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A REALIZATION OF AN AUTOMATED DATA FLOW FOR  
DATA COLLECTING,  
PROCESSING, STORING AND RETRIEVING\*

- GEONET -

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ABSTRACT

GEONET is a database system developed at the Stanford Linear Accelerator Center for the alignment of the Stanford Linear Collider. It features an automated data flow, ranging from data collection using HP110 handheld computers to processing, storing and retrieving data and finally to adjusted coordinates. This paper gives a brief introduction to the SLC project and the applied survey methods. It emphasizes the hardware and software implementation of GEONET using a network of IBM PC/XT's.

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## INTRODUCTION

The Stanford Linear Accelerator Center (SLAC) is in the process of building a new particle collider, the Stanford Linear Collider (SLC) [ERIKSON, 84]. The tunnel which houses the SLC is about 3 Km long and contains approximately 1000 magnets. To do the precision alignment of these magnets nearly 400 control points are established. The positioning of the magnets in X,Y,Z, roll and pitch requires the determination of about 2500 fiducial marks [OREN, 85]. The accuracy requirement for the absolute positioning of each magnet is 1 to 2 mm while the relative positioning between adjacent magnets requested an accuracy better than 0.1 mm. All magnets have to be positioned using an iterative procedure from the rough layout of coordinates for the magnet support systems to the final smoothing of adjacent magnets [PIETRYKA, 86]. This leads to an estimated 50,000 to 60,000 coordinates which have to be determined during the construction time frame of 3 years. To control this huge amount of data an automated data flow from data collection to data processing and finally data storing is essential. Since none of several evaluated software packages [GRÜNDIG, 84] fulfilled our needs or matched the already existing hardware, the decision was made to write a customized data base program, GEONET. Figure 1 shows a finalized sketch of the data flow from the measurements to the coordinate database as it is implemented in GEONET [RULAND, 86].

