RHIC ELECTRONIC DATA COLLECTION AND SURVEY & ALIGNMENT DATABASE

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1. INTRODUCTION

This paper describes the current status of field data collection and database operations for the Relativistic Heavy Ion Collider at Brookhaven National Lab. Data collection and survey equipment are identified together with software, interface and data flow information. Tables, fields, data exchange, application development, report and computational processing for the Survey & Alignment Group (SAG) portion of the RHIC database are summarized.

2. ELECTRONIC DATA COLLECTION

SAG is currently using a combination of PC compatible and Leica data collection hardware. Data collection during horizontal control network operations is accomplished using Zeos 386+ laptop computers with GeoNet software (ME5000.bas & DIRECT.bas), the Kern Mekometer for distance measuring and the Leica T3000K for direction observation. Data is passed from the field to the GeoNet observation database via floppy on a daily basis which serves as a primary backup. Laptop hard disks are periodically archived.

Vertical control is observed using the Leica NA3000 bar code level and recorded in the on board removable REC module. Data is passed on the REC module through a GIF12 reader connected to a PC on an RS232C standard COM port.

Individual magnet assembly surveys for quality assurance and fiducialization are executed with a portable Leica ManCAT system using a Compaq 486c portable computer and T3000s'. Data is passed via floppy. When a permanent QAF operations area is set up, data will be passed on the laboratory site wide communications network.

3. OBSERVATION DATA ANALYSIS & ADJUSTMENT

Horizontal control observations are processed with GeoNet software including MEKRED.exe, REDIR.exe and a custom sorting program for error detection. Star*Net Plus and the GeoNet least squares modules are used for final analysis and adjustment. The Star*Net product functions as a fast data debugging environment. Final adjustments are executed with GeoNet.

Vertical control observations are processed with the Leica NA.exe program. Output from NA is massaged with a text editor for input to Star*Lev and final analysis and adjustment.

QAF data will be analyzed by a custom program (Rapideal.C) that is currently under development by the RHIC Accelerator Physics Group (RAP) and SAG. This program will characterize and orient a magnet assembly to a particular location in the ring and report ideal coordinates to SAG.

SAG also uses a variety of software packages to aid in error detection, analysis, mapping and presentation of survey data such as: AutoCAD, Brief & Kedit text editors, Excel, Word, Chartist, MS Prof. Basic 7.1 and Visual Basic Prof. Ed..

4. DATABASE FUNCTION STATEMENT

The RHIC Survey & Alignment Group Database (SAGdb) functions as a repository of surveyed, analyzed and adjusted coordinate positions of control monuments, fiducials and other

location points, for all collider ring, transfer line and experimental elements requiring alignment by SAG. The database will be active for the life of the machine, maintaining current and chronological information on all pertinent alignment points.

5. OPERATIONS AND MAINTENANCE

The SAG database is operated and maintained by SAG in the Sybase format, and is unique, separate and apart from other RHIC databases. Read only accessibility is enabled for appropriate end users of survey data such as the RHIC Accelerator Physics Group (RAP) and the Controls Group. The SAGdb and the Sybase database engine physically reside on a UNIX server at the Computing & Communications Division (CCD) complex at Brookhaven Lab. Other RHIC databases such as the RAP database (RAPdb) reside at the same complex. Both the RAPdb and the SAGdb will be mirrored onto a UNIX server at the RHIC administration building for daily operations. The SAGdb structure is defined in Table 1. Specific fields are defined in Table 2.

6. INTEGRITY ISSUES

Overall SAGdb integrity is the responsibility of the SAGdb administrator. As noted above, a complete image of the SAGdb will be kept on separate hardware facilities. Access to SAGdb is limited to the database image and is “read only” for all users except the database administrator who executes all update, upload, backup and archive operations. The read only capability will allow users to download desired information and to run computation and report applications that do not attempt to update tables or alter data.

Individual data point integrity is handled by name and date dual indexing which will insure that no unique name+date combination will occur in the database, This method has advantage of preserving chronological point information and allowing historical analysis and reporting.

The problem of expanding table size and performance degradation that will occur over time, is handled by having an archive table. This table will contain historic values for points that have been re-surveyed or re-calculated from the horizontal, vertical, lattice, ideal and smoothing tables. Use of the archive table optimizes access to the normal operations tables while still allowing immediate access to historical point data.

