MROI Delay Line System

AIV Project Plan for PVM5

INT-406-ENG-0005-rev.1.0

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Revisions

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0.2	June 2009	F.Santoro	Few descriptions & WDTSs included
1.0	May-July-2010	F.Santoro	Full descriptions & WDTSs included

DLS-AIV Team

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1. SCOPE AND OBJECTIVES

The purpose of this document is to outline the project plan for assembly, integration and verification (AIV) of the MROI Delay Line System (DLS) in terms of defining detailed information regarding the sequence of engineering activities, the high-level inputs and the preparation tasks necessary to allow the DLS to be delivered so as to meet or exceed all its requirements specification. As for the AIV Planning, the goal is to structure the AIV tasks to achieve all milestones up to PVM5 in accordance with INT-414-TSP-0004 - *Commissioning Plan and Performance Verification Milestones for the MROI Project*. Although the current AIV Plan has been focused on reaching PVM5, it can be easily adapted and used as a guideline for other PVMs at other appropriate phases of the MROI project.

2. RELATED DOCUMENTS (RD)

The following documents are hereby incorporated as reference:

[RD1] *A System Design for the MRO Interferometer* - (Doc. no. INT-402-MIS-0000-rev1.31 - Oct. 2002);

[RD2] University of Cambridge FDR documentation, Feb.2008;

[RD3] *Project Quality Management Plan* - (Doc. no. INT-401-PMG-0011-rev0.7 - Mar. 2007);

[RD4] *Commissioning Plan and Performance Verification Milestones for the MROI Project* - (Doc. no. INT-414-TSP-0004);

[RD5] *Requirements Specification for the MROI DLS* - (Doc. no. INT-406-TSP-0002); and

[RD6] *DLS AIV Planning for PVM5* - (Doc. no. INT-406-ENG-0004).

[RD7] *Device Naming Standard for MRO Interferometer Control System* - (Doc. no. INT-409-COR-0104).

3. ABBREVIATIONS AND ACRONYMS

- AIV Assembly, Integration and Verification
- BCA Beam Combining Area
- BCF Beam Combining Facility
- CAT Campus Acceptance Tests
- DL Delay Line
- DLS Delay Line System
- DLA Delay Line Area
- ICD Interface Control Document
- ISF Interferometer Support Facility
- MA Major Activity
- MROI Magdalena Ridge Observatory Interferometer
- NMT New Mexico Institute of Mining and Technology
- OAT On-sky Acceptance Tests
- OD Outside diameter
- PM Project Manager
- PO Program Office
- R1 Release 1
- SAT Site Acceptance Tests
- TBC To Be Confirmed
- TBD To Be Defined
- UT Unit Telescope
- WBS Work Breakdown Structure
- WDTS Work Definition Task Sheet
- WP Work Package

For clarification:

CAT: The **C**ampus **A**cceptance **T**est takes place at ISF and is performed to ensure that the deliverables meet or exceed the requirement specifications on campus. However, for the DLS subproject CAT was agreed to be replaced by a set of functional testing of the Trolley on an open test track to ensure its integrity during the shipping process. The Trolley is then taken to the site.

SAT: The **S**ite **A**cceptance **T**est takes place at the Magdalena Ridge site and is performed to ensure that the deliverables meet or exceed the requirement specifications on site and to confirm that all deliverables as specified in the SOW are present.

OAT: The **O**n-sky **A**cceptance **T**est takes place at the Magdalena Ridge site using star light from the telescope and is performed to ensure that the deliverables meet or exceed the requirement specifications as a system.

4. INTRODUCTION

This document contains a description of the Delay Line System (DLS) sub-project assembly, integration and verification plan, here called *DLS-AIV Project Plan*, which is tied to the design and commissioning plan of the Magdalena Ridge Observatory Interferometer (MROI). It defines all detailed information for the AIV activities needed for the DLS as a whole, together with an ordering of these activities so as to be consistent with the MROI commissioning plan up to and including Performance Verification Milestone #5 (PVM5). The reader should note that these activities will include the installation and verification of both hardware and software. For a better understanding of the DLS-AIV process, this document should be accompanied by INT-406-ENG-0004 - *AIV Planning*, which also refers on how the DLS is connected to the PVMs up to PVM5.

4.1. PROGRAM BACKGROUND

The MROI is an international partnership between New Mexico Tech (NMT) and the Cavendish Laboratory at the University of Cambridge in the UK. The University of Cambridge is sub-contracted by NMT to undertake the design and development of a cost-effective 200m single stage continuous Delay Line (DL) that meets the performance requirements for MROI, and also to deliver one DL Trolley (hereafter called "Trolley") with associated optics and control electronics. The NMT/MROI Project Team will be responsible for the fabrication & procurement and assembly, integration and verification of all the components of the delay line system.

4.2. TECHNICAL BACKGROUND

The MROI will be equipped with a DLS which consists of up to ten Trolleys with associated optics and electronics, up to ten evacuated DL pipes with associated supports, a laser metrology system with associated hardware and optics for up to ten DLs, and the production control software. This MROI-DLS is expected to meet or exceed all the requirements specification outlined in INT-406-TSP-0002 - *Requirements Specification for the MROI DLS*. INT-406-TSP-0002 points out to the documentation provided by the University of Cambridge where each requirement was originally defined.

Engineering planning is mandatory for proper execution of assembly, integration and verification activities. This is because not only is technical achievement important, but other aspects such as schedule, cost, the allocation of resources and safety are all important too. The AIV Planning document outlines how the DLS sub-project was originally broken down into five work packages (WPs). The individual WPs were then broken down into a list of major activities (and then sub-activities) so that the AIV for each work package could be defined accordingly. Tasks that are outside of these work packages, but that are needed

to allow the AIV to be completed successfully – we will refer to these as "Preparation tasks" – also need to be defined. That exercise was used as the basis for the current AIV Project Plan for the MROI-DLS.

5. PROJECT PLAN FOR THE MROI-DLS AIV

As part of the AIV Project Plan, each sub-activity defined in the AIV Planning may be broken down into a sequence of lower-level tasks. Each of these tasks is then associated with a Description or a Work Definition Task Sheet (WDTS). These are numbered as a subset of the WBS, following the MROI numbering system, and list full details and dependencies of the actual task to be carried out. Each Description provides a brief explanation of the hardware/software being delivered, as well as the technical interfaces and related documentation. Each WDTS provides final level of technical details as information on the requirements for the task, the task input/output, the task duration, resources, required equipment & facilities, applicable documents, task procedure and any special notes. Sub-activities that contain tasks with a significant level of complexity and/or are safety critical must have their procedures documented to an appropriate level of detail to ensure risk mitigation. Estimates on schedule and task duration will also incorporate contingencies. The main subsections of the WDTS are described below:

a. Task name and WBS: This are the name of the task and the MROI p/n;

b. Major input: This lists the hardware required for the task to be realized;

c. Task output: This lists what the outcome is for the task;

d. Requirements: This lists the specialists involved during the task, the major facilities required, the dependencies, the major documents where specific information can be obtained and any specialized equipment;

e. Task procedure: This is a detailed description of the task in terms of preparation, set-up, measurements and technical effort, together with information on safety.

f. Notes: This is optional reserved to special notes and footnotes.

5.1. DLS AIV PLAN LOOKUP TABLE SPREADSHEET

An Excel spreadsheet was first used to assign task levels, MROI-CAM part numbers, task sheet type (Description or WDTS), dependencies, task duration, begin/end dates and ownership. The owner is responsible for defining and supervising a particular task, but not necessarily to execute that task. This information is shown in the following spreadsheet (Table 1).

Table 1 - DLS AIV project plan spreadsheet.

MROI PROJECT	>>> AIV PROJECT PLAN UP TO PVM5 <<<
DELAY LINE SYSTEM	Last update -- FS/CS -APRIL-2010 - INT-406-ENG-00xx-rev02

POSITION	TASK LEVEL	P/N GROUP	P/N IDENT	TYPE	ORDER	DESCRIPTION OF ACTIVITIES	TASK SHEET TYPE	DEPENDENCY	TASK DURATION (weeks)	TASK DURATION (mm/dd/yy) BEGIN	TASK DURATION (mm/dd/yy) END	OWNER
0	0					**MROI - BCF - DLA, OUTER BCA AND INNER BCA**						
1												
2	1	INT	406	AIV	0001	**HIGH LEVEL DELIVERABLES AND MAJOR DLS INPUTS**	Description	-	-	-	-	FS
3	2					**<4.06.01> DL supplementary hardware**						
4	3	INT	406	AIV	0010	Fast acting valves	Description	-	-	-	-	FS
5	3	INT	406	AIV	0011	Gantry crane, ground lifting equipment and caster dolly	Description	-	-	-	-	FS
6	3	INT	406	AIV	0012	Services and communication in the DLA	Description	-	-	-	-	JS
7	3	INT	406	AIV	0013	Insulation of Inner and Outer BCA walls	Description	-	-	-	-	CS
8	3	INT	406	AIV	0014	Alignment hardware for pipes and supports	Description	-	-	-	-	CS
9	2					**<4.06.01> Documentation**						
10	3	INT	406	AIV	0015	Cambridge design documentation	Description	-	-	-	-	MF
11	3	INT	406	AIV	0016	Engineering technical documents	Description	-	-	-	-	FS
12	3	INT	406	AIV	0017	As-built drawing package and product tree	Description	-	-	-	-	CS
13	3	INT	406	AIV	0018	Maintenance/operational manuals	Description	-	-	-	-	MF
14	2					**<4.06.02> Trolley #1**						
15	3	INT	406	AIV	0019	Trolley and associated optics/electronics	Description	-	-	-	-	MF
16	3	INT	406	AIV	0020	Handling gurney hardware	Description	-	-	-	-	FS
17	2					**<4.06.02> Trolley #2**						
18	3	INT	406	AIV	0019	Trolley and associated optics/electronics	Description	-	-	-	-	MF
19	2					**<4.06.01> Open test track at ISF**						
20	3	INT	406	AIV	0021	Open test track system	Description	-	-	-	-	CS
21	3	INT	406	AIV	0022	Safety, handling and transporting hardware	Description	-	-	-	-	CS
22	2					**<4.06.03> DL pipes and supports**						
23	3	INT	406	AIV	0023	16" OD x 12ft length DL pipes	Description	-	-	-	-	FS
24	4	INT	406	AIV	0024	Metrology of DL pipes	WDTS	23	1h/pipe	-	-	CS