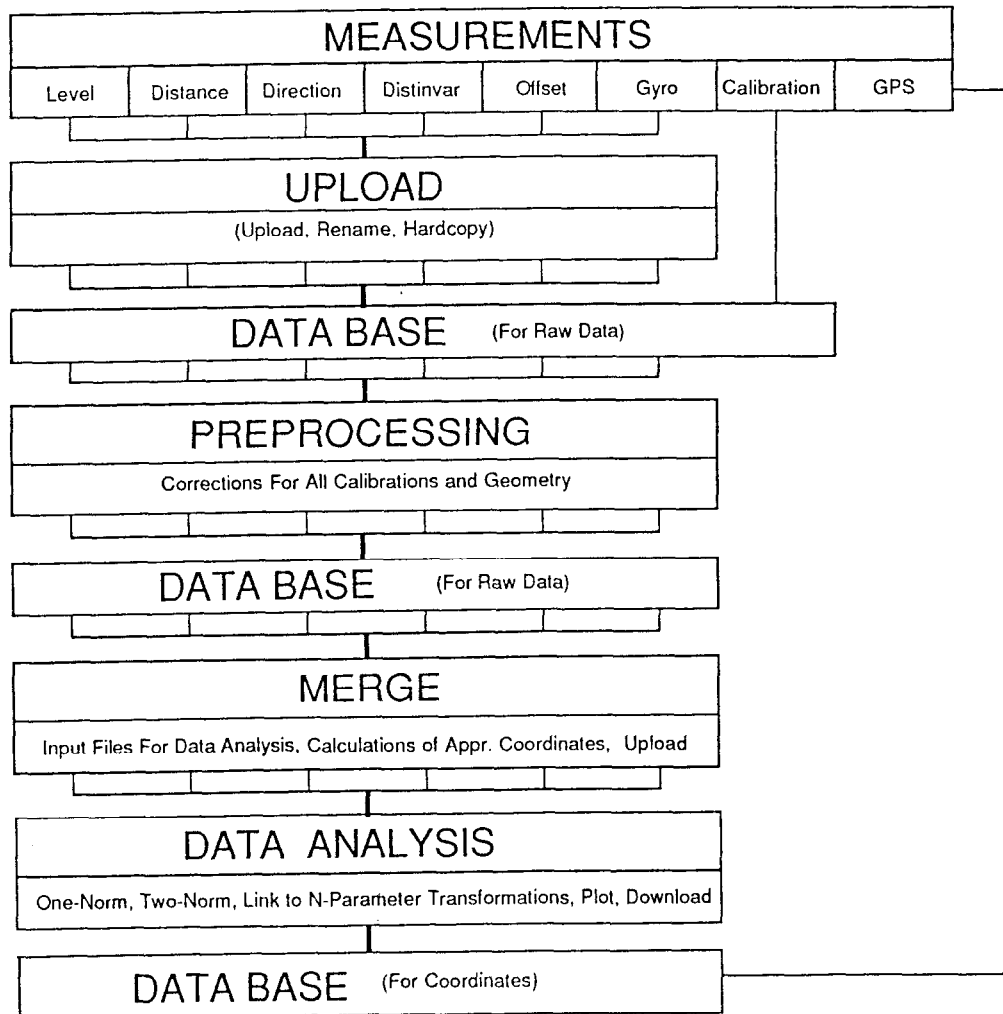


Figure 1 Data Flow Chart

## HARDWARE CONFIGURATION

In order to establish a totally automated data flow procedure each step of the surveying process needed to be computerized as much as practical, beginning with the collection of observations in the field and carrying through to the final least squares adjustment of coordinates. The first step was to find a suitable data collector. After having evaluated several different hand held calculators for example the HP41CX, HP71B, EPSON HX20 etc., the HP110 portable microcomputer from Hewlett-Packard was chosen. Although the HP110 computer has the disadvantage of being heavier than most other available data collectors [DONAHUE, 86], its sturdiness, reliability, ease of data transfer, size of memory and the capability to write specialized data collection programs made it the best choice for a data collector.

The link between HP110's and survey instruments is accomplished using the RS-232 port built into the HP110. In the case of KERN E2 theodolites a SLAC designed interface box, able to serve up to four theodolites, is used to translate the signals from the E2 to the standard RS-232 levels. The communication between E2 and HP110 is bi-directional, making it possible not only to record data but also to send data such as horizontal and vertical angles to the E2 for display or to control its settings.

Two different concepts for the implementation of a geodetic database were considered. The first was to run the data handling and least squares adjustments on a mainframe, either an IBM 3081, VAX 750, or VAX 860 [GRÜNDIG, 84]. The alternative concept was to set up a system of Personal Computers, interconnected by a local area network. Each idea had certain advantages and disadvantages. The obvious advantages of the mainframe approach is its speed and virtually unlimited memory size. But the major disadvantages are the inability to have control regarding operation and maintenance hours and the difficulty to establish a connection to the field data collectors. These are tasks easily accomplished with a PC/XT. Consideration of the advantages of both the mainframe and PC/XT led to the decision to implement a hybrid system combining the best features of both approaches.

The first part of the hybrid system, the data management, is done using a cluster of PCs. The local PC workstations are interconnected by a 10 Mbit Ethernet local area network. Remote access is also possible using modems; this feature is used for the transfer of calibration data between the office and the calibration room, located several miles away from the server. Each PC is equipped with a co-processor, 640 Kbytes of memory, a 20 MByte hard disk and an accelerator board running at a clock rate of 10 MHz. The network permits sharing of a 35 Mbyte hard disk, an internal tape backup system and an HP LaserJet printer. In addition, plot facilities including A-size and E-size plotters are available. A sketch of the hardware setup can be seen in Figure 2.

To establish the connection between the HP110 data collectors and the network, each PC is equipped with an HP-IL interface board which lets the PCs look at the

HP110's as at external disk drives. The actual data transfer is done by using the DOS copy command. This link provides an easy, fast and reliable exchange of files in both directions.

The second part of the hybrid system involves the use of an IBM 3081 mainframe to process least squares adjustments. Input files, created on the individual PC workstations, are uploaded to the mainframe and result files are downloaded via an RS-232 communication port to the PC.

