ACAMS – INTEGRATED SOFTWARE FOR ACCELERATOR ALIGNMENT AND MEASUREMENT*

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1. INTRODUCTION

ACAMS (Accelerator Combined Alignment and Measurement System) is a software package that has been developed at Thomas Jefferson National Accelerator Facility (Jefferson Lab). ACAMS was developed to replace four MS-Dos based software programs. These programs operated independently and commonly used theodolite observations as the basis for data collection. The methodology used to collect the data had similarities, but there were inconsistencies and shortcomings in these various processes.

ACAMS integrates all the reductions, adjustment and reporting into one package. Jefferson Lab Alignment Group now relies on ACAMS for most of the field surveys undertaken. Many new features that were lacking in the older packages have been included in the development of ACAMS. This paper will discuss the reasoning behind the development, currently available features, and the future direction that the software will take.

2. JUSTIFYING DEVELOPMENT

2.1 Commercial vs. In-House Development Packages

Prior to the development of ACAMS, the alignment group at Jefferson Lab evaluated two commercially available software packages. Both commercial packages are very complete, with a long list of features available to the end user. However, both packages appeared to be designed towards certain specific applications in the industrial measurement community, rather than fitting the requirements that were desired at our facility. There are distinct advantages for using an off the shelf package but as this software is crucial to the operation of our group, the decision was made to develop a custom package. Some of the main arguments for and against this decision are outlined below.

One of the main issues addressed when evaluating commercial versus in-house software was the control of the database. Both of the evaluated packages were locked into a proprietary database, which limited the ability to manipulate the data during post processing. Items such as text point names have historically been part of our database, and we wished to continue with this capability.

A second issue was the degree of customization. Again, both packages had some level of customization, but the degree of customization which was required was very high and neither

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package addressed customization to the desired level. Our field crews continually contribute valid suggestions which help guide the development direction of the software. Having the ability to control changes and add features was one of the most important factors in the decision to proceed with in-house development.

The cost of development and debugging were a disadvantage to be considered. Overall the first debugged copy, suitable for field work, took approximately six months or a half man year to deliver. There is also the maintenance costs of the software to consider. There are approximately thirty thousand lines of C++ code to maintain, plus several older FORTRAN routines that have been modified and turned into 32 bit windows DLLs.

Theodolites are used for approximately seventy percent of the field alignment tasks at Jefferson Lab. Optical tooling and a portable coordinate measuring machine (CMM) are used for most of the remaining tasks. There is an effort to decrease the use of optical tooling since there is minimal redundancy of observations. With such emphasis on the use of theodolites, our group felt that our software should maximize the effectiveness of our lab-specific tasks. These tasks included stand and magnet alignment, alignment of various spectrometers, fiducialization of components and other tasks typically carried out by intersecting theodolites.

3. SOFTWARE FEATURES AND DETAILS

3.1 Hardware Requirements and Interface

The requirements for the field version of the software are either a laptop or regular desktop computer, with access to a compact flash (CF) reader and an expanded serial card, or 2 PCMCIA cards. Most laptops allow for 2 PCMCIA cards. One of the cards is for a multi-port serial card (National Instruments part NI PCMCIA 232/4, Socket part SL0751-161 or similar). Each instrument to be connected, must have a serial port available on the computer. The second card is for a CF card adaptor. The CF card is automatically read when the program initializes and all files on the laptop are updated. By using this technique, all files on all the various computers are kept up to date. The office version of the software does not check for a CF card, but all initialization files and software version operations are handled from a lab network server.

ACAMS has been tested on various laptops. The standard operating system is Windows 2000, but it has been used with Windows 98, Windows NT 4.0 and Windows XP, with no apparent problems. The slowest processor speed that the software has been tested on is an Intel Celeron 300. The software has not shown any adverse effects utilizing the latest Pentium 4 processors available. The minimum ram that has been used with a Windows 98 system is 64 megabytes.

The lab has also developed a new multiplexer interface box that powers the theodolites, and handles communications between the computer and theodolites. The cost of these multiplexer boxes is significantly less than the units required for the commercial packages.