7. INTERFACE AND DEVELOPMENT ENVIRONMENT

Management and applications development for the SAG database in Sybase is accomplished from a Windows 3.1 environment running under MS DOS 5.0 The database interface will utilize the commercial software products Q+E MultiLink VB and Microsoft Visual Basic Professional Edition. The Q+E product adds full relational database functionality to Visual Basic for over 20 different database formats including Sybase, Oracle, dBase & Paradox.

The Q+E/VB combination provides a universal, fully functional interface on the PC platform for comprehensive database management and application development. This interface enhances the ability of SAG to work with any other group or experimental team on site and their individual databases. In addition Microsoft has recently designated a subset of Visual Basic as the common macro language for all of its major applications including Word and Excel, which are standards for SAG.

8. APPLICATIONS DEVELOPMENT

Applications developed by SAG and other groups or users access the database to accomplish upload, download, computation, archive and report functions.

Application development for users of the SAGdb is the sole responsibility of the user. SAG will consult with users regarding available data and exchange formats but does not anticipate specialized data processing for individual users. Complete documentation of SAGdb tables and fields is available to all interested parties.

Specific applications development for operations and maintenance of the SAGdb is handled by SAG team members using the Q+E/VB development environment. Included runtime licensing for this environment means that appropriate stand alone applications, such as combined table viewers and report generators, developed by SAG could be made available to users from other groups or experimental teams.

9. DATABASE DATA EXCHANGE

Primary data exchange between RAP and SAG is accomplished through Sybase tables. SAG anticipates granting read only rights for the database to appropriate users such as RAP and Control. Data flow is presented in Figures 1, 2 & 3. Typical data exchanges between SAG, RAP and others are identified below.

9.1 Lattice design information.

This data represents the latest lattice calculations by RAP. It determines the initial location of all alignment elements and is used by SAG to install stands. The fields (defined in Table 2) required by SAG are:

NAME, L_NRTH, L_EAST, L_HGHT, L_DATE, LROT, LTID

9.2. Ideal coordinates computation.

This exchange is bidirectional. Localized Quality Assurance and Fiducialization (QAF) survey data is provided to RAP for analysis and determination of magnet assembly placement in the ring. RAP returns ring coordinates (RHIC Survey Frame) for idealized location of the assembly in the ring. QAF data supplied to RAP will be:

MCD, Q_X Q_X Q_Z, Q_DEV, Q_YDEV, Q_ZDEV, Q_DATE

Required fields for Ideal data supplied to SAG are:

MCID, NAME, I_NRTH, I_EAST, I_HGHT, I_DATE

9.3. Final smoothing coordinates computation.

Complete details of the smoothing process have not been worked out at the time of writing. Preliminary discussion has yielded the following scenario.

This exchange will be bi-directional. SAG will execute an as-built survey of collider components establishing coordinates and elevations of accessible fiducials. Fiducials on the tunnel wall side of an assembly will be surveyed for horizontal position and elevation. Fiducials at the center of the tunnel will be surveyed for elevation. Elevations will be converted to heights prior to data reporting. In the case of a quadrapole assembly four fiducials are known for height, two are known horizontally. Missing horizontal values will be reported as 0. Data reported by SAG to RAP will be:

NAME, F_NRTH, F_EAST, F_HGHT, F_DATE

After analysis by RAP, data regarding the corrective action on the assembly for smoothing will be reported in terms of locally oriented displacements using a “beam follow” convention. Because RHIC is a collider with two beams traveling in opposite directions around the ring, algebraic signs will follow the convention that the beam is assumed to flow in a clockwise direction about the machine center (+Z), radial movement inboard will be negative (-X) and height above the machine plane will be positive (+Y). Data reported by RAP to SAG will be:

NAME, F_DX, F_DY, F_DZ, F_DATE

9.4 Manufacturers Fiducialization and Other Data Exchanges

Exchange of fiducialization data from off site manufacturers of magnet assemblies and other outside users will likely be accomplished with ASCII comma delimited text files via floppy disk. In manufacturing it is expected that the reported information will be similar to that developed by SAG during QAF survey operations. Current indications are that the

manufacturer will also use ManCAT for fiducial measurements and will provide the following data.

