

ALS SURVEY DATA MANAGEMENT SYSTEM*

James Osborn[#], Daniel Pulsifer, Robert Duarte, Alex Gavidia, Christopher Hernikl,

Daniel Ellis, and Harry Meyer, LBNL, Berkeley, CA 94720, U.S.A.

Abstract

A Survey Data Management System has been developed for the Advanced Light Source at Lawrence Berkeley National Laboratory. The system supports standard web browsers on the client side and utilizes open source technologies on the server side (Linux, Apache, PHP, MySQL). The system provides an access controlled means for storing and retrieving current and past survey data, for generating comparison graphs of horizontal and vertical displacements of measured points between up to four different data sets, a work flow process to control which data sets are considered official, and a means of generating a most current global data set called "moncor". The moncor file is composed of the latest official data from all data sets in the system and is used in the field to establish the coordinate system for survey measurement and alignment activities on a daily basis. Usage of the system with emphasis on the data comparison capabilities will be demonstrated.

INTRODUCTION

The Advanced Light Source (ALS) at Lawrence Berkeley National Laboratory (LBNL) is a synchrotron radiation facility. The ALS was built inside an existing building that used to house the 188 inch cyclotron at the LBNL site. Only the skeleton, dome and existing crane as well as the yoke of the original accelerator facility are apparent. During the construction phase of the ALS, as shielding blocks, girders full of accelerator components and other heavy equipment were installed, the floor moved a great deal. Over time the floor movement, which has a great impact on the accelerator performance, has slowed, but there are still seasonal and temperature effects that are not completely understood.

In order to better track these effects over time to better understand them and to evaluate the validity of survey data as it is acquired and processed by comparing it with past data, it was envisioned that a system could be used to manage the data and provide a means of preparing comparisons between past and present data sets.

ALS Components

The ALS utilizes an electron storage ring lattice composed of 12 sectors. Each sector contains a number of bend, focusing and corrector magnets kinematically supported by six adjustable struts that are supported by a girder. Each girder in each sector is in turn supported by six struts that are supported by the storage ring floor. The storage ring resides in a roughly circular tunnel formed by

the slab foundation floor and shielding wall and roof blocks. Realignment of components may thus be done locally relative to a girder, or a full sector of components may be realigned by correcting the position of the entire girder. In practice after more than ten years of operation, mostly girder realignments are now required.

The following discussion extends to insertion devices and experimental beamlines. Insertion devices are synchrotron undulators and wigglers that are "inserted" into the straight sections between storage ring sectors and are treated much like the sector girders. The beamlines are outside of the storage ring tunnel and utilize similar supports and alignment methods as storage ring components. For the purposes of this paper, the discussion will generally refer to and give examples using the storage ring data but should be implied to extend to insertion devices and beamline components as well.

ALS Survey Network

The survey network for locating and aligning the accelerator components is based on a series of monuments installed in the storage ring floor and fiducials on each component. Components are realigned by tying into the monument network, surveying the current position of the fiducials, and then corrections are calculated to move the components back to an ideal position. Girders are realigned similarly using a best fit of all the components to their respective ideal positions.

On a yearly basis, during major ALS shutdowns, the coordinate system of the accelerator (ideally level and at the center of the storage ring) and the positions of the monuments in this coordinate system are determined using multiple instruments and methods (outside of the scope of this paper). A major realignment which may include local and/or girder based corrections are typically performed during these shutdowns. During the course of the time between these major realignments, components outside the storage ring are often located and aligned relative to the established coordinate system by tying into the storage ring monument network and "front end" components, those storage ring components just before the synchrotron radiation leaves the storage ring.