3.2 Survey Selection / Project Details

As stated earlier, ACAMS has been developed to integrate all the various types of theodolite survey packages that existed at Jefferson Lab. After the program initializes, the user is asked to select a method, type of survey, or continue an existing project. The main options are to conduct either stand alignment (rough alignment of stands / bolts etc. Step 1), Step 2 alignment (alignment of machine elements), fiducialization of elements and finally, spectrometer positioning. Other options are available to the user, such as re-starting existing job, copying and using control from an existing job, and resuming the last job.

After the crew has selected the task type the target and control information is generated by following prompts. For example, in the stand alignment option, users are prompted for a nearby control monument. This one monument is used as the basis for a search of nearby stands and other control which are displayed in checklists. Users can chose to either reject or include data in the project. By carrying out these tasks in a specific manner, errors are reduced.

3.3 Common Interface

Upon completion of the job information section, the users are presented with the common interface (Fig. 1). There are a group of commands on the top taskbar that take the user to various options. Two of these options are for moving to the data collection screen. Using the 'New Position' option, allows the users to start a new theodolite position, while 'Resume Position', allows the users to resume theodolite setups (see section 3.5). The upper task bar also contains the Adjustment options (see section 3.4), Observation Tabulator (section 3.5), Spectrometer Options (section 3.6) and the Transfer File option.

					Contro	l Point	Informat	tion				
Ctrl Name	TheoID	Use	Z	X	Y	Wt Z	Wt×	WtY	Std Wt	Std Wt	Std Wt	Comment
ISA0006	8006		79614.24692	59960.69467	2096.98909	Fixed	Fixed	Fixed	1.00E-20	1.00E-20	1.00E-20	
HSA0008	8008		79609.21082	59964.56408	2097.01400	Fixed	Fixed	Fixed	1.00E-20	1.00E-20	1.00E-20	
HSA0010	8010	1	79614.18680	59956.52628	2096.98295	Fixed	Fixed	Fixed	1.00E-20	1.00E-20	1.00E-20	1
HSA0015	8015		79606.39335	59960.78562	2097.00286	Fixed	Fixed	Fixed	1.00E-20	1.00E-20	1.00E-20	
HSA0020	8020		79598.45666	59958.09113	2096.98244	Fixed	Float 💌	Fixed	1.00E-20	1.00E-02	1.00E-20	
HSA0023	8023		79601.76315	59963.93275	2097.00551	Fixed	Fixed	Fixed	1.00E-20	1.00E-20	1.00E-20	
HSA0060	8060		79591.58868	59954.23879	2096.99671	Fixed	Unknown	Fixed	1.00E-20	1.00E-20	1.00E-20	
HSA0070	8070		79592.56336	59964.04105	2096.98309	Fixed	Fixed	Fixed	1.00E-20	1.00E-20	1.00E-20	

Fig. 1 Common Interface

The default screen displays the control points. Control point z, x and y coordinates are displayed along with their associated weight. Weights may be adjusted by clicking on the appropriate cell, and are then updated for use in further adjustments.

At the bottom of the common interface screen are tabs which take you to six associated commands. Figure 2, shows an example of the report generated based on a project's results. Figure 3, shows a sample of the raw data that has been captured. There are a second group of tabs in the Raw Data screen which allow the users to page through to the respective theodolite data. Other options available from the lower task bar include screens for the target data and the adjusted theodolite coordinates.

Jefferson Lab ACam File Edit View Calcula	s : Version 1.0.2.F4 : Ite Heln	2002.07.11 [NETWO	DRK VERSION] < Wor	king Directory : M:\ALI	GN\DATA\AALIGN\EL	ECTRON&S	H\2002\E09 💶 🗙						
New Position	 Resume Position 	Pesume Position Adjustment Observation Tabulator Spectrometer Options Transfer File					🗶 E <u>x</u> it						
	Final Report												
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Get Std Header													
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Get As-Set	name	z >	к У	Z	x	Y							
Get Pointing Data	EDIPF EDIPG	10.737 1. 10.307 1.	.132 1.387 .140 -0.214	79596.176 79596.602	59967.318 2 59967.254 2	101.420 099.818	FIX FIX FIX FIX FIX FIX						
Print Report	EDIPH	14.668 1. 15.626 1.	.139 3.012 .141 2.253	79592.279 79591.329	59967.824 2 59967.948 2	103.043	FIX FIX FIX						
Save Report	EDIPK EBOX9	16.623 1. 14.052 1.	.137 1.496 .085 4.618	79590.341 79592.896	59968.082 2 59967.798 2	101.527	FIX FIX FIX FIX FIX FIX						
	EBOX10	10.165 1.	.076 4.427	79596.750	59967.299 2	104.459	FIX FIX FIX						
View 3dd Output	EBOX11 EBOX12	10.488 1. 7.222 1.	.096 2.619 .077 2.330	79596.428 79599.669	59967.321 2 59966.914 2	102.651	FIX FIX FIX FIX FIX FIX						
View 9Par Results	EBOX15 EBOX16	9.321 1. 9.463 1.	.083 1.162 .084 -0.288	79597.587 79597.447	59967.182 2 59967.199 2	101.194 099.744	FIX FIX FIX FIX FIX FIX						
	EBOXP	8.258 1.	.124 -0.040	79598.636	59967.003 2	099.992	FIX FIX FIX						
Multi Summary	•						_						
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21	002.11.08		SuperUser : tr	emblay		10:03:36	li.						