MCID, M_X, M_Y, M_Z, M_XDEV, M_YDEV, M_ZDEV, M_DATE

10. COMMENTS

Use of GeoNet and commercial software for electronic data collection, handling and processing, held down initial application development time. Additional development is required to approach seamless field data handling. The RHIC database structure and operational environment is developed with commercial products and will service the machine for its' useful life span. Selection of a suite of stable, low cost, multi-format, off the shelf commercial products for database interface and applications development allows continues upgrade of database applications and protects development time investment in the event of a change in the underlying database engine. Also a broader range of support options, in comparison to a proprietary interface, are available. Use of multiple tables relating to operation phases and data characteristics yields an intuitive database structure. Data exchanges are facilitated by a common database engine.

TABLE 1.

Database Table Definitions

No.	TABLE	FIELDS	DEFINITION
1.	RHIC_HRZ	NAME S_DATE S_NRTH S_EAST S_APHI S_AMAJ S_BMIN	Horizontal field survey (measured) data in RHIC Survey Frame with point name, final data adjustment date, northing, easting and observational error ellipse data for the semi-major axis azimuth, the semi-major axis and the semi-minor axis.
2.	RHIC_VRT	NAME V_DATE S_ELEV S_HGHT S_CORR V_SDEV	Vertical field survey (measured) data with point name, acquisition date, gravity elevation in RHIC Datum, computed "w" height in RHIC Survey Frame, computed correction for ellipsoid to machine frame and standard deviation of elevation observation.
3.	RHIC_NAM	NAME COGO REGN MCID LTID	Name/Identification cross reference table with point name, unique integer number for coordinate geometry, machine region, manufacture identification and lattice design identification.
4.	RHIC_ROT	NAME L_ROT B_ROT T_ROT	Rotation table with point name, lattice design magnet assembly rotation in radians, AutoCAD block insert rotation in grads and AutoCAD text labeling insert rotation in grads.
5.	RHIC_LAT	NAME L_DATE L_NRTH L_EAST L_HGHT	Lattice design position data with point name, lattice design date, northing, easting and height in RHIC Survey Frame.
6.	RHIC_IDL	NAME I_DATE I_NRTH I_EAST I_HGHT I_ELEV I_CORR	Ideal installation position data with point name, ideal computation date, northing, easting and height in RHIC Survey Frame, gravity elevation and ellipsoid correction.
7.	RHIC_QAF	MCID Q_DATE Q_X Q_Y Q_Z Q_XDEV Q_YDEV Q_ZDEV	Quality assurance and fiducialization survey data with manufacturing identification, QAF survey date, local X, Y, Z and standard deviation of X, Y and Z.

8.	RHIC_MAN	MCID M_DATE M_X M_Y M_Z M_XDEV M_YDEV M_ZDEV	Manufacturers fiducialization survey data with manufacturing identification, manufacture date, local X, Y, Z and standard deviation of X, Y and Z.
9.	RHIC_FSO	NAME F_DATE F_NRTH F_EAST F_DX F_DY F_DZ	Final smoothing operations data in localized reference system with point name, final smoothing calculation date, smoothing field survey coordinates and analyzed delta displacements in localized X, Y and Z.
10.	RHIC_CHR	NAME, S_DATE, S_NRTH, S_EAST, S_APHI, S_AMAJ, S_BMIN, V_DATE, S_ELEV, S_HGHT, V_SDEV, L_DATE, L_NRTH, L_EAST, L_HGHT, I_DATE, I_NRTH, I_EAST, I_HGHT, I_ELEV F_DATE, F_DX, F_DY, F_DZ	Archive table for chronological data of points re-observed or recalculated during life of machine.