25	4	INT	406	AIV	0025	Machine shop working on DL pipes	Description	24	-	-	-	FS
26	3	INT	406	AIV	0026	Pipe supports	Description	-	-	-	-	FS
27	3	INT	406	AIV	0027	Other parts (end plates, windows, tensioning mechanism etc)	Description	-	-	-	-	FS
28	2					**<4.06.04> Metrology system**						
29	3	INT	406	AIV	0028	Metrology table for the MROI Inner-BCA	Description	-	-	-	-	FS
30	3	INT	406	AIV	0029	Agilent laser head and splitting module	Description	-	-	-	-	DK
31	3	INT	406	AIV	0030	Metrology block and shear camera module	Description	-	-	-	-	FS
32	2					**<4.06.05> DL software**						
33	3	INT	406	AIV	0031	Control Systems at ISF	Description	-	-	-	-	JS
34	3	INT	406	AIV	0032	Control Systems at BCF for DLs - (electronics, computers)	Description	-	-	-	-	JS
35	1	INT	406	AIV	0100	**DLS AIV ACTIVITIES**	Description	-	-	-	-	FS
36	2					**<4.06.01> Planning & Infrastructure**						
37	3	INT	406	AIV	0110	Integration of fast acting valve	WDTS	4,78,84				CS
38	3	INT	406	AIV	0111	Integration of services and communication in the DLA	Description	6	-	-	-	JS
39	2					**<4.06.02> Trolley #1**						
40	3	INT	406	AIV	0112	Trolley preparation at ISF	Description	15	-	-	-	MF
41	4	INT	406	AIV	0113	Unpacking Trolley and associated components	WDTS	41				MF
42	4	INT	406	AIV	0114	Assembly modules and sub-modules of a Trolley	WDTS	42				MF
43	4	INT	406	AIV	0115	Complete assembly of a Trolley	WDTS	43				MF
44	3	INT	406	AIV	0116	Integration of a Trolley to the open test track	WDTS	5,44,77				MF
45	3	INT	406	AIV	0117	Pre-acceptance tests of a Trolley at ISF	WDTS	45,112				MF
46	3	INT	406	AIV	0118	Trolley preparation for transportation to the MROI	Description	46	-	-	-	MF
47	4	INT	406	AIV	0119	Packing and shipping a Trolley to MROI	WDTS	5,47				MF
48	4	INT	406	AIV	0120	Unpacking a Trolley at the DLA	WDTS	5,48				MF
49	3	INT	406	AIV	0121	Integration of a Trolley to the handling gurney	WDTS	5,16,49				MF
50	3	INT	406	AIV	0122	Trolley preparation for a DL	Description	50	-	-	-	MF
51	4	INT	406	AIV	0123	Alignment of handling gurney to the end of a DL	WDTS	51				CS
52	4	INT	406	AIV	0124	First alignment of metrology laser to a Trolley	WDTS	52,99,116				MF
53	4	INT	406	AIV	0125	Integrity functional testing of a Trolley	WDTS	52,53				MF
54	3	INT	406	AIV	0126	Installation and integration of a Trolley to a DL	WDTS	54				MF
55	3	INT	406	AIV	0127	SAT of Trolley in a DL	WDTS	55				MF
56	3	INT	406	AIV	0128	OAT of Trolley in a DL	WDTS	56				MF
57	2					**<4.06.02> Trolley #2**						
58	3	INT	406	AIV	0112	Trolley preparation at ISF	Description	18	-	-	-	MF
59	4	INT	406	AIV	0113	Unpacking Trolley and associated components	WDTS	59				MF
60	4	INT	406	AIV	0114	Assembly modules and sub-modules of a Trolley	WDTS	60				MF

61	4	INT	406	AIV	0115	Complete assembly of a Trolley	WDTS	61					MF
62	3	INT	406	AIV	0116	Integration of a Trolley to the open test track	WDTS	5,62,77					MF
63	3	INT	406	AIV	0117	Pre-acceptance tests of a Trolley at ISF	WDTS	63,112					MF
64	3	INT	406	AIV	0118	Trolley preparation for transportation to the MROI	Description	64	-	-	-		MF
65	4	INT	406	AIV	0119	Packing and shipping a Trolley to MROI	WDTS	5,65					MF
66	4	INT	406	AIV	0120	Unpacking a Trolley at the DLA	WDTS	5,66					MF
67	3	INT	406	AIV	0121	Integration of a Trolley to the handling gurney	WDTS	5,16,67					MF
68	3	INT	406	AIV	0122	Trolley preparation for a DL	Description	68	-	-	-		MF
69	4	INT	406	AIV	0123	Alignment of handling gurney to the end of a DL	WDTS	69					CS
70	4	INT	406	AIV	0124	First alignment of metrology laser to a Trolley	WDTS	70,108,120					MF
71	4	INT	406	AIV	0125	Integrity functional testing of a Trolley	WDTS	70,71					MF
72	3	INT	406	AIV	0126	Installation and integration of a Trolley to a DL	WDTS	72					MF
73	3	INT	406	AIV	0127	SAT of Trolley in a DL	WDTS	73					MF
74	3	INT	406	AIV	0128	OAT of Trolley in a DL	WDTS	74					MF
75	2					**<4.06.03> DL[W2] at MROI (100m)**							
76	3	INT	406	AIV	0129	Assembly/verification of the open test track at ISF	WDTS	20					CS
77	3	INT	406	AIV	0130	Assembly of DL pipes/supports in DLA	WDTS	5,25,26,27					FS
78	3	INT	406	AIV	0131	Initial alignment of DL pipes/supports	WDTS	78					FS
79	3	INT	406	AIV	0132	Integration and verification of a DL to interfaces at BCF	WDTS	79,130					FS
80	3	INT	406	AIV	0133	Verification of vacuum integrity	Description	80,135	-	-	-		FS
81	3	INT	406	AIV	0134	Final alignment of a DL using a Trolley	WDTS	55,80,81,113					MF
82	2					**<4.06.03> DL[W1] at MROI (30m)**							
83	3	INT	406	AIV	0130	Assembly of DL pipes/supports in DLA	WDTS	5,25,26,27					FS
84	3	INT	406	AIV	0131	Initial alignment of DL pipes/supports	WDTS	84					FS
85	3	INT	406	AIV	0132	Integration and verification of a DL to interfaces at BCF	WDTS	85,130					FS
86	3	INT	406	AIV	0133	Verification of vacuum integrity	WDTS	86,135					FS
87	3	INT	406	AIV	0134	Final alignment of a DL using a Trolley	WDTS	73,86,87,117					MF
88	2					**<4.06.04> Metrology system [W2]**							
89	3	INT	406	AIV	0135	Metrology table preparation & install in Inner-BCA	WDTS	29					FS
90	4	INT	406	AIV	0136	Assembly of full metrology table at Inner-BCA	WDTS	90					FS
91	4	INT	406	AIV	0137	Assembly of Agilent laser head to nominal position	WDTS	30,91					DK
92	3	INT	406	AIV	0138	Assembly/integration of Metrology System for a DL	WDTS	31,91					DK
93	3	INT	406	AIV	0139	Integration of shear camera to the Metrology System	WDTS	31,91,115					DK
94	3	INT	406	AIV	0140	Integration of Metrology System to Trolley	WDTS	55,92,93,114					MF
95	3	INT	406	AIV	0141	Integration of shear camera to Trolley	WDTS	55,92,94,115					MF
96	3	INT	406	AIV	0142	Final alignment of Metrology System to a Trolley	WDTS	95					MF

97	3	INT	406	AIV	0143	Final alignment of shear camera to a Trolley	WDTS	96				MF
98	3	INT	406	AIV	0144	Verification of Metrology System for a DL	WDTS	97				MF
99	3	INT	406	AIV	0145	Verification of shear camera system for a DL	WDTS	98				MF
100	2					**<4.06.04> Metrology system [W1]**						
101	3	INT	406	AIV	0138	Assembly/integration of Metrology System for a DL	WDTS	31,91				DK
102	3	INT	406	AIV	0139	Integration of shear camera to the Metrology System	WDTS	31,91,119				DK
103	3	INT	406	AIV	0140	Integration of Metrology System to Trolley	WDTS	73,92,102,118				MF
104	3	INT	406	AIV	0141	Integration of shear camera to Trolley	WDTS	73,92,103,119				MF
105	3	INT	406	AIV	0142	Final alignment of Metrology System to a Trolley	WDTS	104				MF
106	3	INT	406	AIV	0143	Final alignment of shear camera to a Trolley	WDTS	105				MF
107	3	INT	406	AIV	0144	Verification of Metrology System for a DL	WDTS	106				MF
108	3	INT	406	AIV	0145	Verification of shear camera system for a DL	WDTS	107				MF
109	2					**<4.06.05> DL Software (Trolley#1 at DL[W2])**						
110	3	INT	406	AIV	0146	Integration and verification of Controls for ISF	Description	20,33,45	-	-	-	JS
111	3	INT	406	AIV	0147	Integration and verification of Controls for a DL	Description	34,50	-	-	-	JS
112	2					**<4.06.05> DL Software (Trolley#2 at DL[W1])**						
113	3	INT	406	AIV	0147	Integration and verification of Controls for a DL	Description	35,69	-	-	-	JS
114	1	INT	406	AIV	0500	**PREPARATION TASKS BREAKDOWN STRUCTURE**	Description	-	-	-	-	FS
115	2	INT	406	AIV	0501	**<4.06.01> Monumentation**	Description	-	-	-	-	FS
116	3	INT	406	AIV	0502	To prepare scope of work/requirements for monumentation	Description	-	-	-	-	RS
117	3	INT	406	AIV	0503	To secure, monitor and close a contract for successful delivery	Description	-	-	-	-	RS
118	3	INT	406	AIV	0504	To procure proper tools needed to install & align the DLS	Description	-	-	-	-	SR
119	2	INT	406	AIV	0505	**<4.06.01> Measurements**	Description	**-**	-	-	-	FS
120	3	INT	406	AIV	0506	To measure the shape & flatness of the DLA technical slab	Description	124,125	-	-	-	RS
121	3	INT	406	AIV	0507	To measure any temperature gradient along the DLA	Description	-	-	-	-	DK
122	3	INT	406	AIV	0508	To install anchor bolts on the DLA main slab	WDTS	7,121				FS
123	2	INT	406	AIV	0509	**<4.06.01> Controlling of interfaces**	Description	**-**	-	-	-	FS
124	3	INT	406	AIV	0510	To manage the ICD: Delay Line to SCS	Description	-	-	-	-	JS
125	3	INT	406	AIV	0511	To manage the ICD: Delay Line to Beam Relay System	Description	80,86	-	-	-	FS
126	3	INT	406	AIV	0512	To manage the ICD: Delay Line to BCF infrastructure (building)	Description	80,86	-	-	-	FS
127	3	INT	406	AIV	0513	To manage the ICD: Delay Line to Metrology System	Description	93,102	-	-	-	FS
128	3	INT	406	AIV	0514	To manage the ICD: Delay Line to Vacuum System	Description	80,86	-	-	-	FS
129	3	INT	406	AIV	0515	To manage the ICD: Metrology System to BCF	Description	80,86	-	-	-	FS
130	3	INT	406	AIV	0516	To manage the ICD: Metrology System to Beam Relay System	Description	93,102	-	-	-	FS
131	2	INT	406	AIV	0517	**<4.06.01> Signals and Services in the BCF**	Description	6	-	-	-	RS
132	3	INT	406	AIV	0518	Determine signal & service requirements for anticipated DLs	Description	6	-	-	-	JS

133	3	INT	406	AIV	0519	To design & install the required electrical service	Description	139	-	-	-	RS
134	3	INT	406	AIV	0520	To design & install the required data communications service	Description	140	-	-	-	RS
135	3	INT	406	AIV	0521	To set the requirements needed for operations & maintenance	Description	-	-	-	-	RS
136	2	INT	406	AIV	0522	**<4.06.01> Supplies in the DLA**	Description	-	-	-	-	RS
137	3	INT	406	AIV	0523	To setup a limited shop with tools and fasteners in the DLA	Description	-	-	-	-	RS
138	2	INT	406	AIV	0524	**<4.06.01> Temporary work areas**	Description	-	-	-	-	RS
139	3	INT	406	AIV	0525	To arrange workspace in the BCF	Description	-	-	-	-	RS
140	2					**<4.06.03> Open test track at ISF**						
141	3	INT	406	AIV	0526	To arrange workspace and workbenches at ISF	Description	-	-	-	-	CS
142	3	INT	406	AIV	0527	To provide tools and handling hardware at ISF	Description	-	-	-	-	CS

5.2. MROI-DLS AIV TASK SHEET

This section presents the Description or the WDTS associated with each task shown in Table 1 of section 5.1. The tasks are presented by MROI-CAM part number followed by the name of the task. Each Description provides a brief explanation of the hardware/software being delivered, as well as the technical interfaces and related documentation. Each WDTS provides final level of technical details as information on the requirements for accomplishment of the task, the task input/output, the task duration, resources, required equipment & facilities, applicable documents, task procedure and any special notes.