MonCor Files

Most of the movement in the floor (and thus the monuments and girders supported by it) are elevation changes. There is the opportunity to quickly acquire accurate elevation survey data many times during the year in between major survey and realignment cycles. There is therefore a need to continually update the best known positions of monuments by overlaying the latest trusted three dimensional data with newer trusted elevation only

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[#] JROsborn@lbl.gov

data. The survey and alignment group at the ALS uses a set of data called MonCor (Monument Coordinates) which is the current best known position of the monuments formulated in this way. The need to organize and archive past data and provide comparison capabilities provided a natural benefit of allowing the possibility of an automatic calculation of MonCor data based on date stamp information of survey data imported into the system.

SYSTEM FEATURES

The Survey Data Management System described in this paper evolved over a period of approximately a year and a half. The need for comparisons to generate confidence in survey data during major shutdown and realignment cycles was the primary driver in the beginning of development. As the system grew other features became apparent such as the need for different “states” for data imported into the system and access controls to determine which users could make changes to the data or states. And some features such as the algorithmic generation of MonCor data were not considered until the system started to be used in earnest. Table 1, 2, and 3 show the resulting basic features resulting from this evolution, classified by user interface, data organization, and access control, respectively.

Table 1: System User Interface

Feature	Purpose
Web based user interface	Simultaneous access by multiple users and reviewers on different platforms
Horizontal comparisons	Observe magnified differences in horizontal positions between surveys
Elevation comparisons	Observe magnified differences in elevations between surveys
Generate MonCor	Use date stamp and state information to generate MonCor for “free”

Table 2: System Data Organization

Feature	Purpose
State based data	Support for provisional as well as official and other states
Time and user stamp data	Keep track of who made changes and when
Import ZXY data	ALS 3D coordinate system is based on Z, X, Y, origin at machine height center of storage ring
Import Y data	ALS elevation survey data
Import MonCor data	Past MonCor data includes ZX and Y data points which may have independent date stamps

Table 3: System Access Control

Feature	Purpose
Access controlled	Only authorized users can review and/or make changes to data or states
LDAP authenticated	LBNL single sign-on accounts leaves many security issues to IT dept

IMPLEMENTATION

Platform

To maximize server resource utilization, the Survey Data Management System runs within a virtualized Linux (CentOS 5.1) operating system environment which in turn runs on a VMWare/ESX server. This allows for better allocation of processor and memory resources by running the system along side other virtualized operating systems.

The system is built upon another tier of virtualization at the Apache web server layer. It utilizes a core library system built by LBNL using PHP for program logic and MySQL for data storage. This library provides an environment that handles the generic operation of the site like security, authentication using the LBNL site LDAP server, authorization, database access and basic website layout and themes.

By employing these central libraries, the Survey Data Management System is another application module that can be run in conjunction with other production LBNL websites. Site-specific logic then resides within the application layer which is separated into it’s own directory and virtual web host by listening on a dedicated “alssurvey” site IP address. Most of the basic system logic is encoded into an application layer class that is called from the various pages/scripts that comprise the system. The system uses a number of special classes for handling monument/component grouping and ordering as well as graphing functions.

For sorting a large number of components into a predefined preferred order when the component data can be acquired and subsequently imported into the system in any order, the system takes advantage of the Modified Pre-ordered Tree Traversal (MPTT) algorithm [1]. MPTT allows the system to order the data based on a complex nested structure rapidly using only one query instead of recursive queries. The MPTT algorithm is ideal for performing fast reads/selects from databases, but has some extra processing overhead when adding components, but this does not happen as often as reading the structure. For the case at hand, the MPTT sorting table is essentially static until new components and/or monuments are added to the network.

Another special class that the system employs is JPGraph [2] for generating the comparison plots that the system supports. JPGraph is a graphing library built with PHP that utilizes the GD libraries installed in Linux to allow the dynamic creation of graphical images in PNG format. These graphs can be embedded within web pages and/or converted to PDF documents for high resolution

output. This provides a great number of graphing options that are utilized by the system to build comparison plots that help the users of the system interpret and compare survey data sets.