TABLE 2.
Database Field Definitions

No.	FIELD	TABLE(s)	DEFINITION
1.	NAME	RHIC_HRZ RHIC_VRT RHIC_NAM RHIC_ROT RHIC_LAT RHIC_IDL	Standardized name of component position in accelerator ring. NAME is the link between all tables other than RHIC_MAN & RHIC_QAF where MCID is used because the position in the ring of a particular magnet assembly is not known during manufacture or quality assurance and fiducialization surveys.
2.	COGO	RHIC_NAM	Coordinate geometry point number unique for each point NAME in database (integer < 100,000).
3.	MCID	RHIC_NAM RHIC_QAF RHIC_MAN	Magnet control identification name used by Magnet Division and Manufacturer during construction and quality assurance & fiducialization process.
4	LTID	RHIC_NAM	Lattice design name of component position in accelerator ring containing yellow or blue designation.
5.	REGN	RHIC_NAM	Ring region ID for component position (INSertion, ARC, TRaNsfer, INJection or EXPeriment plus 01 - 12 clock sector or descriptor i.e. ARC05, INS10, INJ-X, EXP08 etc.).
6.	S_NRTH	RHIC_HRZ	RHIC Survey Frame north coordinate (field survey).
7.	L-NRTH	RHIC_LAT	Lattice design north coordinate in RHIC Survey Frame reported by RHIC Accelerator Physics group (RAP).
8.	I_NRTH	RHIC_IDL	Ideal north coordinate in RHIC Survey Frame for specific component point at specific position in ring computed after Quality Assurance & Fiducialization (QAF)survey.
9.	F_NRTH	RHIC_FSO	Final smoothing operations field survey north coordinate in RHIC Survev Frame.
10	S_EAST	RHIC_HRZ	RHIC Survey Frame east coordinate (field survey).
11.	L-EAST	RHIC_LAT	Lattice design east coordinate reported in RHIC Survey Frame by RHIC Accelerator Physics Group (RAP).
12.	I_EAST	RHIC_IDL	Ideal east coordinate in RHIC Survey Frame for specific component point at specific position in ring computed after QAF survey.
13.	F_EAST	RHIC_FSO	Final smoothing operations field survey east coordinate in RHIC Survev Frame.
14.	S_HGHT	RHIC_VRT	Field survey height ("w") computed by SAG in RHIC Survey Frame from S_ELEV and S_CORR.
15.	L_HGHT	RHIC_LAT	RHIC Survey Frame lattice design height ("w") reported by RAP.
16.	I_HGHT	RHIC_IDL	Ideal height value in RHIC Survey Frame for specific component point at specific position in ring computed after QAF survey.
15.	S_ELEV	RHIC_VRT	Field survey elevation relative to gravity.
18.	I_ELEV	RHIC_IDL	Ideal gravity elevation for specific component at specific position in ring, computed after QAF survey

19.	S_CORR	RHIC_VRT	Field survey vertical correction value indicating difference between RHIC machine plane and gravity elevation computed by SAG from S_NRTH, S_EAST, S_ELEV
20.	I_CORR	RHIC_IDL	Ideal vertical correction value for specific component at specific position in ring, computed after QAF survey.

21.	S_DATE	RHIC_HRZ	Date of horizontal field survey epoch.
22.	V_DATE	RHIC_VRT	Date of vertical field survey epoch.
23.	L_DATE	RHIC_LAT	Date of lattice design report from RAP to SAG.
24.	Q_DATE	RHIC_QAF	Date of quality assurance & fiducialization field survey.
25.	I_DATE	RHIC_IDL	Date of ideal computations epoch.
26	M_DATE	RHIC_MAN	Date of manufactures reported information.
27.	F_DATE	RHIC_FSO	Date of final smoothing operation calculation.

28.	S_APHI	RHIC_HRZ	Phi (azimuth) of A axis (semi-major) of absolute error ellipse for adjusted field survey point.
29.	S_AMAJ	RHIC_HRZ	A axis (semi-major)of absolute error ellipse for adjusted field survey point.
30.	S_BMIN	RHIC_HRZ	B axis (semi-minor)of absolute error ellipse for adjusted field survey point.
31.	V_SDEV	RHIC_VRT	Field survey gravity elevation standard deviation.

32.	L_ROT	RHIC_ROT	Lattice design magnet assembly rotation in radians.
33.	B_ROT	RHIC_ROT	AutoCAD block insert rotation in grads.
34.	T_ROT	RHIC_ROT	AutoCAD text labeling rotation in grads.

35.	Q_X	RHIC_QAF	X coordinate in local QAF survey coordinate system
36.	M_X	RHIC_MAN	X coordinate in local manufacturers coordinate system.