INT-406-AIV-0001 - High level deliverables and major DLS inputs

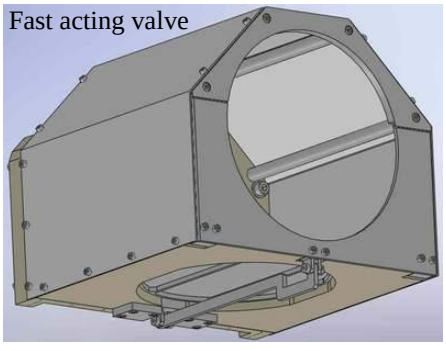
Type of Task Sheet: Description
Owner: FS

The high level deliverables of the DLS subproject were originally set by work package, as presented in INT-406-ENG-0004 - *AIV Planning*. As far as the AIV project plan is concerned, it is important to understand what inputs are needed to allow any given DLS high-level deliverable to be accomplished. For example, the work package 4.06.03 - 'DL Pipes and Supports' aims to deliver a full functioning system of pipes and supports installed in the DLA that supports the operation of the as-designed Trolleys. It is this fully functioning system that is the high-level deliverable, but this requires as inputs components as finished section of pipes, pipe supports, etc. The major DLS inputs are listed from line 3 to line 34 in Table 1.

INT-406-AIV-0010 - Fast acting valves

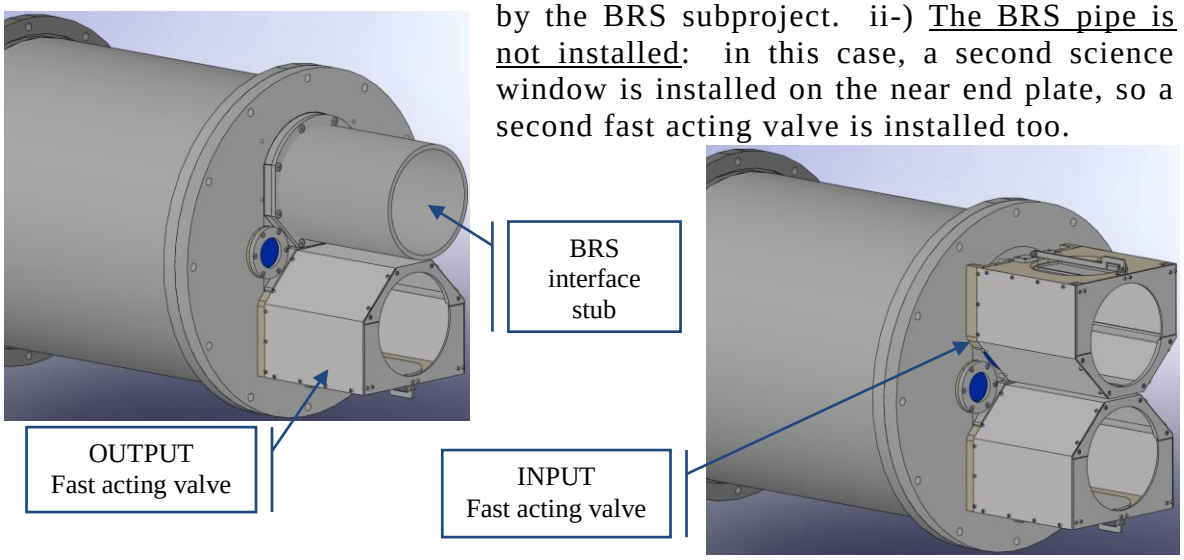
Type of Task Sheet: Description
Owner: FS

Catastrophic re-pressurization (or catastrophic failure of vacuum integrity) of the DLS may represent damage to the Trolley, the DL pipes/supports and personnel. Although the risk is very small, this event is taken into account in the design of the DLS. The DLS fast acting valve (also called safety mechanism) is installed externally to the near end plate of each delay line, inside the Inner-BCA. It occupies a volume of 195x190x160mm and weights about 1.5kg (basically aluminum construction). It will greatly reduce the rate at which air fills the evacuated DL pipe in the event of a science window breaking. The valve is passive actuated and manually operated and is capable of shutting in a time of a few tens of milliseconds.


Fast acting valve

Two scenarios are considered in the design. i-) The BRS pipe is connected to the DLS near end plate: in this case, only the science window at the bottom portion of the DL end plate needs to be protected with a fast acting valve. Catastrophic

re-pressurization in the DLS caused by breaking of the BRS science window installed elsewhere or due to a severe rupture of a beam relay pipe is carried out by the BRS subproject. ii-) <u>The BRS pipe is not installed</u>: in this case, a second science window is installed on the near end plate, so a second fast acting valve is installed too.



Reference documents on analysis of occurrence of catastrophic re-pressurizing, design of fast acting valve, description of interfaces and mounting instructions:

Identifier	Description	MROI-CAM P/N
AIV-5040	Analysis of catastrophic re-pressurization of the delay line - v0.3 - Jan2008	-
AIV-4013	Delay Line Pipes and Supports Design Description	INT-406-VEN-0115
AIV-4001	Assembly drawings and mounting instructions	MROI-193,194,196,199
AIV-5043	Fast acting valve - IEEE Transactions on Nuclear Science 1967, John S.Moenich, Argonne National Lab.	-

INT-406-AIV-0011 - <u>Gantry crane, ground lifting equipment and caster dolly</u>

Type of Task Sheet: Description
Owner: FS


Hoist

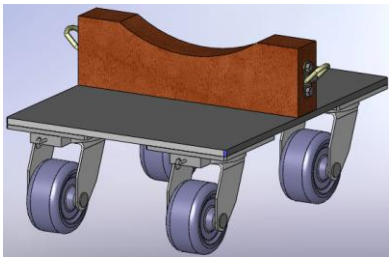
An overhead <u>gantry crane</u> in the DLA has multiple uses. It is required to facilitate the access to the inner DLs for performing occasional maintenance, scheduled changes of seals or removal of a Trolley from a stacked position. It is also suggested to smooth the progress of transporting finished DL pipes from the far end of the DLA to the position where that pipe will be installed. A gantry crane will have wheels on both sides of the main slabs (on both walkways), requiring a crew of two people to push it from one place to another inside the DLA, and probably a third person to stabilize the hardware being transported (DL pipe, Trolley etc). When not in use, the gantry crane should be parked (stored) close to the far end of the DLA.

Gantry crane technical data:

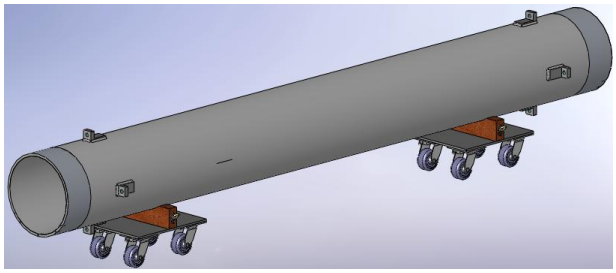
Description	Data
Load capacity	1 ton
Overall span	7.6m (25ft)
Clear span	7.3m (24ft)
Adjustable height	2.1m (7ft) to 3.1m (10ft)
Electric chain dual speed hoist w/ push trolley	1 ton capacity
Standard lift	3.1m (10ft)
Higher lifting speeds	14ft/min (2.8 inches/sec)
Lower lifting speed	5ft/min (1 inch/sec)

Gantry crane and ground lifting equipment should only be operated by trained personnel when precision loads are being managed.

The ground lifting equipment used to transport and install a Trolley from one position to another is a counter balanced floor crane. It can also be used to handle and position a pipe section during installation. It has an adjustable boom to allow for maximum adjustment, which can be raised with a manual hydraulic hand pump. Boom also telescopes when greater reach is required. It has 0.5 ton capacity at bottom height of 0.6m (24"). Maximum height is 2.2m (86"). These are enough for installing a Trolley on the open test track (INT-406-AIV-0021) at the Interferometer Support Facility (ISF) or MROI, or on the handling gurney (INT-406-AIV-0020).



Two caster dollies are used to transport a finished DL pipe from the far end of the DLA to the position where that pipe will be installed. Each dolly has four swivel casters to offer full 360 degree maneuverability.



Pipe is carried on wood supports and secured with rubber slings and grab hook. Suggested minimum distance from the end of the pipe is 500mm.

Reference documents:

Identifier	Description	MROI-CAM P/N
AIV-4016	Proposed delay line tools, jigs and handling procedures	INT-406-VEN-0119
AIV-5090	Gantry Crane for the MROI Delay Line Area - v0.2 - Jan2008	-

INT-406-AIV-0012 - Services and communication in the DLA

Type of Task Sheet: Description
Owner: JS

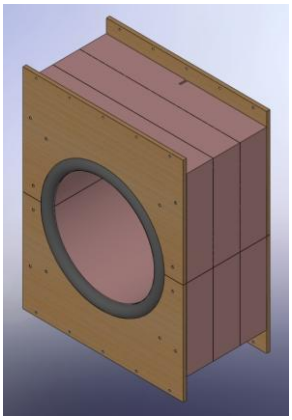
The DLS requires signals and services that are to be provided by electronics situated at locations in the DLA. Utility power of 120V AC must be supplied at four locations for each DL to accommodate intermediate DL buildout lengths. These power outlets supply each DL local electronics cabinet and temporary AIV activities such as extra lighting, a soldering iron or test equipment. An additional outlet is required for a fiber-to-copper network switch at a midpoint along the length of the DLA. A low latency analog signal cable must be installed from the far end of each DL to the controls cabinet located in the Outer-BCA. A network cable, copper or fiber depending on the phase of the buildout, is installed from the Outer-BCA controls cabinet to the end of each DL. Power supplies 5V and 48V DC are installed at the end of each DL in the local electronics enclosure for the Trolley inductive power and RF transceivers. A cable is installed from the near end of each DL to the Outer-BCA cabinet for the datum optical switch signal.

Reference documents:

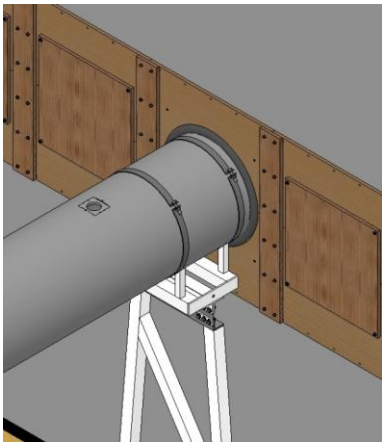
Identifier	Description	MROI-CAM P/N
AIV-4051	ICD: Delay Line to Beam Combining Facility	INT-406-VEN-0009
AIV-5070	Delay Line Signals and Service in the DLA (by MF)	-
AIV-5072	DLA Power System - Scope of Work (July 2009)	-

INT-406-AIV-0013 - Insulation of inner and Outer-BCA walls

Type of Task Sheet: Description
Owner: CS



DL pipes must pass through the two slots opened in the walls between the Inner/Outer-BCA and the DLA. These slots must be properly insulated in order to prevent heat to transfer from one area to another and also to be light tight. To accomplish this, removable modular panels consisting of insulating material are installed. The panels have openings in the solid sheets of insulating materials that allow for the passage of the DL pipes and can be plugged with a cylinder of insulating material in the case where there is not a DL pipe passing through it. The panels are centered to the DL axis by using wood dowel pins mounted in a wood spacer. Soft isolation pieces of insulation material are fitted in the gap between the outer panel and the pipe too guarantee vibration free connection. Cover plates are installed on the external parts of the wall for protection. The modularity of this design allows the insulating material to be removed for the purposes of future re-alignment of DL pipes and supports.