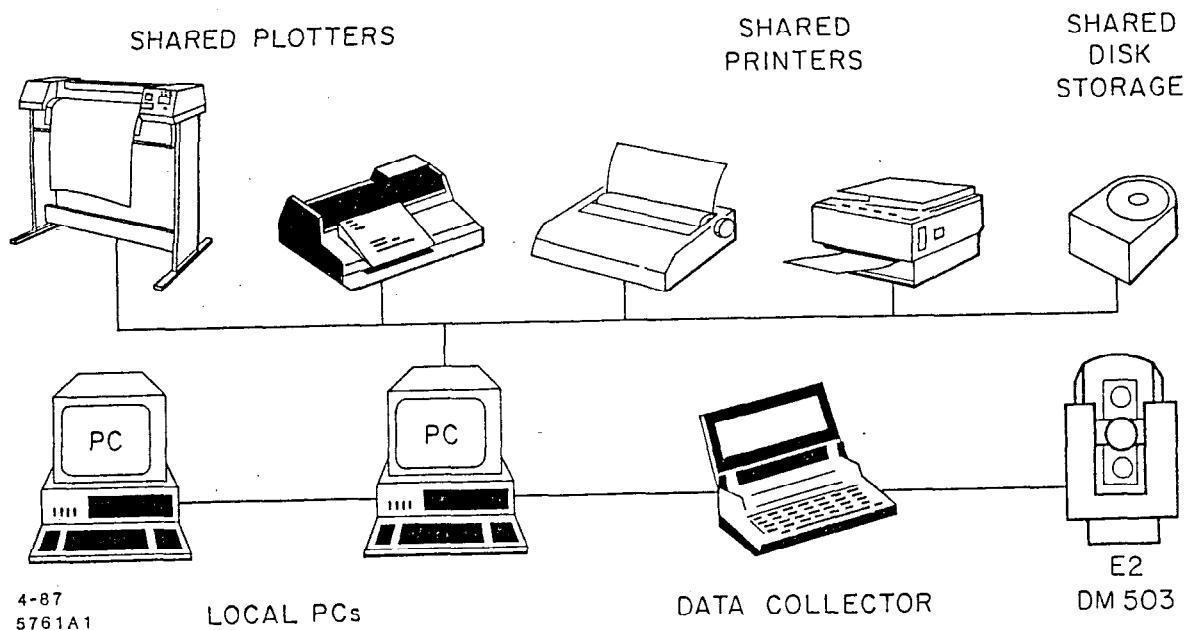


Figure 2 Hardware setup

## SOFTWARE CONFIGURATION

### Basic Structures

During a large scale survey project such as the construction of the SLC several different forms of data have to be managed. Among these forms are:

- recorded field data observations
- calibration data for various instruments used
- reduced measurement data
- and several different coordinate databases

GEONET provides data structures and programs to handle all of the above data forms.

GEONET takes advantage of the subdirectory structure provided by the DOS operating system on the PC. Each recorded field observation is transferred from the

HP110 data collectors to the PC and stored in a data file system. All data files are stored in a four level hierarchal structure and can be accessed via a menu by using a pathname of the following form :

$$\text{pathname} = \backslash \text{basename} \backslash \text{location} \backslash \text{type} \backslash \text{epoch}$$

where *basename* is the data file system identifying name.  
*location* is the location of the points surveyed.  
*type* is the type of survey data.  
*epoch* is the survey epoch.

GEONET can handle more than one data file system at a time and it is possible to use up to 16 unique names for each of the location, type and epoch variables. The result files created by the reduction programs are stored together with the measurement data using the same pathname. Calibration data is stored in a similar form using a calibration file structure also of four levels. The coordinate database is defined as a two level subdirectory structure. In this case the pathname is created as follows:

$$\text{pathname} = \backslash \text{COORD} \backslash \text{location}$$

where *COORD* is the coordinate database identifying name.  
*location* is the location of the points in the database.