Importation of Data

The system does not aim to process or store raw survey data but rather is a repository for processed survey data sets. These can be either elevation data only surveys or 3D data surveys, typically acquired using a laser tracker and preprocessed and rectified into the ALS coordinate system using a variety of methods. From the early stages of development, it was clear that the system needed to be able to import old and new data from a variety of sources.

In order to do this consistently through web pages on any platform, the system supports the import of three types of data, all in Comma Separated Value (CSV) format:

- **Y Only** – NAME, Y
- **ZX & Y** – NAME, Z, X, Y
- **Moncor** – NAME, Z, X, ZX-Date, Y, Y-Date

Where NAME is the unique identifier of a monument or component fiducial and Z, X, and Y are in meters using the standard ALS coordinate system conventions. For elevation and 3D surveys, the user is given the opportunity to provide one date that applies to every data

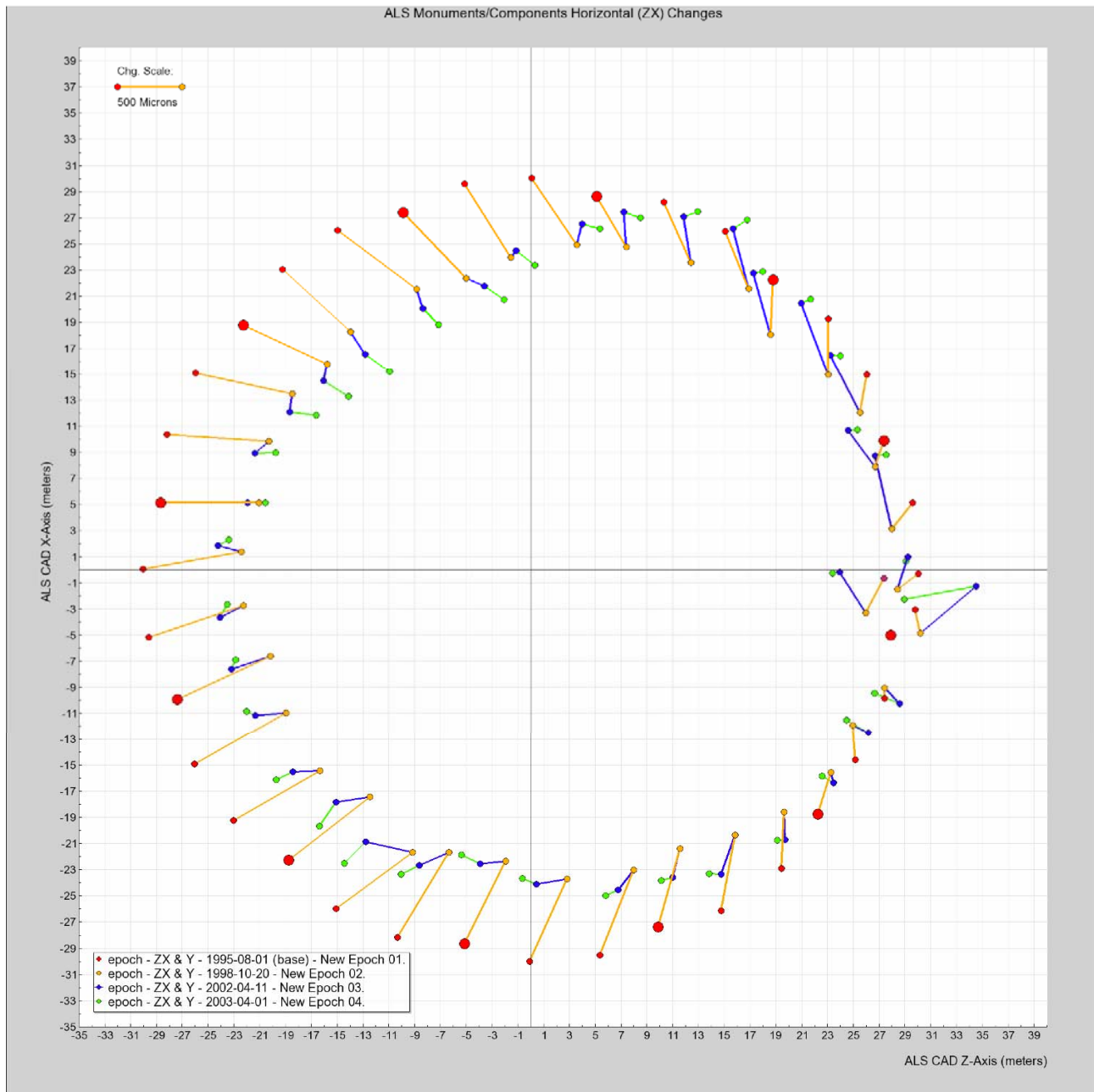


Figure 1: An example of a horizontal change comparison between four major ALS surveys covering the years from 1995 through 2003. The selected reference monument used to anchor the coordinate system is apparent (no changes).

point in the imported file, a legend (to appear on plots), a description, the list of staff involved, and the list of instruments used. The moncor format allows data to be imported that may have unique dates for the horizontal ZX and/or elevation Y components on a per data point basis.

Data States

The system currently provides for a number of data states (but new states are easily added if and when the need arises):

- **provisional** – un-vetted, temporary and/or

experimental data

- **official** – vetted, permanent, trusted data
- **epoch** – major set of official ALS data
- **moncor** – a combination of the most recent moncor, epoch, and official data, overlaid onto each other on a per data point basis
- **archive** – old experimental or temporary data
- **ideal** – hypothetical ideal component locations

Permission to read, modify and/or change states for data sets can be controlled on a per user basis. Some users are allowed only to import data while others are permitted to move data out of the provisional state. Any