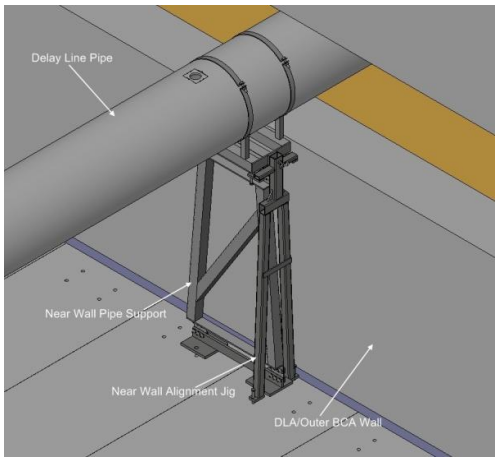


Reference documents for more detailed information on the insulation modules:

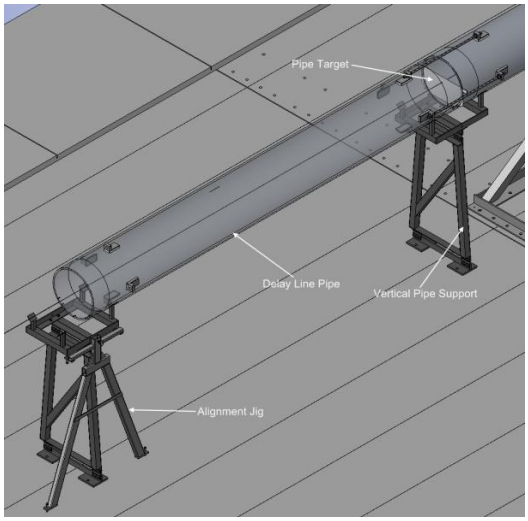
Identifier	Description	MROI-CAM P/N
AIV-4051	ICD: Delay Line to Beam Combining Facility	INT-406-VEN-0009
AIV-6002	Assembly drawings and mounting instructions	INT-406-DWG-0071 INT-406-DWG-0072 INT-406-DWG-0086

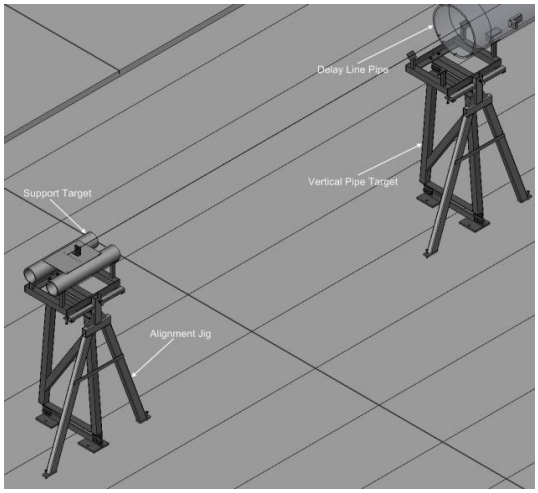
INT-406-AIV-0014 - Alignment hardware for pipes and supports

Type of Task Sheet: Description
Owner: CS



The alignment hardware for pipes and supports consists of support tools needed for alignment and installation of the DL pipes and supports (reader shall refer to AIV-4016). The alignment hardware includes jigs for aligning and installing the supports and targets for aligning. The alignment jig will be used to stabilize the pipe support before the pipe is installed and set the support at a desired height. Bolts mounted on the top and bottom of the jig can be used to adjust the height of the support and provide a means to level it as well. There are two different alignment jigs, one that is used on narrower support that is near the wall at the near end of the DLA and the other jig is used for the rest of the supports. The jig for the narrow support functions the same as the larger jig, but is narrower to allow it to be used close to the wall. There are two targets, the support target and the pipe target. The support target consists of a plate mounted on two pipes and a target mounted on the top of the plate. The pipe target is a thin plate that can be slid into a small gap between two pipes. The target consists of four points were it sits on the dowel pins in the pipe and a small hole for aligning a virtual line. A virtual line from a laser theodolite is used to align the targets. The support target will be used to align the support to a nominal height. The pipe target will be used to make the final alignment with the pipe installed on the support. This will allow for any deviations in the pipe to be taken into account.





Reference documents for required information on hardware and procedures:

Identifier	Description	MROI-CAM P/N
AIV-4016	Proposed DL Tools, Jigs, and Handling Procedures	INT-406-VEN-0119
AIV-6002	Assembly drawings and mounting instructions (see INT-406-DWG-0101 for general assembly)	INT-406-DWG-0101 INT-406-DWG-0103 INT-406-DWG-0105 INT-406-DWG-0106 INT-406-DWG-0108 INT-406-DWG-0109 INT-406-DWG-0110 INT-406-DWG-0111

INT-406-AIV-0015 - Cambridge design documentation

Type of Task Sheet: Description
Owner: MF

The components of a single DLS are the Trolley and its on-board software, the shear camera and associated computer and software, one channel of the metrology system which shares a laser head and a VME system (with associated software) with the other DL, and power and communications modules which reside at the far end of the DL.

Design documentation was produced by the Cambridge team for the Final Design Review. The content of these documents will have been updated to correspond with the as-built system as will the drawing package for the Trolley and metrology system. System overview and software design descriptions are valid only for the prototype system delivered and production software design and description will be significantly different. Details of the DL documentation are given in INT-406-VEN-0120 MRO Delay Line Documentation Plan but the list of documents is provided in the tables below. The Cambridge design documentation is numbered in the AIV category at the 4000 sequential group. Hard copies of all documents are available in the DLS-AIV binders where information can be retrieved at any time as necessary.

Identifier	Description - Design Drawings	MROI-CAM P/N
AIV-4000	Trolley (assemblies: MROI-323 for the Trolley, MROI-310 for the Lower Shell and MROI-324 for the Cat's Eye)	Drawing set
AIV-4001	DL Pipes and Supports	Design set
AIV-4002	Metrology Layout (for MROI)	Drawing set

Design drawings are provided by Cambridge and include detailed manufacturing drawings with sufficient information in order to reproduce a Trolley and associated subsystems. Drawings for pipes and supports are design drawings only; the detailed manufacturing drawings were produced by MROI.

Identifier	Description - Hardware Design Documentation	MROI-CAM P/N
AIV-4010	Trolley Mechanical Design Description	INT-406-VEN-0111
AIV-4011	Trolley Electronics Design Description	INT-406-VEN-0112
AIV-4012	Metrology System & VME Hardware Design Description	INT-406-VEN-0113

AIV-4013	Delay Line Pipes and Supports Design Description	INT-406-VEN-0115
AIV-4014	Trolley components List	-
AIV-4015	Metrology system components list	INT-406-VEN-0118
AIV-4016	Proposed delay line tools, jigs and handling procedures	INT-406-VEN-0119
AIV-4017	Risk and Hazard document	INT-406-VEN-0121

Hardware design documentation covers the optical, mechanical and electronics design of the Trolley and its associated subsystems, including communications links and inductive power supply, and the design and layout of the metrology system. The DL pipes and supports design description should be read in the context of the actual design of pipes and supports as settled upon at MROI. Components lists for commercially available components are correct at the time of provision but it should be recognized that some components will become unavailable for future Trolleys and be replaced by similar types.

Identifier	Description - System Design Overview Documentation	MROI-CAM P/N
AIV-4020	System Overview	INT-406-VEN-0100
AIV-4021	Control Software Architecture	INT-406-VEN-0101
AIV-4022	Trolley Software Functional Description	INT-406-VEN-0102
AIV-4023	Workstation Software Functional Description	INT-406-VEN-0103
AIV-4024	VME Software Functional Description	INT-406-VEN-0104
AIV-4025	Shear Camera Software Functional Description	INT-406-VEN-0105
AIV-4026	MRO Delay Line - Derived Requirements	INT-406-VEN-0107
AIV-4027	Network Message Protocols and Telemetry/Status/Logs File Format	-

Software design documentation is rather more complex because of the provision of prototype software to aid in debugging of the prototype Trolley and to carry out acceptance testing and initial integration into the delay line in the absence of an interferometer control system. Production software will be similar but with specific difference and improvements. Final software documentation will supersede the prototype software descriptions but the functional descriptions will still apply or be updated where necessary. Production software design documentation is tabulated below.

Identifier	Description - Production Software Design Documentation	MROI-CAM P/N
AIV-4020	System Overview	INT-406-VEN-0100
AIV-4030	Production Delay Line Control Software Architecture	INT-406-VEN-1001
AIV-4031	Production Trolley Software Functional Description	INT-406-VEN-1002
AIV-4032	Production Workstation Software Functional Description	INT-406-VEN-1003
AIV-4033	Production Metrology Software Functional Description	INT-406-VEN-1004
AIV-4034	Production Shear Sensor Software Functional Description	INT-406-VEN-1005
AIV-4035	Delay Line Analysis GUI Functional Description	INT-406-VEN-1006
AIV-4036	Network Message Protocols and Telemetry/Status/Logs File Format	INT-406-VEN-1007
AIV-4037	Verification plan for the MROI production DL software	INT-406-VEN-1009
AIV-4038	dlmsg Library Manual	-

ICDs are useful for reference when systems are integrated or if modifications are envisaged. In this sense they are useful design documents.

Identifier	Description - Interface Control Documents	MROI-CAM P/N
AIV-4050	ICD: Delay line to Beam Relay system	INT-406-VEN-0008
AIV-4051	ICD: Delay Line to Beam Combining Facility	INT-406-VEN-0009
AIV-4052	ICD: Delay line to Metrology System	INT-406-VEN-0010
AIV-4053	ICD: Delay line to Vacuum System	INT-406-VEN-0011
AIV-4054	ICD: Metrology System to Beam Combining Facility	INT-406-VEN-0012
AIV-4055	ICD: Metrology System to Beam Relay System	INT-406-VEN-0013

INT-406-AIV-0016 - Engineering technical documents

Type of Task Sheet: Description
Owner: FS

The engineering technical documents are all technical material distributed by the MROI and Cambridge teams during the development phase of the DLS subproject which notes are relevant to both the design and the DLS-AIV process. Also, packages with major data sheet and technical information for some off-the-shelf components of the DLS are included. What follows is a list of such documents with a brief explanation on the content the reader will find in each of them. The engineering technical documents are numbered in the AIV category at the 5000 sequential group. Hard copies of all documents are available in the DLS-AIV binders where information can be retrieved at any time as necessary. They will be referred at least once at a Description or WDTS presented in the AIV project plan document and are organized below in different groups.

Pipes and Supports

Identifier	Description - For future procurements on extruded pipes	MROI-CAM P/N
AIV-5020	Summary of delay line pipe status and suggestions for a way forward (CAH - Sept 2005)	-
AIV-5021	Delay Line Pipe - specification and procurement	-
AIV-5022	Visit to BA Tubes in the UK - April 2008	Memo

Content: This are reference documents for future procurement processes of 16"OD extruded aluminum tubes. It is included here because the DL pipes are major DLS inputs and is considered a critical procurement with impact on cost and control quality of the DLS.