37.	Q_Y	RHIC_QAF	Y coordinate in local QAF survey coordinate system
38.	M_Y	RHIC_MAN	Y coordinate in local manufacturers coordinate system.

39.	Q_Z	RHIC_QAF	Z coordinate in local QAF survey coordinate system
40.	M_Z	RHIC_MAN	Z coordinate in local manufacturers coordinate system.

41.	Q_XDEV	RHIC_QAF	Standard deviation of X in local QAF coordinate system.
42.	M_XDEV	RHIC_MAN	Standard deviation of X in local manufacturers system.

43.	Q_YDEV	RHIC_QAF	Standard deviation of X in local QAF coordinate system.
44.	M_YDEV	RHIC_MAN	Standard deviation of X in local manufacturers system.

45.	Q_ZDEV	RHIC_QAF	Standard deviation of X in local QAF coordinate system.
46.	M_ZDEV	RHIC_MAN	Standard deviation of X in local manufacturers system.

47.	F_DX	RHIC_FSO	Final smoothing displacement along local X axis.
48.	F_DY	RHIC_FSO	Final smoothing displacement along local Y axis.
49.	F_DZ	RHIC_FSO	Final smoothing displacement along local Z axis.

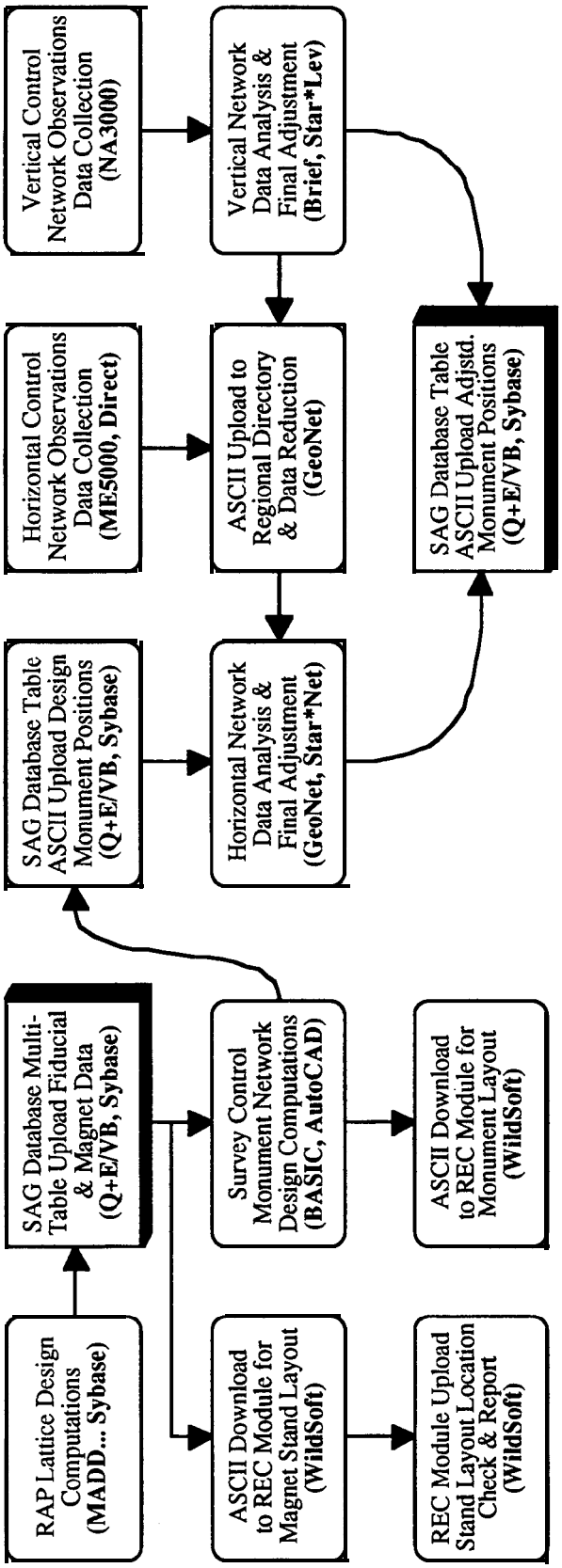

Figure 1.
Data Collection & Analysis Flow Diagram
Lattice Design & Survey Control Network