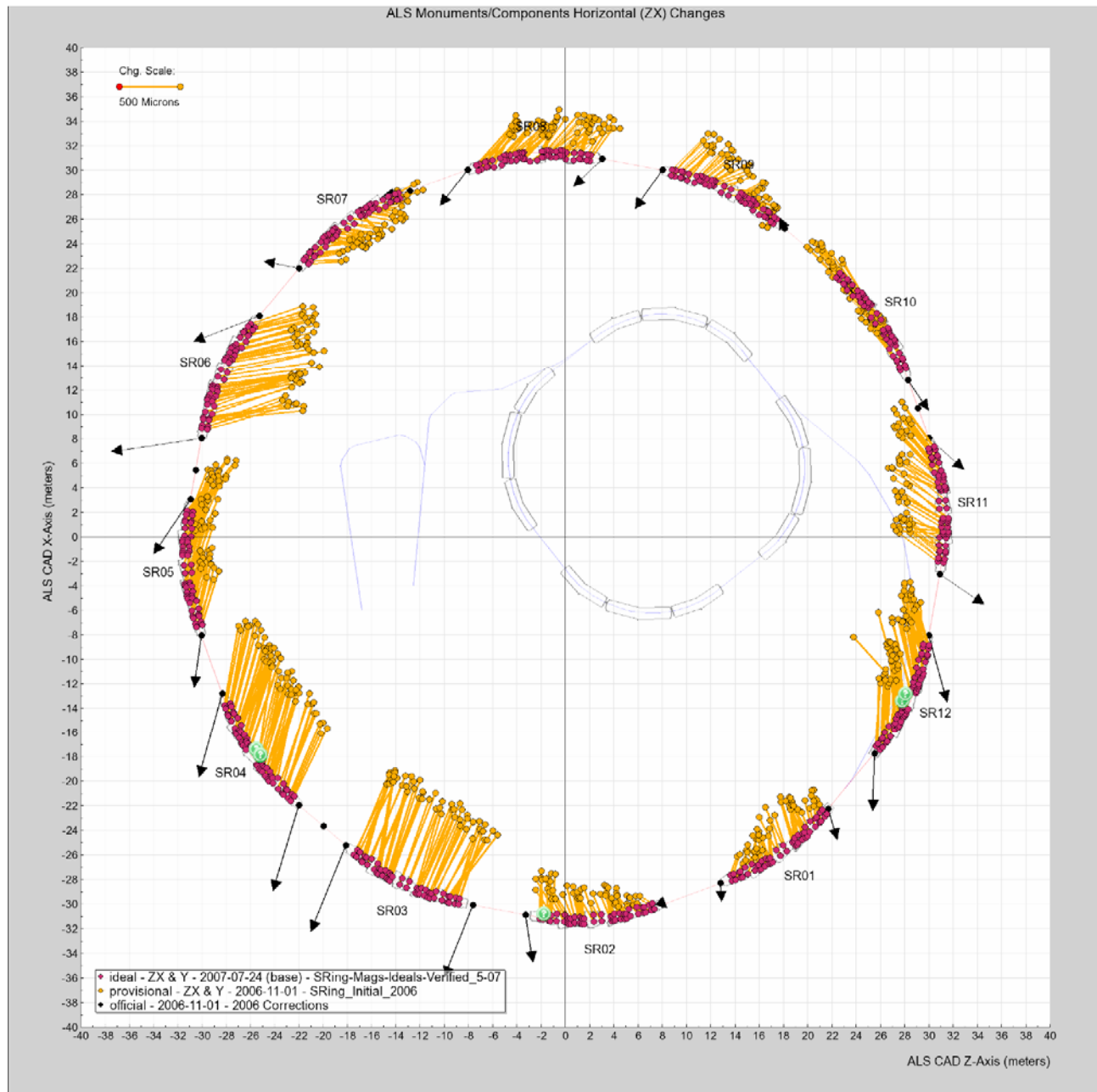


Figure 2: An example of a horizontal change comparison between ideal coordinates and component survey data. This plot demonstrates the inclusion of girder outlines and the effects on flex connections from girder corrections that were calculated to bring the girders back into alignment. The question mark icons (?) are missing survey data points.

time a data set is modified, the user and time stamp is recorded to keep track of who made changes to what and when.

Data is always initially imported in the provisional state. Data in this state can be later deleted or modified to exclude individual points and/or correct the legend, description, involved staff, etc. Modification or deletion is not permitted for data moved from the provisional state.

Data in the ideal state is taken from the ideal coordinates that are used to calculate component corrections. Comparison of current surveyed positions to these ideals graphically depicts how far away from perfect alignment the accelerator is at any given time.

Data can be used in comparison plots regardless of its state which provides for the possibility to import data, use it in a comparison, and then reject (delete) it if desired. If experimental pre-processing techniques or “what if” scenarios need to be investigated, the data can still be imported into the system and used in comparisons against other provisional or official data without the possibility of inadvertently being used as official data. Experimental data imported into the system in this way can be moved to an archive state to be safely ignored if it is desired to keep

it in the system instead of deletion.

MONCOR CALCULATION

With a history of trusted and vetted data in the system, the generation of the MonCor file can be automated. The algorithm simplifies to the following two steps:

1. Independently select the newest ZX and Y value for every monument in the system using only official, moncor and epoch data.
2. For each monument determined in the first step, independently determine the oldest survey that has exactly the same ZX and the oldest survey that has exactly the same Y values, within a specified tolerance.