Identifier	Description - Pipes	MROI-CAM P/N
AIV-5030	Pipe join analysis (MF)	-
AIV-5031	DL pipes - quality control on installed pipes	Spreadsheets

Identifier	Description - Supports	MROI-CAM P/N
AIV-5035	Provisional Anchor Requirements for DL (MF - Jan 2007)	-
AIV-5036	Pipe anchor fixing	-

Identifier	Description - End plates components	MROI-CAM P/N
AIV-5040	Analysis of catastrophic re-pressurization of the delay line - v0.3 - Jan2008	-
AIV-5041	Fast acting valve - IEEE Transactions on Nuclear Science 1967, John S. Moenich, Argonne National Lab.	-
AIV-5042	Draft window specifications for the MROI delay lines - v2 (CAH - 2007-0907)	-
AIV-5043	Specification of the Science and Metrology Windows for the MROI Delay Lines - v1.1	INT-406-TSP-0004

Identifier	Description - Test Facilities	MROI-CAM P/N
AIV-5050	Delay Line Test Facilities (by MF)	-
AIV-5051	Delay Line Pipe Design and Test Rig	-

Metrology System

Identifier	Description	MROI-CAM P/N
AIV-5060	Preliminary single channel metrology system alignment	INT-406-VEN-00xx

Software

Identifier	Description	MROI-CAM P/N
AIV-5065	DL workstation configuration instructions	-
AIV-5066	Cambridge software installation and testing instructions	-
AIV-5067	Test Plan	INT-409-VEN-0108
AIV-5068	ICD: Delay line to ICS	INT-406-ENG-0002
AIV-5069	ICD: Delay line to Fringe Tracker	TBD UofC / MROI

DLA related documents

Identifier	Description	MROI-CAM P/N
AIV-5070	Delay Line Signals and Services in the DLA (by MF)	-
AIV-5071	Cabling Plan for DLS and Metrology System	INT-406-ENG-000x
AIV-5072	DLA Power System - Scope of Work (July 2009)	INT-406-ENG-000x
AIV-5073	Connecting the VS to the MROI DLs - v0.1 - Jan2008	-
AIV-5074	DLA Floor Slab - shape measurements - v0.1 - Oct2007	-
AIV-5075	Installation Report by Summit Engineering	-
AIV-5076	Survey Equipment List	INT-412-CON-0200
AIV-5077	Derived Tool List for AIV at BCF	INT-412-CON-0300
AIV-5078	DLA Electrical Systems Statement of Work	INT-412-CON-0500
AIV-5079	Provisional list of tools and test equipment for DL and Trolley installation and testing at MROI	-

BCA related documents

Identifier	Description	MROI-CAM P/N
AIV-5080	Armstrong Static Dissipative Product Data	-
AIV-5081	Calibration of a set of Pace temperature probes (DAK)	-

Lifting/Handling equipment

Identifier	Description	MROI-CAM P/N
AIV-5090	Gantry Crane for the MROI DLA - v0.2 - Jan2008	-

Monumentation

Identifier	Description	MROI-CAM P/N
AIV-5100	Installation of Survey Monuments in the MROI-BCF	INT-406-TSP-0100
AIV-5101	Alignment Tasks for the MROI-BCF and Array Infrastructure (Date: 2007-0520)	-
AIV-5102	Monumentation for the MROI-BCF (Date: 2006-1215)	-
AIV-5103	Monumentation Phase I Statement of Work	INT-412-CON-0100
AIV-5104	DLA technical slab characterization report (EDM Works)	-

Content: AIV-5140 is the Statement-Of-Work and top-level requirements document that covers the scope of work for a professional surveyor to install monuments inside the BCF, more specifically inside the Inner-BCA and DLA. It presents the intended use for the monuments as wells as the coordinate system adopted, its origin and tridimensional position for the monuments installed. AIV-5141 describes the equipment that needs to be installed and aligned at the MROI both inside and outside the BCF. It presents the number, location and type of benchmarks needed to fulfill the needs of the project. AIV-5142 is the first document distributed about monumentation. It presents the very first thinking regarding the needs for the monumentation network required for the MROI BCF and array infrastructure.

Important data-sheet and technical information from manufactures

Identifier	Description	MROI-CAM P/N
AIV-5110	5517GL Laser Head - from Agilent Technologies	Agilent package
AIV-5111	Trolley datum sensor - from Contrinex	Data sheet
AIV-5112	DLS Rubber sleeve - material Data Sheet	Data sheet
AIV-5113	Inner-BCA Tile - Static Dissipative Product Data	Product data

INT-406-AIV-0017 - As-built drawing package and product tree

Type of Task Sheet: Description
Owner: CS

The University of Cambridge is responsible for the design of the DLS and for the delivery of one Trolley. As-built drawings are also part of this deliverable, which includes fabrication drawings for the Trolley, pipes, supports, end plates and accessories, and metrology system. Major as-built drawings are numbered in the AIV category at the 6000 sequential group. Hard copies of all drawings are available in the DLS-AIV binders where information can be retrieved at any time as necessary. Major drawings are listed below:

Identifier	Description - Cambridge drawings	MROI-CAM P/N
AIV-4000	Trolley (assemblies: MROI-323 for the Trolley, MROI-310 for the Lower Shell and MROI-324 for the Cat's Eye)	Drawing set

AIV-4001	DL Pipes and Supports	Design set
AIV-4002	Metrology Layout (for MROI)	Drawing set

The MROI team has also produced drawings for pipes and supports (as part of RFP processes), handling gurney, insulation modules, alignment hardware, open test track, metrology system (also part of RFP process), control system and various jigs for testing, measuring and installation. Relevant drawings of the BCF from M3 Engineering are also included. Major drawings are listed below:

Identifier	Description - MROI drawings	MROI-CAM P/N
AIV-6000	Delay Line System Product Tree	INT-406-DWG-XXXX
AIV-6001	Delay Line System SKT Product Tree	INT-406-DWG-XXXX
AIV-6002	Assembly drawings for DLS production parts	INT-406-DWG-0070 INT-406-DWG-0100 INT-406-DWG-0210 INT-406-DWG-0305 INT-406-DWG-0530 INT-406-DWG-2000 INT-406-DWG-3000
AIV-6003	Assembly drawings for DLS sketch parts	INT-406-SKT-0001 INT-406-SKT-0042 INT-406-SKT-0048 INT-406-SKT-0100 INT-406-SKT-0110
AIV-6004	Electrical and electronics drawings	Drawing package
AIV-6005	Delay Line Area Electrical	Drawing package
AIV-6006	BCF construction drawings by M3 and MROI (4.12)	Drawing package

INT-406-AIV-0018 - Maintenance/operational manuals

Type of Task Sheet: Description
Owner: MF

Separate maintenance and operation manuals will be produced for the Trolley subsystem whereas a combined one is more suitable for the metrology system. A brief description of each manual is given below. Note that the structure of software documentation has yet to be decided. The maintenance and operational manuals documentation is numbered in the AIV category at the 7000 sequential group. Hard copies of all documents are available in the DLS-AIV binders where information can be retrieved at any time as necessary.

Trolley

Trolley Maintenance Manual:

This manual covers the hardware aspects of maintaining the Trolley. It is necessary to read this in conjunction with the operations manual in order to make best use of the status information available from the Trolley when de-bugging a problem. The following topics are covered in this manual:

- Preparation of the Trolley from unpacking to the installation in the pipe
- Trolley handling and necessary precautions
- Standard maintenance requirements and procedures
- Setting up and calibration of components
- Tuning of servo loops
- Disassembly and replacement of major components
- Removal and replacement of optical components
- Re-alignment of optical components
- Maintenance of auxiliary Trolley subsystems (communications and inductive power)
- De-bugging Trolley faults

Trolley Operations Manual:

This manual describes how to control the Trolley from an engineering GUI (rather than from the high level control system) and how to perform particular actions and interrogate status. The following topics are covered:

- Starting up/closing down the Trolley
- Communicating with the Trolley
- Performing standard operations with the Trolley
- Performing non-standard operations with the Trolley
- Testing the Trolley performance
- Logging Trolley performance
- Analysis of Trolley logs

Testing the Trolley performance refers to a test list "List of Tests INT-406-VEN-0108" and the Matlab analysis GUI described in "Delay Line Analysis GUI Functional Description INT-406-VEN-1006".

Metrology

A hardware manual for the metrology system will comprise the following two documents:

Metrology Parts List:

The document "Parts list for MROI Metrology System INT-406-VEN-0200" describes the parts required to implement the metrology system and the parts required to add a further single channel, or two channels, to the existing metrology system.

Metrology Installation and Alignment:

The document "Preliminary single channel metrology system alignment INT-406-VEN-0201" describes the alignment process for a single channel of metrology but including the alignment of the laser-head and beam-splitting system that feeds up to ten delay lines.

INT-406-AIV-0019 - Trolley and associated optics/electronics

Type of Task Sheet: Description
Owner: MF

The DL Trolley system comprises the Trolley itself, the inductive power system, the wi-fi network link and the low-latency link. The latter three are modules which mount on the end plate at the far end of the delay line and inject power and communications signals into the pipe. The Trolley (which runs inside the DL pipe rather like a torpedo) is a 14 inch diameter tube approximately 2.4m long which houses a 'cat's eye' retro-reflector composed of a primary mirror and a small flat secondary mirror at the focus. The cat's-eye is suspended in an inverted pendulum fashion so that its movement is virtually frictionless and it is positioned by a voice coil which is under control of the delay line metrology system. The secondary mirror can be tip/tilted under control of the external shear measurement system so that the metrology laser beam is always returned to the correct position irrespective of the any lateral deviation in the delay line pipe. An on-board drive system and anti-roll system coarsely positions the Trolley and a local position loop on the Trolley keeps the Trolley precisely under the cat's eye so that vibration coupling is minimized. On-board electronics and a computer control the Trolley's functions, receive commands and sends telemetry via the wi-fi network link. Corrections to the cat's eye position are received over the low-latency link.

The design of the Trolley and a description of the control loops involving the shear camera and metrology systems can be found in the documents listed below:

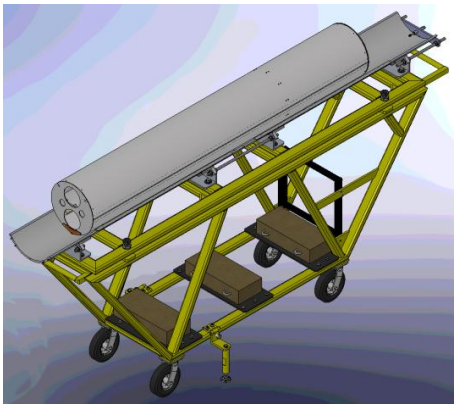
Identifier	Description	MROI-CAM P/N
AIV-4010	Trolley Mechanical Design Description	INT-406-VEN-0111
AIV-4011	Trolley Electronics Design Description	INT-406-VEN-0112

INT-406-AIV-0020 - Handling gurney hardware

Type of Task Sheet: Description
Owner: FS

A specialized handling and testing cart for the Trolley is the handling gurney. It can be mounted at the far end of each of any DL piping run or at the MROI electro-mechanical laboratory, and is used for specific services in the Trolley. When mounted and aligned to a DL piping run, the Trolley can be removed off the DL and metrology signal can be maintained active. It carries a power supply so that the Trolley can be powered in the MROI lab. Special procedures for integration of the Trolley to the handling gurney and for alignment of the handling gurney to a DL are described in

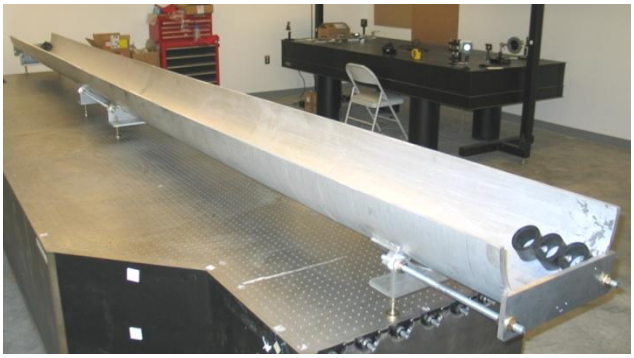
activities AIV-0121 and AIV-0123, respectively. The handling gurney is composed of a steel frame mounted on pneumatic wheels. A 4m track made of two aluminum 16"OD pipe halves sits on a steel frame that, by its turn, can be alignment in tip-tilt and height. Alignment is possible through three adjustment screws. A forth screw is added for stability but should not be used during alignment. Three counterweights are placed at the bottom of the main frame from bringing the CofG safely down. As the handling gurney is too narrow and long to fit within two DL pipes, it has two articulated leveling feet for lateral stability.



INT-406-AIV-0021 - Open test track hardware

Type of Task Sheet: Description
Owner: CS

The open test track assembly will be set up on an optical table in the ISF and used to test functions of the Trolley before it is taken to Magdalena Ridge. The open test track is approximately 6m long and made up of a single DL pipe that has been cut in half. The track provides mounting for the inductive power cable and is equipped with rubber bumpers at each end to ensure the Trolley can be stopped without sustaining any damage.



