100 in the north township. In CMM the function of the corner is determined by connectivity in .REC file.

The PLSS is very much more complex a system to be able to easily define rules to apply to all cases, user intuition and creativity will have to deal with unusual cases.

Appendix 3 - CMM Glossary

LEAST SQUARES ANALYSIS SECTION

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)

Observation - a fancy word for measurement

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.

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.

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.

Non-Linear Equation - An equation with trigonometric functions and/or powers in it, such as the inverse distance or azimuth equations

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

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.

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.

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.

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 sqaures problems, and especially allows "big" problems to be solved on a personal computer

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.

Number of measurements - equals # of distances + number of angles + number of azimuths + number of control coordinates

Number of unknowns - 2 * total number of stations (1 N, 1 E coordinate)

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

Residual - the difference between a measurement and its computed quantity based on coordinates; It is how much the measurement adjusted.

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 modelled 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).

RMS error - 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.

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 sytematically 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.

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.

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 (68.3% 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.

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 35% confidence (roughly 68.3% 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.

Robustness - This is a method of using least squares as a filtering mechanism for detection of blunders. Robustness averages the absolute value of a measurement's residual with its error estimate, and that average becomes the new error estimate in a readjustment. The measurements with large residuals get reassigned larger error estimates, and vice-versa. This enables the adjustment to be filtered to the suspect measurement. The success of robustness in blunder detection is a function of size of the blunder, number of blunders, and the geometry and redundancy of the the traverse network.

GEODESY / STATE PLANE COORDINATES SECTION

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!

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.

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 type of projections that exist are Lambert - a conic projection for states elongated east-west, and Mercator - a cylindrical projection for states elongated north-south. The size of a zone was limited by defining a a state plane distance will not differ from its geodetic counterpart by 1/10000 of the distance. Thus larger states are covered by more than zone.

NAD 27 state plane coordinates - 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 state plane coordinates - 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.

Geodetic distance - a horizontal distance between two points measured on the earth.

Grid distance - a geodetic distance which has had scale and elevation factors applied to it to reduce it to the state plane zone.

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.

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.

Elev. Factor = R / (R+h) where R = radius of the earth (20,906,000 ft)

h = elevation

Relation of Geodetic and Grid Distance

Grid Distance = Geodetic Distance * Scale Factor * Elevation Factor

Geodetic Distance = Grid Distance / (Scale Factor * Elevation Factor)

Geodetic azimuth - the direction of a line relative to geodetic north

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

Convergence angle - the angle between grid and geodetic north at a point. It is a function of location in the zone.

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.

Relation of Grid and Geodetic Azimuth

Grid Azimuth = Geodetic Azimuth - Conv. Angle + second term correction

Geodetic Azimuth = Grid Azimuth + Conv. Angle - second term correction

GENER error message explanations

MISSING NECESSARY DATA FOR COORDINATE GENERATION

This means you are missing control coordinates, directional control, and/or measurements which enable coordinate generation by traverse.

NO DISTANCE TO CONTROL POINT. STOP

It is impossible to generate coordinates by traverse if there are no distances to any control coordinates.

APPROXIMATE COORDINATE LINE NOT FORMATTED CORRECTLY

If the "use existing coordinates" option is used any approximate coordinate line in the .LSA file which is formatted incorrectly will trigger this message and the line will be ignored. This can only happen if one has been editing the .LSA file with a text editor.

ERROR - TRAVERSE LINK GENERATOR LIMITS EXCEEDED

A traverse has more than 3000 stations in it.

MISSING ANGLES ON TRAVERSES BETWEEN CONTROL STATIONS
PROCEED WITH ANGLE-DIST ON ASSUMED DIRECTION

If more than one control station exists in your data this message will appear if input angle/distances do not allow a traverse between control stations to be identified. GENER will then compute a series of angle distance combinations from the first control station until traverse is possible. Rotation of the network to fit existing control occurs after a coordinate pair is generated for every station.

FROM STATION A TO STATION B DISTANCE CLOSURE = 1.23 FT.

This message is associated with the previous message. When rotation to fit control occurs (2 control stations required) a distance comparison of traverse to control can also be computed.

ROTATION NOT POSSIBLE - MISSING DATA

If only one control point exists, an azimuth must be used for directional control. If GENER cannot compute coordinates for the azimuth endpoints due to an omission of data the rotation of the assumed coordinate system used in coordinate generation cannot occur.

DIRECTION ASSUMPTION HAS BEEN CORRECTED

If only one control point exists, GENER computes all coordinates based on an assumed direction. After all coordinates are generated the coordinates are rotated based on the first input azimuth.

*** COORDINATES UNDETERMINED FOR STATION A

This is a good message if you have intentionally eliminated all messages regarding station A. It verifies you succeeded. If station A is supposed to be part of your traverse network for some reason coordinates could not be generated for it and you must correct the situation before procedding any further.

ERROR - TOO MANY STATIONS IN INPUT NETWORK -STOP

The 3000 station limit has been exceeeded.