Fig. 2 Report Screen

🍈 Jeff	🔓 Jefferson Lab ACams : Version 1.0.2.F4 2002.07.11 [NETWORK VERSION] < Working Directory : M:\ALIGN\DATA\AALIGN\ELECTRON&SH\2002\E 💶 🗙													
File Ed	File Edit View Calculate Help													
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	Raw Data For Position 2 Theo ASB # 5													
25	Position :	2 >>	ASB#:5>	> Seria	#345311 >>	Obs : HARD	ISTY >> TiltLe	eft : 000.0	0014 g >	> TiltRi	ght 000.000	129 g Port	#4	
Pos#	∆ ASB#	Port#	Name	Theo Id	HCR	VCR	Dist	wgt Her	wgt Ver	Reflecto	Temp	Press	Date:Time	Comment
2	5	4	HSA0010	8010	100.494530	105.271050	0.00000	0.00050	0.00050	NONE	0.0	0.0	10:39:42<	
2	5	4	HSA0010	8010	300.495160	294.727700	0.00000	0.00050	0.00050	NONE	0.0	0.0	10:40:04<	
2	5	4	HSA0006	8006	286.826170	295.028570	0.00000	0.00050	0.00050	NONE	0.0	0.0	10:40:23<	
2	5	4	HSA0006	8006	86.826050	104.971130	0.00000	0.00050	0.00050	NONE	0.0	0.0	10:40:41<	
2	5	4	HSA0015	8015	72.622360	107.730290	0.00000	0.00050	0.00050	NONE	0.0	0.0	10:40:57<	
2	5	4	HSA0015	8015	272.621700	292.269530	0.00000	0.00050	0.00050	NONE	0.0	0.0	10:41:14<	
2	5	4	HSAUUUS	8008	266 241890	294 363620	0.0000	0 00050	0 00050	NONE	0.0	0.0	10-41-352	
Post	17 Pos	: 15	Pos: 27	Dac: 27	5 Post 37	Post 3.5 Po	s: 4.5 Pos: 6	5.5						
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		20	02.11.08			:	5uperUser : trem	blay				08:33:	15	///

Fig. 3 Raw Data Screen

The main screen also has a traditional Windows menu interface with numerous options available under, 'File', 'Edit', 'View', 'Calculate' and a 'Help' section but are not discussed here.

3.4 Adjustment

The raw data file is processed in 2 steps. The first step uses the program APPROX which creates an input file for the least-squares bundle adjustment 3DCD^[1] (originally developed at the Stanford Linear Accelerator). APPROX determines whether the control is local or object

oriented. There is no need for orientation of the theodolites, as APPROX will create an iterative solution to arrive at a theodolite position. 3DCD has been modified at the lab and now runs as a background Windows DLL, with the results generated and displayed as shown in figure 4. Other options available through this screen allow you to view the complete adjustment results, weight the observations (figure 5), and control points and allowances for a gravity / non-gravity adjustment.