Reference documents for more detailed information on the open test track:

Identifier	Description	MROI-CAM P/N
AIV-5050	Delay Line Test Facilities (by MF)	-
AIV-6002	Assembly and mounting drawings instructions for ISF	INT-406-DWG-0305 INT-406-DWG-0306

INT-406-AIV-0022 - Safety, handling and transporting hardware

Type of Task Sheet: Description
Owner: CS

To be able to move the open test track safely and easily it is recommended that the counter balanced floor crane and nylon sling be used. The floor crane will allow the test track to be moved using only one person (though two are recommended). For transporting the test track it is recommended that the wood pipe-storage supports be used during transportation. This will allow the pipes to be supported safely during transportation and keep them from rolling around. The picture included shows the floor crane, sling and wood supports.

Reference documents:

Identifier	Description	MROI-CAM P/N
AIV-0011	AIV activity INT-406-AIV-0011	INT-406-ENG-0005

INT-406-AIV-0023 - 16" OD x 12ft length DL pipes

Type of Task Sheet: Description
Owner: FS

DL pipes are seamless extruded tubing which mechanical characteristics are in accordance to the Aluminum Standard and Data (ASD-1977). For more comprehensive information the reader should refer to:

Identifier	Description	MROI-CAM P/N
AIV-4026	MRO Delay Line - Derived Requirements	INT-406-VEN-0107
AIV-6002	MROI manufacturing drawings	INT-406-DWG-0540 INT-406-DWG-0543 INT-406-DWG-0546 INT-406-DWG-0549 INT-406-DWG-0551 INT-406-DWG-0553

Material: Extruded Seamless Aluminum Alloy (nominally 6061-T6).

Length: The length per section is 3.66m (12ft). For the DLS subproject, total length was balanced between achievable straightness per section, transportability, minimum number of supports/joints and cost.

External diameter: 406.4mm (16") ±2.16mm (0.085") [ASD= 0.085"].

Wall thickness: 12.7mm (0.5 inches) ±1.16mm (0.045") [ASD= 0.045"].

Eccentricity: Less than 1.27mm (0.06") [ASD= 0.06"]. This is the allowable deviation on wall thickness, at any point, from mean wall thickness.

Straightness: Less than 6.6mm (0.254") per section (3.66m long pipe) and less than 0.4mm per 304.8mm (0.0158" per foot) for any measured length over 304.8mm (1 foot) [ASD= 0.02"/foot for total length or any segment of 1 foot or more, giving 0.328" per 3.66m length and 0.02"/foot for any measured length over 1 foot]. This is the maximum deviation of the inner pipe surface from an imaginary cylinder of radius 190.5mm (7.5") (internal radius) and centered on the nominal axis. The nominal axis is defined to be the line joining the centers of each end of the pipe.

Circularity: Less than 5.1mm (0.2") [ASD= 0.2"]. This is the allowable deviation of diameter, at any point, from the specified diameter.

Internal surface quality: Less than 0.3mm (0.012") surface roughness. The internal surface of the pipe will be used as the guide rail on which compliant wheels of Trolley will run. Longitudinal die and mandrel marks are acceptable but transverse marking on the interior is to be avoided or, if due to necessary handling or forming equipment in the production process, allowance must be made for the pipes to be cut shorter to remove these. Marking of the exterior surface near the ends will be removed as part of the pipe preparation process bur shall in any case not exceed the specification.

Conformity of each DL pipe to these requirements is assessed through inspection and measurements as described in INT-406-AIV-0024.

INT-406-AIV-0024 - Metrology of DL pipes

Type of Task Sheet: WDTS
Owner: CS

Work Definition Task Sheet (WDTS)	
WBS	**Task Name**
INT-406-AIV-0025	Metrology of DL pipe

MROI Sub-Project (WBS - Name)		
4.06.00 - Delay Line System		
Major Input	**Start Date**	**Task Duration**
16" OD x 12 ft length DL pipes	when pipe arrives	1 hour per pipe

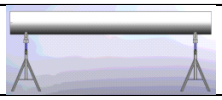
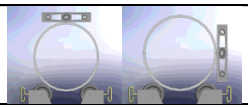
TASK OUTPUT

Metrology of DL pipe (straightness, roundness and wall thickness) and pipe marked per INT-406-DWG-0550

REQUIREMENTS

Specialists		**Facility**		**Test/special equipment**	
1	Chris Salcido	1	NMT/MRO ISF	1	Pipe Measuring Devices
2	SFI staff	2		2	Pipe Support Stands
3		3		3	Engine Hoist
Pre-requisites		**Applicable documents**		4	Pipe Sling
1		1	Methods for in-house …	5	Spirit Level
2		2	DL Pipe - spec and proc.	6	Caliper and tape measurement
3		3	Prototype DL Test Rig …	7	Pipe Marking Template
4		4	Pictures 4.06.03.000.1	8	Miscellaneous (string etc)

TASK PROCEDURE

Phase	Step	Description	Comments/Illustrations
PREPARATION	1	Move pipe from wood supports to stands. Suggestions: Place stands about 3m apart. Stands should be about 1m in height. Center pipe to stands.	
	2	Clean pipe ends (the ends are considered to be from the end of the pipe up to 400mm in) to remove any contaminations. Mark end A and end B.	Suggestions: use isopropyl alcohol and shop cloths to clean ends.
	3	Perform visual inspection for internal and external surface quality. Record results on the supplied spreadsheet.	Refer to INT-406-XXX.xxxx.
	4	Orient the pipe on the stands with maximum sag pointed downwards. Suggestion: Use run-out method with gauge.	A dial gauge placed in the middle of the pipe will indicate the maximum sag.
	5	Find upper most point and mark it. Find the lateral most point and mark it (points are 90 degrees apart). Use a level to find the points for each mark.	
	6	Use the template to add the remaining 10 marks.	Use a permanent marker pen.
SETUP	7	Install a measuring device at end A of the pipe. Level and center it. Then level/center the second device at end B so that it matches the first. Use upper mark as reference.	
MEASUREMENT	8	Perform the wall thickness measurement at each mark. Filed inside edge of pipe.	Use a caliper for measurement.
	9	Perform roundness measurements for all marks (run dial indicator CW for end A and CCW for end B.	Measurement on both sides. CW stands for clockwise, CCW for counterclockwise.
	10	Tension string on top groove of each measuring device. Perform the straightness measurements every 332.5mm.	Measuring device must remain centered.
	11	Rotate device arm by 90 degrees CW. Repeat Step-10.	Use tape measurement (.5mm accuracy).

NOTES

1	A part number should be assigned for each pipe.
2	Measurements (straightness, roundness and wall thickness) are to be recorded on the supplied spreadsheet.
3	Pipes should be marked for maximum deviation according to INT-406-XXX-xxxx, as well as ends A and B.

INT-406-AIV-0025 - Machine shop working on DL pipes

Type of Task Sheet: Description
Owner: FS

The work required to be performed on each 16”OD DL pipe (which includes the near-end and far-end sections) can be divided into four different parts as:

1. **Welding process**, which presents how the brackets shall be fixed at the end of the pipes and how flanges shall be vacuum welded. It is envisaged that Aluminum Gas Metal Arc Welding (GMAW) process be used (American Standard ANSI-AWS E6010). It is also envisaged that long electrode be used to achieve a continuous weld with deep penetration. Testing for vacuum leak is required to ensure that it will hold a vacuum of 0.5mbar ($3.75x10^{-1}$ Torr). MRO owns a set of jigs used to locate all lugs to be welded and to support them in place during the welding process.


Locating jig

2. **Machining process**, which presents the specification for machining the ends of the pipes, drilling dowel holes and polishing their ends. It is envisaged that the end faces of each pipe be machined perpendicular to its nominal axis. MRO owns a set of jigs used to set up a pipe section of any length up to 12ft on a "big" milling machine. MRO also owns a "go-no-go" gauge used to ensure that dowel holes are drilled within specs to avoid steps between pipes where the Trolley wheels run. As a reference, machining was performed at JW Industries in Albuquerque - NM.


Go-no-go gauge

3. **Finishing (soup washing and alodine)**, which defines the finishing process envisaged for each DL pipe. As a reference, soup washing and alodine were performed at Kehr Plating in Albuquerque - NM.
4. **Handling/protection**, which describes how each DL pipe shall be protected for shipment and handling during installation so as not to damage their ends. The work required to protect the ends of each pipe can be described as:

    4.1. Move pipe from wood supports to pipe stands (yellow). Suggestions: Place stands about 3m apart. Stands should be about 1m in height. Center pipe to stands.
    4.2. Roll out a corrugated paperboard (18" wide) and cut off a section that is about 150cm long.
    4.3. Wrap paperboard around pipe end firmly and tape the overlapping section down using clear packing wrap. Leave about 5cm sticking out from the end.
    4.4. Fold over the paperboard that sticks out so that it covers the end of the pipe.
    4.5. Wrap the plastic wrap around the pipe several times making sure to cover the open end of the pipe twice. The plastic wrap should extend about 5cm past the paperboard.
    4.6. Place two rubber bands over the wrap, one over the 5cm section of wrap and the other about 2cm or 5cm from the end of the pipe.
    4.7. Repeat steps 2 through 6 for the other end.


Pipe stand

For detailed description/specification, the reader should refer to:

Identifier	Description	MROI-CAM P/N
AIV-4013	Delay Line Pipes and Supports Design Description	INT-406-VEN-0115
AIV-4001	Cambridge manufacturing drawings	MROI-084 - MROI-088 MROI-124 - MROI-131
AIV-6002	MROI manufacturing drawings	INT-406-DWG-0540 INT-406-DWG-0543 INT-406-DWG-0546 INT-406-DWG-0549 INT-406-DWG-0551 INT-406-DWG-0553

INT-406-AIV-0026 - Pipe supports

Type of Task Sheet: Description
Owner: FS

A full design description and FEA analysis of the DL pipe supports are shown in AIV-4013 and AIV-5035 and should be used as a reference to the reader. The reader should also refer to AIV-4001 for the full layout of the DL pipes/supports. Each DL pipe run is mounted on the DLA technical slab using two types of supports. One is called anchor support (AIV-5035 - section 2.2.2) and the other is called flexure support (AIV-5035 - section 2.2.1). The anchor support is installed on the thicker portion of the technical slab and designed to take all expected longitudinal workloads, which includes: installation loads, accident loads and earthquake loads (which calculations are shown in AIV-5035). The flexure supports take expected gravitational load due to the pipe and accidental lateral loads, and allow the expansion and contraction of the aluminum pipe run over the temperature variation inside the DLA. They are composed of three parts joined together using stainless steel flexure plates. The three parts are the cradle, middle frame and base plate. These supports are steel frame construction painted white. The picture below is a demonstration setup of pipes and supports in the DLA. Notice that alignment jigs are installed and the flexure supports are not anchored to the technical slab. Also, the anchor support is not anchored and grouted.

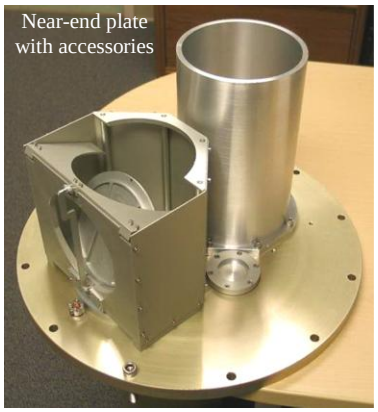
For detailed description/specification, the reader should refer to:

Identifier	Description	MROI-CAM P/N
AIV-4013	Delay Line Pipes and Supports Design Description	INT-406-VEN-0115
AIV-5035	Provisional Anchor Requirements for DL (MF - Jan 2007)	-
AIV-5036	Pipe anchor fixing	-
AIV-4001	DL Pipes and Supports	Design set

INT-406-AIV-0027 - Other parts (end plates, windows, tensioning mechanism)

Type of Task Sheet: Description
Owner: FS

A full design description of the two end sections and end plates is shown in AIV-4013 (Section 2.1.4) and should be used as a reference to the reader. The end sections are the mounting interfaces for the end plates. Although both end plates are primarily used to cover the ends of each DL pipe run, they have other different purposes in the DLS. The near-end plate is used to hold the science/metrology windows and to interface with the BRS pipe. It is also used to support the two fast acting valves (see AIV- 0010 and AIV-0110) and to attach the inductive power termination and the buffer assembly. The limits target plate at the near-end is supported at that end section (see Figure 4 of AIV-4013). The far-end plate is used to hold the aerials with accessories for radio communication links, low latency link and the inductive power connection. The limits target plate at the far-end (see Figure 3 of AIV-4013) and the tensioning mechanism are supported at that end section. Sealing between end section and end plate is provided by O-ring seal. Similar sealing strategy is used for the windows. Special features as vacuum port and datum facility are described in section 2.1.5 of AIV-4013.