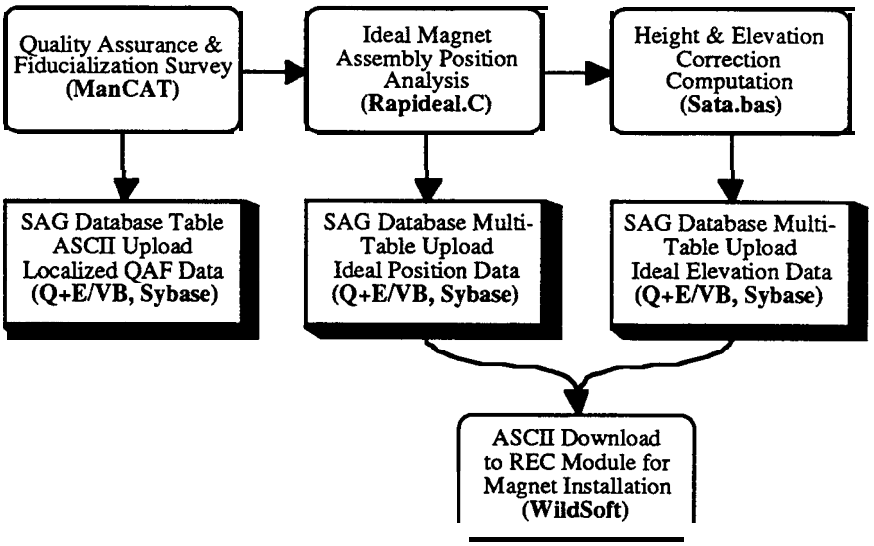

Figure 2.
Data Collection & Analysis Flow Diagram
Quality Assurance and Fiducialization Survey

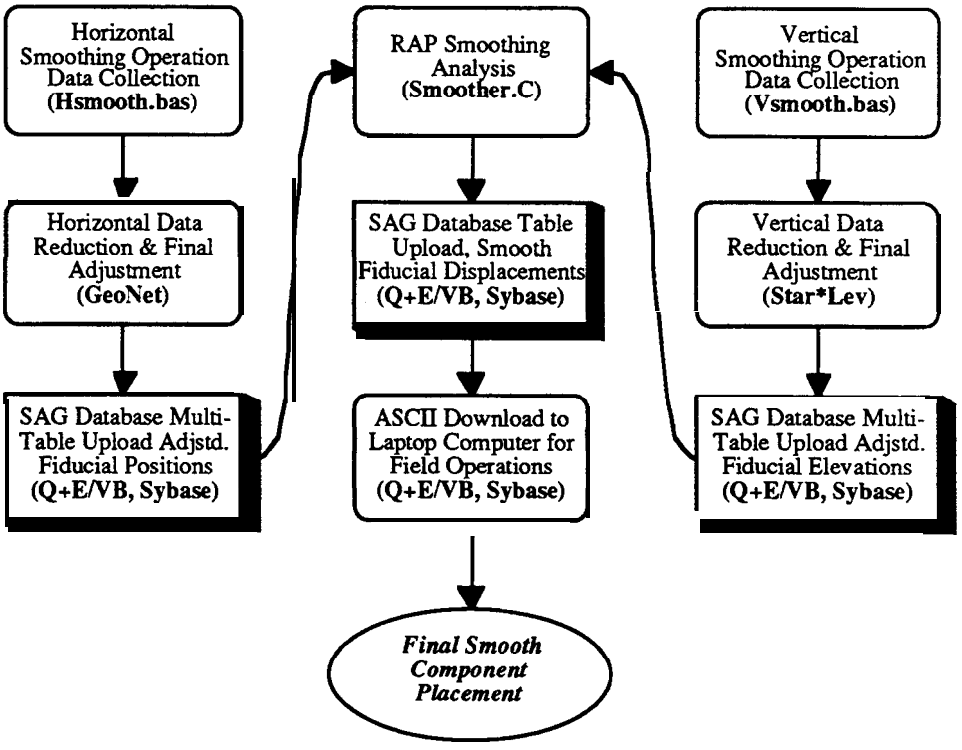

Figure 3.
Data Collection & Analysis Flow Diagram
Final Component Placement Smoothing Operations