STATION A IS NOT ON A DISTANCE IN INPUT FILE

Usually each station should have a distance connected to it.

STATION A IS NOT ON AN ANGLE IN INPUT FILE

Usually each station should have an angle connected to it.

YOU NEED TO INPUT SOME CONTROL STATIONS

GENER cannot compute coordinates unless one control station and one azimuth, or more than one control station, has been input.

YOU HAVE ONLY ONE CONTROL POINT & NO AZIMUTHS - CANNOT BE SOLVED

There is no way to control direction.

DO YOU WANT TO QUIT WITHOUT COORDINATE GENERATION (Y/N)? <Y>

If either of the previous two situations exist you may exist GENER to save data without generating coordinates.

ERROR - INPUT FILE EXCEEDED ONE OF THE FOLLOWING LIMITS
NUMBER OF STATIONS = 3000
NUMBER OF DISTANCES = 4000
NUMBER OF ANGLES = 4000
NUMBER OF AZIMUTHS = 3500

GENER has some size restrictions.

FORMAT ERROR DETECTED IN CONTROL STATIONS - RUN SETUP

FORMAT ERROR DETECTED IN DISTANCES - RUN SETUP

FORMAT ERROR DETECTED IN ANGLES - RUN SETUP

FORMAT ERROR DETECTED IN AZIMUTHS - RUN SETUP

You have probably edited the .LSA file with an editor and the file is no longer correctly formatted.

NO COORDINATES FOR STATION A WRITTEN TO FILE

This is a good message if you have intentionally eliminated all messages regarding station A. It verifies you succeeded. If station A is supposed to be part of your traverse network for some reason coordinates could not be generated for it and you must correct the situation before procedding any further.

TEMP.JOB IS MISSING PROJECT NAME - RUN PROGRAM PROJEC
This file holds the project name. For some reason it does not exist.

.DEF FILE FOR THIS PROJECT IS SCREWED UP - ERASE IT AND RUN PROJEC

The .DEF file contains project definitions. It has probably been edited with a text editor and is no longer formatted correctly.

LSAQ error message explanations

STATION A NOT ON ANY MEASUREMENTS - IGNORED

If an unknown station has approximate coordinates for it in the .LSA file but no measurements to it it is ignored. This can only happen if the .LSA file was editted with a text editor.

ONE OF THE FOLLOWING LIMITS HAS BEEN EXCEEDED
TOTAL NUMBER OF CONTROL STATIONS = 900
TOTAL NUMBER OF STATIONS = 3000
TOTAL NUMBER OF DISTANCES = 4000
TOTAL NUMBER OF ANGLES = 4000
TOTAL NUMBER OF AZIMUTHS = 900

LSAQ has some size restrictions.

FORMAT ERROR DETECTED IN CONTROL STATIONS - RUN SETUP
FORMAT ERROR DETECTED IN DISTANCES - RUN SETUP
FORMAT ERROR DETECTED IN ANGLES - RUN SETUP
FORMAT ERROR DETECTED IN AZIMUTHS - RUN SETUP
APPROXIMATE COORDINATE LINE NOT FORMATTED CORRECTLY - RUN SETUP

UNEXPECTED END TO INPUT FILE - STOP

You have probably edited the .LSA file with an editor and the file is no longer correctly formatted.

MEASUREMENT FOUND WITHOUT STANDARD ERROR
RUN COMPUTER PROGRAM SD BEFORE RUNNING LSAQ - STOP

If you are using the read error estimates from .SD file option there must be a one-to-one correspondence of it to the .LSA file. This message appears if this is not true. Running SD fixes this. The error occurs when you add data in GENER and do not run SD prior to LSAQ when this option is used.

MISSING PROJECT NAME - RUN PROJECT MANAGER

TEMP.JOB holds the project name. For some reason it does not exist.

.DEF FILE FOR THIS PROJECT IS SCREWED UP - ERASE IT AND RUN PROJECT MANAGER

The .DEF file contains project definitions. It has probably been edited with a text editor and is no longer formatted correctly.

*** INSUFFICIENT AMOUNT OF CONTROL TO PERFORM THE ADJUSTMENT ***

LSAQ cannot compute coordinates unless one control station and one azimuth, or more than one control station, has been input.

CANNOT FIT INTO PAGING ALGORITHM - STOP

The least squares solution uses a technique called paging to store equations for very large surveys. It is remotely possible to reach size restrictions of this algorithm.

*** MAXIMUM NUMBER OF ITERATIONS REACHED ***

LSAQ quits at 10 iterations if updates are still larger than 0.005 ft.

*** SOLUTION DIVERGING - ITERATION HALTS ***

In cases of large blunders the solution will not converge.

NO ERROR ANALYSIS DUE TO NETWORK SIZE

If paging has to be used LSAQ cannot compute error ellipses.

NO SUITABLE INFORMATION FOUND IN ELEVATION FILE
SO FIX FILE OR USE PROJECT ELEVATION - STOP

You have selected the read elevations from .LEV file option and no suitable information is in that file.