For detailed description/specification, the reader should refer to:

Identifier	Description	MROI-CAM P/N
AIV-4013	Delay Line Pipes and Supports Design Description	INT-406-VEN-0115
AIV-4001	DL Pipes and Supports	Design set

INT-406-AIV-0028 - Metrology table for the MROI Inner-BCA

Type of Task Sheet: Description
Owner: FS

The metrology table is primarily responsible for housing the DL metrology system as described in:

Identifier	Description	MROI-CAM P/N
AIV-4012	Metrology System & VME Hardware Design Description	INT-406-VEN-0113
AIV-4052	MRO-DL-ICD - DL to Metrology System	INT-406-VEN-0010
AIV-4054	MRO-DL-ICD - Metrology System to BCF	INT-406-VEN-0012

The metrology table is composed of three breadboards 2438x700x317.5mm each and three sets of rigid table stand (VERE Inc.). The breadboards are structurally joined together using joiner plates to make up an optical table 7314x700mm with the table top at a nominal height of 1265mm related to the BCF grade. The joiner plates are attached to the underside of the skins, providing an optical table without interruption in the 25mm grid of M6x1.0 hole pattern.

The breadboards are 3.175mm thick AISI 304 stainless steel skins laminated to a non-metallic honeycomb core. Total weight is approximately 152.86kg (337lb). They are coated in an anti-reflective black polyurethane finish. Flatness of the working surface is reported to be better than 0.25mm over 300mm cumulative distance.

The breadboards are directly supported by rigid stands. These are constructed of 2" square mild steel tubes, coated in black polyurethane, with a brace near the bottom. It has one leveling foot under each leg that can be anchored to the Inner-BCA technical (concrete) slab using anchor bolts (see AIV-0135). The leveling feet allow adjustment ±38.1mm of nominal height. Care must be taken when tightening the locking nut against the bottom of the leg as that nut can slightly push the leg up.

Leveling foot and locking nut

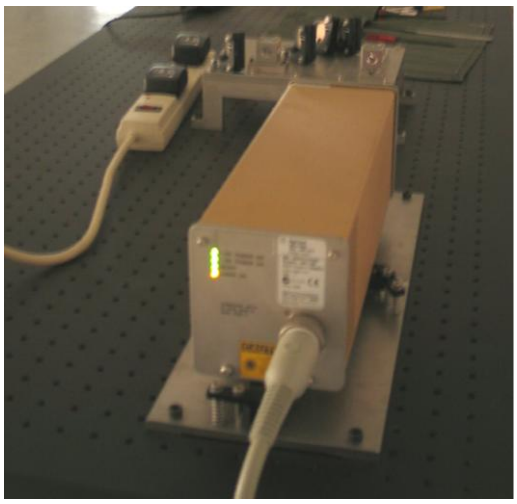
The footing part is made of hard plastic and the pivoted threaded rod is made of galvanized steel (#1/2-13 by 115mm long). Two 8.8mm thru holes located 55.8mm apart allow each footing to be anchored to the floor.

The first natural frequency is measured as xxHz for each optical table when not anchored to the floor. The first natural frequency is measured as xxHz for the metrology table when not anchored to the floor and xxHz when anchored.

Care must be taken to not stress the breadboards when tightening the stands.

INT-406-AIV-0029 - Agilent laser head and splitting module

Type of Task Sheet: Description
Owner: DK



The Agilent laser head provides the laser beam for the DL metrology system. Only one laser head is required to supply sufficient light to all 10 of the DL metrology systems. The laser beam will be directed through numerous beam splitters, mirrors, linear interferometers, beam expanders and compressors towards the cat's eye in the Trolleys and back to the interferometers. This will allow the accurate measurement of the Trolley position. The laser head will be located on the south end of the metrology optical table.

Agilent laser head to be accessed for authorized personnel only. Visible laser light. Do not stare into beam. Minimum optical density eyewear may be required.

For detailed description/specification, the reader should refer to:

Identifier	Description	MROI-CAM P/N
AIV-4012	Metrology System & VME Hardware Design Description	INT-406-VEN-0113
AIV-4015	Metrology system components list	INT-406-VEN-0118
AIV-4026	MRO Delay Line - Derived Requirements	INT-406-VEN-0107
AIV-4052	ICD: DL to Metrology System	INT-406-VEN-0010
AIV-4054	ICD: Metrology System to BCF	INT-406-VEN-0012
AIV-5060	Preliminary single channel metrology system alignment	INT-406-VEN-00xx
AIV-5110	5517GL Laser Head - from Agilent Technologies	Agilent package
AIV-4002	Metrology Layout (for MROI)	Drawing set

INT-406-AIV-0030 - Metrology block and shear camera module

Type of Task Sheet: Description
Owner: FS

A full design description of the metrology block and shear camera module is shown in AIV-4012 (Section 3.0) and should be used as a reference to the reader. The reader should also refer to AIV-4060 and AIV-4002 for the full layout of the metrology system. To guarantee mechanical stability due to temperature variation inside the Inner-BCA (±0.1ºC overnight), the metrology blocks are all stainless steel construction, the same material as the optical table top skin. Each block weights about 30.6kg and should be handled with care during assembly and installation. Components for the metrology block are the main support, beam expanders, interferometer, motorized beam alignment mirrors and the

beamsplitter for shear camera. The beam expanders are the two projectors that sit on the V-groove provided on top of the main support. The lightweight cuts in the vertical plates (side frames and central web plates) allow the science and metrology beams to go through the mount without vignetting.

The shear camera module houses the shear camera, beam compressor and laser line filter. It is assembled on the metrology table behind the metrology block. All custom components are made of aluminum.

For detailed description/specification, the reader should refer to:

Identifier	Description	MROI-CAM P/N
AIV-4012	Metrology System & VME Hardware Design Description	INT-406-VEN-0113
AIV-4015	Metrology system components list	INT-406-VEN-0118
AIV-5060	Preliminary single channel metrology system alignment	INT-406-VEN-00xx
AIV-4002	Metrology Layout (for MROI)	Drawing set

INT-406-AIV-0031 - Control Systems at ISF

Type of Task Sheet: Description
Owner: JS

The ISF requires: a DL workstation with software provided by Cambridge; wireless network access point; cable tray; electronics cabinet; computer desk; 8-port network switch at computer desk; 48 VDC power supply with cabling. Cambridge wants to be able to verify that no damage to the Trolley has occurred during shipping and that basic tests can be passed before transport of the Trolley to the Ridge. This can be accomplished by using only the workstation software (i.e. no metrology or shear camera hardware/software needed). Trolley power and communications will be provided via the standard inductive and wireless systems respectively.

Reference material is given by:

Identifier	Description	MROI-CAM P/N
AIV-5065	DL workstation configuration instructions	-
AIV-5066	Cambridge software installation and testing instructions	-
AIV-6004	Standalone 48V DC power supply cabling	INT-409-DWG-65xx

INT-406-AIV-0032 - Control Systems at BCF for DLS (electronics, computers)

Type of Task Sheet: Description
Owner: JS

The BCF requires: Outer-BCA control cabinets; network switch; KVM with console keyboard and monitor; DL workstation computer; shear camera computer; VME chassis with computer and peripherals; metrology power supplies; metrology receivers; IRIG-B timing source; software provided by Cambridge. The DL control systems in the BCF interface with the Interferometer Supervisory Control System (SCS), Fringe Tracker and components of the DL Metrology System in addition to the DL themselves. The hardware components of these systems must match the ICD specifications for the Cambridge software to function properly. Installation of the hardware, operating system and Cambridge software should be complete and tested (via a software simulation of the Trolley provided by Cambridge) prior to the arrival and installation of the Trolley.

Reference material is given by:

Identifier	Description	MROI-CAM P/N
AIV-4051	ICD: Delay Line to Beam Combining Facility	INT-406-VEN-0009
AIV-4054	ICD: Metrology System to Beam Combining Facility	INT-406-VEN-0012
AIV-6004	Outer-BCA Control Cabinets	INT-409-DWG-6001 INT-409-DWG-6002 INT-409-DWG-6020 INT-409-DWG-6530 INT-409-DWG-6531
AIV-6004	DL local enclosure cabling	INT-409-DWG-65xx
AIV-5065	DL workstation configuration instructions	-
AIV-5066	Cambridge software installation and testing instructions	-

INT-406-AIV-0100 - DLS AIV ACTIVITIES

Type of Task Sheet: Description
Owner: FS

The DLS AIV activities for the DLS subproject were originally set by work package, as presented in INT-406-ENG-0004 - *AIV Planning*. As far as the AIV project plan is concerned, these activities were developed to meet PVMs up to PVM5. Once accomplished, one is expected to have checked: the functional operations of the Trolleys on an open test track, the functional and performance characteristics of the Trolleys in the DLs at the MROI, the characteristics of pipes and supports (alignment and matching of pipe sections) in the DLA, the performance and alignment of the metrology system, all the DLS interfaces, and the DLS as a system. Testing of the DLS integrated to the MROI will then fall under the commissioning plan of the interferometer project, which seeks to verify the overall system performance at different level of capability.

INT-406-AIV-0110 - Integration of fast acting valve

Type of Task Sheet: WDTS
Owner: CS

Work Definition Task Sheet (WDTS)			
WBS	**Task Name**		
INT-406-AIV-0110	Integration of fast acting valve		

MROI Sub-Project (WBS - Name)		
4.06.00 - Delay Line System		
Major Input (WBS - Name)	**Start Date**	**Task Duration**
Installation of Delay Line Pipes	DL Installation	1/2 hour

TASK OUTPUT
Installation of the fast acting valve

REQUIREMENTS					
Specialists		**Facility**		**Test/special equipment**	
1	MROI-DLS Staff	1	MROI BCF - I-BCA	1	Metric hex key set
2		2		2	Small flat head screw driver
Pre-requisites		**Applicable documents**		3	Metric wrench set
1	Pipes and Supports installed	1	MROI-193	4	
2		2	MROI-194	5	
3		3	MROI-196	6	

TASK PROCEDURE			
Phase	**Step**	**Description**	**Comments/Illustrations**
OUTPUT VALVE	1	The output science window should be installed beforehand.	
	2	Pre-assemble fast acting valve before installation.	See drawing #: MROI-193
	3	Clean o-ring surfaces and other mounting surfaces to insure a good seal.	Suggestion: use isopropyl alcohol for cleaning.
	4	Install o-ring in groove on fast acting valve mounting flange.	
	5	Install fast acting valve to end plate as shown in MROI-194.	Four M5x35 socket head cap screws are needed for mounting.
INPUT VALVE	7	The beam relay pipe must be uninstalled and the input science window installed before beginning installation of the fast acting valve.	
	8	Repeat steps 2-4 for input valve.	
	9	Install fast acting valve to end plate as shown in MROI-196.	Four M5x35 socket head cap screws are needed for mounting.