**Data Management System Function Menu**

1. Upload field data	2. Process pending updates
3. Data reductions	4. Transfer to shared disk
5. Generate Input file	6. Perform Adjustment
7. Coordinate database	8. NSC800 operations
9. Access server disk files	10. Access calib data
11. System configuration	12. Archive subsystem
13. Escape to DOS	14. Exit Geonet

Enter function number:

Figure 3. GEONET Main Menu

The interaction between these various data forms is organized by the GEONET data management system function menu shown in Figure 3. It is presented after the user enters his password. Each password allows access to a unique group of GEONET functions depending on the user's privilege. The upload function for instance can be used by each member of the survey crew while the reduction of data is a restricted function only accessible for privileged users.

The following sections describe each of the options addressed in the data management system function menu in more detail.

### Upload Field Data

The function "Upload field data" is used to transfer data collected, using the HP110, to the local hard disk of the PC and then to a shared temporary storage disk maintained by the server. Each individual data collection program creates its own filename and a unique filetype for each observation. For instance, the filename for a direction set is given by the station name and the filetype is defined as .DIR, thus simplifying the upload procedure by using wildcards for the file transfer. Other measurements such as EDM or Distinvar observations obtain a filetype .DST and .INV, respectively. During the upload procedure the filetype is replaced by the Julian date of the day the measurements were recorded. At the same time the filetype of the original data file still residing on the HP110 is changed to .999 thus eliminating the possibility to upload a file twice and making it an easy task to erase all uploaded files on the HP110 after the data transfer is done.

The upload program also accesses an index file stored in the same subdirectory as the recorded observations. It is always updated whenever a new observation file is added to a subdirectory. The index file is used by other programs, mainly reduction programs, to open and read each individual file of a specified subdirectory.

Currently, data collection programs for the following observation types exist:

- Direction measurements
- EDM measurements
  - DM503
  - Mekometer
- Distinvar measurements
- Level measurements
- Set-out of points [CURTIS, 86]
- Control of dial gauges

Most of these programs incorporate error checking routines which are performed in the field while measuring. For example the direction collection program checks for

gross errors, such as pointing to the wrong target, and also performs a statistical analysis after three sets of direction measurements are completed. This analysis verifies for the user the reliability of the measurements made on a station by calculating the mean square error for the direction sets. In case the statistical check fails an additional set is requested by the program. If the statistical analysis still fails after the fourth set is measured, the station has to be remeasured completely. Another example of error checking is used while leveling. By using double scaled level rods it is possible to compare the difference of the left and right scale reading against the known offset between both scales and thus check for gross errors. An even number of setups within a level loop is required by the program, to eliminate the level rod offset when using two different rods.

### **Process Pending Updates**

After uploading the recorded field data to the PC, the next step is to transfer these observation files from the shared disk to the actual database for permanent storage. This is done by function two of GEONET's main menu called "Process pending updates".

### **Data Reduction**

Before the input files for a least squares adjustment can be formed, certain observations must be reduced for geometric or atmospheric corrections, while others have to be reformatted. Level lines, for instance, are reduced for the effects of the level rod calibration, as well as for the measured temperature of the rod tape during leveling [PELZER, 83]. Distances are reduced to a reference surface, in this case a Gaussian sphere best fitting the ellipsoid at the longitude and latitude of SLAC. Atmospheric corrections are also taken into account [BRUNNER, 84]. Direction sets are summarized and reformatted to their final form.

Reduction programs for the following measurements are currently available:

- Level measurements
- EDM measurements
  - DM503
  - MEKOMETER
- Distinvar measurements
- Direction measurements
- Offset measurements

After having evaluated the results of the reduction programs the user can move the result files from the local disk to the GEONET database using again option two "Process pending update". The next step will be to generate an input file for the

appropriate least squares adjustment.

## Generate Input File

The input file generation function creates input files for a group of geodetic adjustment programs used at SLAC [BURSTEDDE, 87]. These adjustment programs include 1-norm and 2-norm adjustments for 1, 2 or 3 dimensional networks. The datum of the network may be chosen as a unconstrained, minimal constrained, constrained or as a connected net bound to a superior net. The program for which the input file is required is determined using the menu shown in Figure 4.