Step 2 is database intensive because it requires two separate queries for every component selected in Step 1 which requires only two queries. The purpose of the second step is to carry date information forward so that components that have not been surveyed for some time do not give the appearance of having been recently surveyed

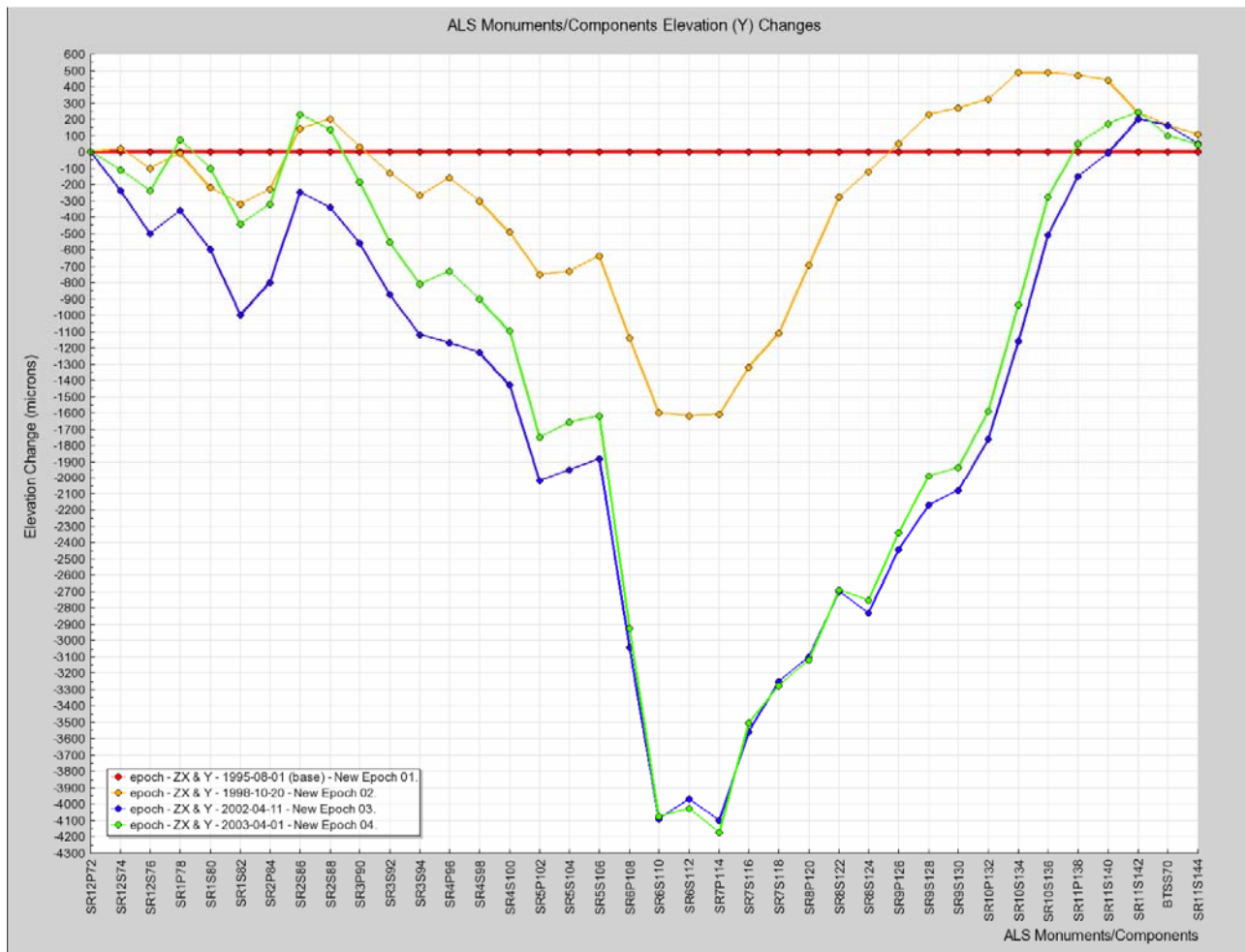


Figure 3: An example of an elevation change comparison between four major ALS surveys covering the years from 1995 through 2003. The selected reference monument used to anchor the coordinate system (SR12P72) is apparent (no changes). This is the complementary plot to the horizontal change plot shown in Figure 1.

just because they are included in a past MonCor file. The tolerance value allows the possibility of ignoring insubstantial changes to the position of a monument over time since there is some minor fluctuation of the coordinate system during each major survey and realignment cycle.