🎄 Adjustment		×									
Ele Edit											
	Approximation Results (NON-Gravity System)										
Run Adjustment	HSA0060 79591.58868 59954.23879 2096.99671 HSA0070 79592.56336 59964.04105 2096.98309	-									
View Adjustment		⊡									
Edit Weights	Least Squares Bundle Adjustment Results										
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	Readions: 2 Sid Enor: 1.5A15789514383 Deg Freedom: 210										

Fig. 4 Adjustment Results Screen

Theo. Po	Haw sition : 1	2 Theo. I	Position : 1 6	ig File : C:V 	ACAMSIDA	AINSORAL	PIZELIAW	
Position	ASB #	Point Name	Point Number	Horz. Angle	Vert, Angle	Horz. Weight	Vert. Weight	Omit Poir
1	2	HFE018D	8180	43.64643	265.91823	0.00050	0.00050	D -
1	2	HFE0180	8180	243.64881	134.08255	0.00050	0.00050	
1	2	HFE0190	8190	187.0144	110.69206	0.00050	0.00050	
1	2	HFE0190	8190	387.01277	289.30944	0.00050	0.00050	
1	2	HFE0290	8290	170.70459	112,77555	0.00050	0.00050	
1	2	HFE0290	8290	370.70338	287.22564	0.00025	o costo	F I
1	2	HFE0295	8295	172.0201	108.6654	0.00050	Jouble Weight	- 3
1	2	HFE0295	8295	372.01873	291.33539	0.00050	Weight Out	
1	2	HFE0385	8385	136.08797	119.64096	0.00050 F	Reset Weight	
1	2	HFE0385	8385	336.08629	280.36068	0.00050	0.00050	
1	2	HFE0390	8390	156.20422	110.79229	0.00050	0.00050	
1	2	HFE0390	8390	356.20254	289.20908	0.00050	0.00050	Γ
1	2	P12F10C	10	41.70879	286.5518	0.00050	0.00050	
1	2	P12F10C	10	41.86252	286.15601	0.00050	0.00050	
					4	Omit All Poin	its for Current	Station

🎄 Observati	on Tabulator						×
Target	Theo Id	P1ASB7	P1ASB5	P 2 ASB	P 2 ASB 5	TOTAL	-
HSA0006	8006	 	~	~	 Image: A second s	4	
HSA0008	8008	 Image: A state Image: A state<td>~</td><td>~</td><td> Image: A second s</td><td>4</td><td></td>	~	~	 Image: A second s	4	
HSA0010	8010	 	 Image: A second s	~	 Image: A second s	4	
HSA0015	8015	 	~	~	 	4	
HSA0020	8020	-	~	~	 Image: A start of the start of	4	
HSA0023	8023	-	-	~	×	3	
HSA0060	8060	 Image: A second s	~	×	1/2	2	
HSA0070	8070	-	~	~	×	3	
TARGET	90	×	×	×	×	0	
JACK	91	×	×	×	×	0	
EDIPF	25	-	×	-	-	3	
EDIPG	26	-	 Image: A second s	~	×	3	
EDIPH	27	×	 Image: A second s	~	 Image: A second s	3	
EDIPJ	28	-	~	~	~	4	
EDIPK	29	-	~	~	~	4	
EBOX9	39	-	 Image: A second s	~	×	3	
EBOX10	40	-	~	~	-	4	
EBOX11	41	-	~	×	~	3	
EBOX12	42	×	~	~	×	2	
EBOX13	43	×	×	×	×	0	
EBOX14	44	×	×	×	×	0	
EBOX15	45	-	-	-	~	4	
EBOX16	46	-	 Image: A second s	~	×	3	
EBOXP	50	-	~	~	~	4	
ESLITG	60	1	~	1	1/2	3	
ESLITH	61	-	~	~	1/2	3	
QUAD1J	1	~	1	×	1	3	
QUAD1G	2	1	1	~	~	4	
	3	1	1	1	1	4	-
		Press	to Up	late			
		Press	to Ref	urn			

Fig. 5 Weighting Schemes

Fig. 6 Observation Tabulator

3.5 Observation Tabulator

The observation tabulator (fig 6) allows the user to see which targets or control points have been observed at the various theodolite stations. It displays whether a point has been observed with both faces (displays a \checkmark), single face (½), or not at all (shows a X) for each station. This allows the users to ensure that the proper number of observations have been recorded for each target or control point.