Definition of the Program Name			
Adjustment type	(OT)	=>	
Network dimension	(123)	=>	
Input data	(ERD)	=>	
Orientation	(UATCF)	=>	
<u>Adjustment</u>	<u>Network</u>	<u>Input</u>	<u>Orientation</u>
O...1 Norm	1...One Dimen	E...Error Prop.	U...Min. constrained
T...2 Norm	2...Two Dimen	R...Real Obs.	A...Constrained
	3...Three Dimen	D...Def Analysis	C...Connected
			F...Unconstrained

Figure 4. Definition of Adjustment Program Name

The program names are all four letter combinations where the first letter indicates the adjustment type, the second letter the network dimension, the third letter the input data type and the fourth the datum of the net. The user types one letter after each arrow on each line of the menu. These letters are then concatenated to form the program name .

Once the name of the program is known, the user is presented with a series of sub-menus which allow the user to specify which points to include in the adjustment, what types of observations are to be used and from which epochs the data should be taken. The data is then merged automatically into the input file in the format required by the adjustment program.

## Perform Adjustment

Only 2 out of the 24 different possible adjustment programs running on the main-



frame, were implemented on the PC network; a one-dimensional constrained adjustment (T1RA) for a level net with up to 60 benchmarks and a two-dimensional constrained adjustment (T2RA), which allows the adjustment of a net with a maximum of 40 points. All other adjustments are being processed on the mainframe after uploading the input file to the IBM 3081.

### **Coordinate database**

Choosing this option takes the user to a sub-menu , which provides two options:

- Updating of an existing database
- Retrieving of coordinates from a database

In order to update a certain coordinate database, a specially formatted file, created by each least squares adjustment, has to be downloaded from the mainframe to the PC workstation. The coordinate database can then be updated using this function. An input file created for a later least squares adjustment then always picks up the most recent coordinates as approximate coordinate values.

The second option of the sub-menu can be used to retrieve coordinates of the coordinate database, thus providing a history of the movement of each survey monument.

### **NSC800 Operations**

This option is provided for up and downloading programs and data files between the PC/XT and NSC800 micro processor controlled devices such as the SCHAEVITZ inclinometer, the hydrostatic level ELWAAG [THIERBACH, 79] and OFFSET measurement devices for the linear accelerator section of the SLC. The programs and interfaces which control these devices have been custom developed at SLAC.

### **Access server disk files**

A privileged user is allowed to browse through the database, verify the contents of a selected subdirectory and print or edit certain files, by using this function.

### **Access calibration data**

Similar to the previous function, this option enables one to browse through the calibration database.

### **System configuration**

The system configuration option allows the user to create a new survey epoch for the data and calibration file system or to delete obsolete ones. The deletion of a survey epoch is only possible if the selected subdirectory does not contain any files.

A separate coordinate database can be assigned to each survey project. This option

provides the possibility to create new coordinate databases using the standard basic structure described earlier.

### Archive subsystem

Considering the fact that even the smallest files allocate 2 Kbytes of disk space, this function allows the user to combine several files into one file, in order to save disk space. This process is called data compression and is mostly used after the data reductions are done and the raw data is no longer used. Another part of this function allows one to archive obsolete data onto floppy disks in order to free up even more disk space. In both cases archived and compressed files can be retrieved and split into individual files at any time if necessary.

### Escape to DOS

The escape to DOS function permits the user to temporarily return to the DOS command level while running GEONET. This is useful for examining the contents of the hard disk or performing a DOS command. To return to the GEONET session, the 'exit' command is used.

### Exit GEONET

The Exit Geonet function terminates a GEONET session. It returns the user to the subdirectory from which GEONET was originally invoked.

## CONCLUSION

The experience with GEONET has shown that the time it takes from recording measurements in the field to obtain adjusted coordinates is reduced tremendously by using an automated data management system. Without a system like GEONET it would have been impossible to align the Stanford Linear Collider in the given time frame of three years.

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