Historically only the MonCor file was maintained (manually using spreadsheets) by the ALS Survey and Alignment group. However, the system now also supports the calculation of a MonMagCor in which the same algorithm is used on EVERY component in the system, not just monuments. This will be helpful particularly in updating the best known positions of front end components which are often used as tie-in points (in addition to monuments) for beamline survey and alignment tasks.

DATA COMPARISONS

Horizontal Changes

Lateral changes of data points over time can be conveniently visualized by first plotting the “base” survey data set in correct relative position on a plan form view. Subsequent data sets to be compared are plotted as color-coded exaggerated offsets from the base data points. The system allows for the comparison of up to four data sets in this fashion. As an example, Figure 1 depicts the horizontal changes in the primary and secondary ALS storage ring monuments in the years between 1995 and 2003.

The comparison plotting routines provide for a variety of switches and options. Plot ranges may be selected to zoom in on a particular area of interest. The exaggeration factor for comparisons can be adjusted. Various items can be enabled or disabled and components can be filtered from appearing on the plots.

Using a scaled plan form view of the data allows for the possibility of superimposing physical representations for clarity. For example the outlines of the storage ring girders, beam paths, and even the effects on flex connections of calculated correction sets can be included on comparison plots as shown in Figure 2. This figure clearly shows that offsets from the execution of the correction set will serve to bring the girders back into alignment with the ideal positions.

Elevation Changes

Elevation changes of data points over time are most conveniently visualized using a simple category style plot. The base survey for comparison is represented as a zero offset on the plot. Subsequent comparison data sets are color coded and simply graphed as the difference from the base survey. Figure 3 shows the elevation changes in the primary and secondary ALS storage ring monuments in the years between 1995 and 2003 (the compliment to Figure 1). This plot highlights a very noticeable trend wherein one side of the ALS storage ring keeps sinking over the years.

In order for the category style plot to make sense, it is

important that the components are plotted in a sensible order. In the example shown, the first monument (monument SR12P72) is the one traditionally used as the anchor point from year to year as the coordinate system is rectified with current survey data. The remaining monuments are in the correct order around the storage ring in a clockwise sense.

Ordering of monuments and component fiducials in elevation comparison plots is enforced using an MPTT table. Essentially the preferred ordering of components is pre-established in a static table in the database. Subsequently no matter what order components appear in imported data, they will be sorted and plotted according to the preferred order.

CONCLUSIONS

The development of the ALS Survey Data Management System was originally motivated by the need to easily and consistently generate comparison plots between past and present survey data sets. The system has succeeded entirely for this need. The group has grown to use the comparison capability as a daily tool for verifying the validity of data as it is acquired and processed. The design of the system has evolved naturally to include the automated creation of the group’s MonCor reference data file. As historical data accumulates in the system, the comparison capabilities will enable investigations to better understand the seasonal and temperature effects on floor movements in the accelerator.

Future Improvements

The means of configuring comparison plots is quite simple. The options available to the user are powerful to allow the creation of instructive and insightful plots. However the options available to the user are many. Once the user leaves the comparison page, the effort that went into creating the tailored plot settings is lost.

The problem is currently only a hard copy of the comparison plots can be retained. While all the data that is used to create the plots remains in the system, a means is needed of storing and recalling comparison plots that were previously generated. This can be implemented as an additional table in the database with some supporting pages to navigate, select, and recall past configured comparison plots. With this feature implemented, smart plots could also be devised that could automate the regular creation of standardized plots (e.g. “Storage Ring Monuments, Past 4 Years”).

REFERENCES

- [1] Gijs Van Tulder, “Storing Hierarchical Data in a Database”, <http://www.sitepoint.com/article/hierarchical-data-database>
- [2] Johan Persson, <http://www.aditus.nu/jpgraph>