3.6 Data Collection

From the main menu, once 'New Position' or 'Resume Position' are selected, the program passes into data collection mode. Theodolites, attached via a serial port, are automatically sensed and polled. In theory, up to nine theodolites could be attached at one time, although the maximum tested to date has been five. Figure 7 shows the data capture screen, which displays the target name, plus the theodolite ID number on the left pane; the observations are displayed on the right pane. The theodolite ID number or target ID is defined as the numeric value that the theodolite sends for each observation. Each theodolite operator may observe any point in any sequence. Additionally the operators can shoot forward and reverse face observations in any order. If theodolite positions have been established by shooting the control points first, 'AutoPoint' can be invoked to determine which point is being observed without the operator having to enter in any point ID number at the theodolite. Another feature available is that all observations are kept in the data file, but any point can be re-observed, with the latest points being used for calculations. The earlier observed data can also be used in calculations so that it can show a final difference between as-found targets, and as-set targets in the report.

As shown in the capture data screen, points that have both a forward and reverse observation are updated by highlighting the cells displaying the target name in green. If an observation is out of tolerance the cells displaying the angles are highlighted in red. This color coding gives the operators an immediate warning of any problems. If a point ID is sent from the theodolite to the computer, and there is no matching angle or matching ID number, the point is flagged but does not cause the operation to come to a halt. The crews review the data before moving the theodolites to a new position, and determine if the point was erroneous or if it was a new point to be added.

Another feature available from the top tool bar is the 'Show Movements' option. This option allows the users to see how far a surveyed object is from its design or ideal location (figure 8).

Also available are standard windows drop down menus that include fitting routines, calculation options, real time positioning (RTP) options and a short cut to the observation tabulator.

Distances can be observed in the data capture routine. There is a facility for selecting particular prisms, as well as recording atmospheric conditions. The data can also be reduced directly from ACAMS and incorporated into the adjustment routine.

Add New Point Set Pt		Pt# AutoPo	Hide Dist Info	Adjustment	Obs T	abulation	Sir	nulate SH	now Movements	RTP To	oggle			
Common Nar	n TheoID #	Obs # times	Name 🛆	Theo ID	Position	ASB#	Port#	HCR	VCR	Dist	Reflector	Temp	Press	Date:Tim.
HFE0170	8170	0	GU2F00C	32	1	6	4	236.06810	291.67991	0.00000	NONE	0	0	09:01:22<>
HFE0180	8180	0	GU2F00C	32	1	6	4	36.07414	108.32060	0.00000	NONE	0	0	09:08:15<>
HFE0275	8275	0	GU2F00C	32	1	6	4	236.07042	291.67908	0.00000	NONE	0	0	09:09:01<>
HFE0370	8370	0	GU2F00C	32	1	6	4	36.07579	108.32347	0.00000	NONE	0	0	09:48:39<>
HFE0385	8385	0	GU2F00C	32	1	6	4	36.07423	108.32242	0.00000	NONE	0	0	09:50:38<>
GV2F00A	10	0	GU2F00C	32	1	6	4	36.07471	108.32328	0.00000	NONE	0	0	09:56:11<>
GV2F00B	11	0	GU2F00C	32	1	6	4	236.07047	291.67680	0.00000	NONE	0	0	09:57:36<>
GV2F00C	12	0	GU2F00D	33	1	2	5	309.51894	107.41967	0.00000	NONE	0	0	08:58:48<>
GV2F00D	13	0	GU2F00D	33	1	2	5	109.51680	292.58004	0.00000	NONE	0 1	0	08:59:11<>
SV2F0AA	20	0	GU2F00D	33	1	2	5	309.52232	107.41785	0.00000	NONE	0	0	09:10:22<;
SV2F0AB	21	0	GU2F00D	33	1	2	5	109.52040	292.58208	0.00000	NONE	0	0	09:10:39<>
GV2F0AC	22	0	GU2F00D	33	1	2	5	309.51992	107.42509	0.00000	NONE	0	0	09:51:17<:
GV2F0AD	23	0	GU2F00D	33	1	2	5	309.52111	107.42490	0.00000	NONE	0	0	09:53:58<>
GU2F00A	30	0	GU2F00D	33	1	2	5	109.51861	292.57553	0.00000	NONE	0	0	09:55:45<:
GU2F00B	31	0	GU2F00D	33	1	6	4	40.26810	107.78882	0.00000	NONE	0	0	09:00:48<>
JU2F00C	32	0	GU2F00D	33	1	6	4	240.26490	292.21197	0.00000	NONE	0	0	09:01:06<>
GU2F00D	33	0	GU2F00D	33	1	6	4	40.26853	107.78725	0.00000	NONE	0	0	09:08:27<:
			GU2F00D	33	1	6	4	240.26502	292.21215	0.00000	NONE	0	0	09:08:46<>
			GU2F00D	33	1	6	4	40.27027	107.79199	0.00000	NONE	0	0	09:51:36<>
			GU2F00D	33	1	6	4	40.27019	107.79180	0.00000	NONE	0	0	09:55:59<>
			GU2F00D	33	1	6	4	240.26673	292.20827	0.00000	NONE	0	0	09:57:50<>
			GV2F00A	10	1	2	5	130.05500	291.83878	0.00000	NONE	0	0	08:03:12<>
			GV2F00A	10	1	2	5	130.03278	291.82606	0.00000	NONE	0	0	08:09:33<>
			GV2F00A	10	1	2	5	130.03220	291.82654	0.00000	NONE	0	0	08:14:37<>
			GV2F00A	10	1	2	5	330.03461	108.17373	0.00000	NONE	0	0	08:15:52<:
			GV2F00A	10	1	6	4	246.19472	293.84176	0.00000	NONE	0	0	08:02:39<>
				-										Þ

Figure 7 Capture Data Screen

🍈 ACAMS	ACAMS : Display Movements													
Display Move C Loca	ements tions				Delta V	'alues In	dicate M	.ovemen	ts to Ideal.					
Target	Theold	d Z BFS	6 d X BFS d Y BFS Ideal Z		Ideal X	Ideal Y	Yaw	Fnd Z	Fnd X	Fnd Y	sd Z(fnd)	sd X(fnd)	5	
EBOX10	40	-79586585.	-59966222.	-2100032.1	10.16533	1.07648	4.42703	0.00000	79596.7504	59967.29918	2104.45914	0.00008	0.00018	0
EBOX11	41	-79585940.	-59966225.	-2100031.9	10.48790	1.09613	2.61863	0.00000	79596.4284	59967.32142	2102.65061	0.00009	0.00033	0
EBOX12	42	-79592446.	-59965836.	-2100032.5	7.22207	1.07709	2.33028	0.00000	79599.6687	59966.91386	2102.36280	0.00008	0.00010	0
EBOX15	45	-79588265.	-59966099.	-2100032.2	9.32116	1.08273	1.16192	0.00000	79597.5871	59967.18232	2101.19416	0.00007	0.00012	0
EBOX16	46	-79587984.	-59966114.	-2100032.2	9.46250	1.08418	-0.28843	0.00000	79597.4469	59967.19911	2099.74379	0.00008	0.00011	0
EBOX9	39	-79578844.	-59966713.	-2100031.5	14.05193	1.08507	4.61803	0.00000	79592.8961	59967.79831	2104.64953	0.00007	0.00022	0
EBOXP	50	-79590377.	-59965879.	-2100032.3	8.25809	1.12366	-0.04037	0.00000	79598.6359	59967.00280	2099.99198	0.00007	0.00010	0
EDIPF	25	-79585439.	-59966186.	-2100032.1	10.73725	1.13195	1.38750	0.00000	79596.1764	59967.31843	2101.41963	0.00008	0.00021	0
EDIPG	26	-79586295.	-59966114.	-2100032.3	10.30723	1.13975	-0.21404	0.00000	79596.6022	59967.25428	2099.81826	0.00008	0.00013	0
	77	70577011	FOOCCOF	0100001.1	14.00705	1.10040	2.01.225	0.00000	70500 0700	50007-00440	0100 03050	0.00000	0.00007	┍┻╢
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Figure 8 Display Movements Screen

3.7 RTP Routine

One of the main features available in ACAMS is the Real Time Positioning (RTP) routine. This routine is used to position any object into its desired alignment. The procedure requires the crew to observe the control points, the components to be aligned, and obtain an adjustment from 3DCD. They can then use the 'RTP Toggle' option on the main data capture toolbar. This takes the program to a new screen (figure 9) where the theodolites are polled at set time intervals or the

instrument operators take manual observations, to align a component to any given set of design coordinates.

As the instrument operators take observations, the coordinates are automatically updated, using a least squares solution. A value, based upon the original forward and reverse observations taken to the targets, is used to correct single face observations taken in RTP. The input file to 3DCD is updated with the corrected angles, and after the adjustment, the differences between design and the presently located target are calculated. The differences are then displayed (fig 9), and the crew can make the necessary adjustments to the object, and iterate to an acceptable position. After adjusting all the required elements by using the RTP routine, the crews will lock-down the elements and conduct a final survey using forward and reverse observations. An additional feature currently being added, is the tie to our fiducial database and calculating the reverse least squares transformation to find the component center.





3.8 Spectrometer Alignment

Jefferson Lab's Hall A contains two high resolution spectrometers and Hall C has a High Momentum (HMS) and a Short Orbit (SOS) spectrometer. All four spectrometers rotate about a central target. The alignment group is frequently called upon to determine the angle between the incoming beam and the centerline of the spectrometers. ACAMS is used to survey the spectrometer with respect to the local monuments. After a satisfactory adjustment with 3DCD, the results are processed using transformation software to determine the central axis of the spectrometers with respect to the beam. ACAMS automates this process resulting in smooth flow of information.

3.9 Reporting

Final reports can be auto-generated based on specific job related tasks or there is a facility for building a custom report. These reports are useful summaries, as well as providing a means for our group to track the history of various projects.

4. FUTURE ENHANCEMENTS

One of the main reasons for developing ACAMS was to allow our group to customize the software as circumstances dictated. To this end, some of the planned enhancements are outlined.

4.1 Enhanced Coordinate System Manipulation and Shape Fitting Routines

Currently ACAMS uses SLAC's geometric fitting routines in WINFIT^[2] that were developed in the early 1990's. It is envisioned that, as time allows, our software group will develop our own set of shape fitting routines and at the same time integrate the use of alternate coordinate systems which will allow the field crews greater flexibility while undertaking various surveys.

4.2 Integration with Portable CMM

Traditionally, the target surveys have been performed with theodolites, but as the experiments have become more complex, lines of sight have disappeared, which has necessitated the greater reliance on the portable CMM. The group's portable CMM has successfully been used for target alignment in experimental Halls A and C. Many of these operations have required that local control first be established with the use of theodolites. It is our goal to integrate the portable CMM into ACAMS, and have all the data for the project be collected using one set of data collecting tools. Preliminary work has been undertaken, with communications being worked out and the calculation of coordinates from the portable CMM being successfully achieved. Further work is required to make this addition a smooth operation.

4.3 Wireless Data Updates

Many areas of Jefferson Lab are now equipped to accept wireless network connections. Occasionally, there is a need to update information required for immediate use in the field. This now requires a return trip to the office to receive an updated CF card. Tapping into the capabilities of the wireless network is a possibility which may alleviate this situation.

4.4 Additional Theodolite Integration

ACAMS was designed to be as modular as possible. As updated theodolite equipment becomes available, we will endeavor to integrate it into the software.

4.5 Integration with Laser Tracker

At some stage, it is envisioned that the lab will obtain a laser tracker. It is hoped that prior to our obtaining a tracker, we will be able to obtain a unit temporarily, in order to work out the communication parameters, and integrate it into our data collection routines. As with other labs, the tracker will probably become one of our more heavily used tools, and an evaluation will be undertaken whether to use the supplied software or integrate it into ACAMS.

5. CONCLUSION

With an investment of approximately a half man-year of coding, ACAMS has combined several disjointed field operations and procedures into a tightly integrated operation. Additions have been made to the software, which have provided several new and valuable tools to the users. The crews have commented on the software's ease of use, the ability to rapidly align components, and conduct other essential alignment tasks.

ACAMS was developed in order to integrate Jefferson Lab's existing theodolite based alignment software into one package. ACAMS is now the main tool used by the Alignment Group. The software has given Jefferson Lab a tool that fits it's requirements, and traditional alignment operations while also allowing the group to have the flexibility and control over its development as circumstances dictate.

Future development that includes integration of updated and new equipment, and the ability to customize the software to specific tasks should make ACAMS a tool that will be used at the lab for many years.

6. ACKNOWLEDGMENTS

We would like to thank and recognize the alignment group at the Stanford Linear Accelerator for supplying the original code for the bundling program 3DCD, and a particular thanks to Catherine LeCocq for the use of the WINFIT program. A special thanks also goes out to all the field staff at the lab for their patience, suggestions and verification of all the processes developed for ACAMS.

7. REFERENCES

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