NOTES	
1	

INT-406-AIV-0111 - Integration of services and communication in the DLA

Type of Task Sheet: Description
Owner: JS

The DLA requires: network cabling; network switch; low-latency cabling; datum cabling; local enclosure; power supplies, UPS. Some connections are wired directly from the Outer-BCA control cabinet to the DL (i.e. for datum switches and low-latency link). Others are provided via an individual local enclosure placed at the end of each DL. This enclosure contains power supplies and networking equipment. Cables are connected from the end plate of each DL to the enclosure. All cable lengths should be sized so they reach the far end of the handling gurney when it is attached to the end of the DL plus some additional slack so that cables can be moved out of the path of any servicing activities. The low-latency link cables must be fabricated to accommodate the full DL length of 190 meters even though shorter intermediate length DLs will be constructed.

115V utility power will be available near the ends of the DLs. The building IP telephones can be plugged into the network switch ports inside the local enclosure to facilitate, for example, communication with someone inside the Inner-BCA at the metrology system or at the controls cabinet in the Outer-BCA.

Reference material is given by:

Identifier	Description	MROI-CAM P/N
AIV-4051	ICD: Delay Line to Beam Combining Facility	INT-406-VEN-0012
AIV-6004	DL local enclosure cabling	INT-409-DWG-65xx
AIV-6004	Outer-BCA Control Cabinets	INT-409-DWG-65xx

INT-406-AIV-0112 - Trolley preparation at ISF

Type of Task Sheet: Description
Owner: MF

INT-406-AIV-0113 - Unpacking Trolley and associated components

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0114 - Assembly modules and sub-modules of a Trolley

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0115 - Complete assembly of a Trolley

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0116 - Integration of a Trolley to the open test track

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0117 - Pre-acceptance tests of a Trolley at ISF

Type of Task Sheet: Description
Owner: MF

INT-406-AIV-0118 - Trolley preparation for transportation to the MROI

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0119 - Packing and shipping Trolley to the MROI

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0120 - Unpacking a Trolley at the DLA

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0121 - Integration of a Trolley to the handling gurney

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0122 - Trolley preparation for a DL

Type of Task Sheet: Description
Owner: MF

INT-406-AIV-0123 - Alignment of handling gurney to the end of a DL

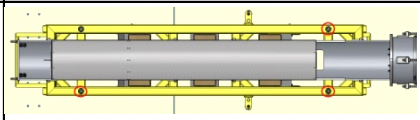
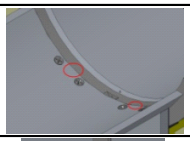
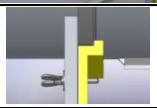
Type of Task Sheet: WDTS
Owner: CS

Work Definition Task Sheet (WDTS)			
WBS	**Task Name**		
INT-406-AIV-0123	Alignment of handling gurney to DL end		

MROI Sub-Project (WBS - Name)		
4.06.00 - Delay Line System		
Major Input (WBS - Name)	**Start Date**	**Task Duration**
INT-406-AIV-0122 - Trolley preparation for a DL	Trolley injection	1/2 Hour

TASK OUTPUT
Alignment of the handling gurney to the end of a Delay Line

REQUIREMENTS					
Specialists		**Facility**		**Test/special equipment**	
1	MROI-staff	1	BCF-DLA	1	1-5/8" wrench
2		2		2	14mm hex key
3		3		3	spirit level
Pre-requisites		**Applicable documents**		4	masking tape
1		1		5	measuring tape
2		2		6	

TASK PROCEDURE		
Step	**Description**	**Comments/Illustrations**
1	Begin by laying down tape to guide the wheels of the gurney. The tape should be spaced about 20.5" apart (center-center) and centered to the DL pipe.	The tape should be long enough to easily see it from the rear end of the gurney.
2	Loosen the clamping plate from the front of the track	
3	Push the gurney into position against the delay line pipe end and lock the brakes.	Track should be flush against the pipe end.
4a	Adjust the gurney track using the push-pull screws. Only THREE of the screws should be used for adjustment. See picture for which screws to use. The fourth screw is only used for stability.	
4b	The track should be aligned to the pipe end so that there is no step between the two where the trolley wheels run (marked in red). The track should also be leveled with a spririt level.	
5	Tighten down the clamping plate onto the flange of the pipe end.	
6	Install the leveling feet so that they only provide stability.	The leveling feet should not be used for adjusting the height of the gurney.

NOTES	
1	
2	

INT-406-AIV-0124 - First alignment of metrology laser to a Trolley

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0125 - Integrity functional testing of a Trolley

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0126 - Installation and integration of Trolley to a DL

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0127 - SAT of Trolley in a DL

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0128 - OAT of Trolley in a DL

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0129 - Assembly/verification of the open test track at ISF

Type of Task Sheet: WDTS
Owner: CS

Work Definition Task Sheet (WDTS)	
WBS	**Task Name**
INT-406-AIV-0129	Assembly/verification of open test track

MROI Sub-Project (WBS - Name)		
4.06.00 - Delay Line System		
Major Input (WBS - Name)	**Start Date**	**Task Duration**
INT-406-AIV-0148 - Open test track preparation at ISF	Mar. 2010	1 Hour

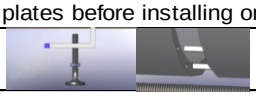
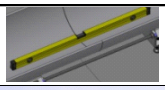
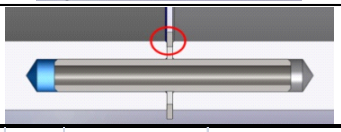
TASK OUTPUT

Full assembly of the open test track at ISF.

REQUIREMENTS

Specialists		**Facility**		**Test/special equipment**	
1	Chris Salcido	1	ISF	1	Measuring tape
2	Steve Wallace	2		2	Spirit level
3	Ed	3		3	Metric/Imperial Wrench set
Pre-requisites		**Applicable documents**		4	Metric hex keys
1		1	INT-406-DWG-0305	5	Dead blow hammer or rubber mallet
2		2	INT-406-DWG-0306	6	

TASK PROCEDURE

Phase	Step	Description	Comments/Illustrations
Prepartaion	1	Before beginning be sure that the optical bench is clear and clean. Be sure to also clean the pipe halves if necessary before moving them into the lab.	Suggestions: use isopropyl alcohol and shop cloths to clean bench and pipe halves.
	2	Place wood blocks on the bench to set the two pipe sections on. Leave enough space beneath the pipes to install the supports.	
Assembly	3	Place the first pipe on the wood blocks and install the dowel pins and internal lock washers.	A dead blow hammer or rubber mallet may be needed to gently drive the pins in.
	4	Place second pipe on wood blocks so that it lines up with the dowel pins of the first pipe.	
	5	Install supports, leveling feet, end plates and threaded rods but do not tighten down.	The rubber bumpers should be installed on the end plates before installing on track.
	6	Level the pipes to each other using the leveling feet so that the dowel pins and holes line up straight.	
	7	Using the threaded rods, pull the two pipe halves together slowly and evenly until the ends are touching.	When pulled together track ends should be about 315mm[12.4"] from end of bench.
	8	Tighten down the threaded rods and level the track as much as possible using a spirit level.	
	9	Tighten down the lock nuts on the leveling feet to finish assembly.	
Verification	10	It should be verified that the "step" between pipes is less than 0.5mm. This is most important where the dowel pins are installed on the sides of the pipe halves.	

NOTES

1	See INT-406-DWG-0306 for detailed assembly views.
2	See INT-406-DWG-0305 for more detailed placement on the optical bench.

INT-406-AIV-0130 - Assembly of DL pipes/supports in DLA

Type of Task Sheet: WDTS
Owner: FS

Work Definition Task Sheet (WDTS)	
WBS	**Task Name**
INT-406-AIV-0130	Assembly of DL pipes/supports in DLA

MROI Sub-Project (WBS - Name)		
4.06.00 - Delay Line System		
Major Input (WBS - Name)	**Start Date**	**Task Duration**
INT-406-AIV-0025 - AIV-0026 - AIV-0027	as per phase	30min/pipe

TASK OUTPUT

Full assembly of a DL pipe run of any length (defined per phase)

REQUIREMENTS

Specialists		**Facility**		**Test/special equipment**	
1	DLS staff	1	BCF-DLA and Inner-BCA	1	Measuring tape
2	Steve Wallace staff	2		2	Spirit level
3	SFI staff	3		3	BCF toolset
Pre-requisites		**Applicable documents**		4	Support stand jig
1	INT-406-AIV-0011	1	AIV-4013	5	Support stand target
2	INT-406-AIV-0025 - 0026 - 0027	2	AIV-4016	6	Pipe target

TASK PROCEDURE

Phase	Step	Description	Comments/Illustrations
Prepartaion	1	Position of chemical anchor bolts are marked out by surveyor and anchor bolts are installed per AIV-0508.	Surveying to be done by MROI staff.
	2	Location of all DL axes are measured and marked on the DLA technical slab for reference.	Marking out the location of anchor bolts for these axes will be done later in phases.
	3	DLA technical slab are vacuum cleaned (per SFI staff to define procedure).	Pipes (external surfaces) and supports are cleaned before installation.
Set-up	4	Set-up a laser theodolite (MROI total-station) at the far-end of the DLA, above the monument of the DL to be installed, at 1.60m above the BCF grade.	BCF grade to be checked using origin monument inside the Inner-BCA. Survey reports shall be available.
	5	Set-up a target above the corresponding monument inside the Inner-BCA. Site target with theodolite.	This defines the line-of-sight of the DL to be installed.
Assembly	6	Install the first three support stands at their nominal height/tilt and stabilize them using the support stand jig.	Use nuts in the anchor bolts and the base adjuster in the support stand jig to adjust the height/tilt (see AIV-4016) by looking at the support stand target using theodolite.
	7	Install the first section of pipe on the two supports and pass a wire through it. Wire is longer than pipe run being installed. Insert dowel pins into the pipe end with a washer in the lower one. Insert and fold rubber seal at the end.	This is the flanged pipe. Hang pipe with sling and floor crane. Three clamping strips shall be pre-positioned along the pipe. Washer is 1.1mm thick.
	8	Install the anchor support frame and use the four adjusters to set level and height. Grout under the anchor support.	Clamp plywood strips around the anchor support to retain grout until cured. Lightly rough-up slab for better joint.
	9	Pass wire through anchor pipe and install it by mating dowel pins. Insert threaded rods through pipe lugs of both pipe sections and anchor support. Unfold rubber seal and install band clamps. Remove support stand jig.	Alignment of pipe ends takes place (see AIV-0131). Draw pipes together using threaded rods. Clamp pipes to supports.
	10	Insert dowel pins into the pipe end with a washer in the lower one. Insert and fold seal at the end.	Tighten threaded rods at anchor support for anchoring the pipe run.
	11	Repeat installation of additional support stands and pipe sections starting from the 3.4m long.	See AIV-0131 for alignment procedure and INT-406-VEN-0119 for detailed procedure.

NOTES

1	See AIV-4016 (INT-406-VEN-0119) for instructions on maintenance (realignment of pipes, replacement of parts, temporary anchor, replacement of a seal, replacement of a pipe section).
2	See AIV-0131 for initial alignment of DL pipes/supports.

INT-406-AIV-0131 - Initial alignment of DL pipes/supports

Type of Task Sheet: WDTS
Owner: FS

INT-406-AIV-0132 - Integration and verification of DL to interfaces at BCF

Type of Task Sheet: WDTS
Owner: FS

INT-406-AIV-0133 - Verification of vacuum integrity

Type of Task Sheet: Description
Owner: FS

INT-406-AIV-0134 - Final alignment of a DL using a Trolley

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0135 - Metrology table preparation & install in Inner-BCA

Type of Task Sheet: Description
Owner: FS, SJ

The three optical tables that make up the metrology table are assembled close to the position where they will be installed (see AIV-4054). Thus, this area at the Inner-BCA shall be cleaned in advance (cleaning products and procedure are to be defined by the FSI staff (vacuum cleaning followed up with wet cloth wiping using alcohol)).

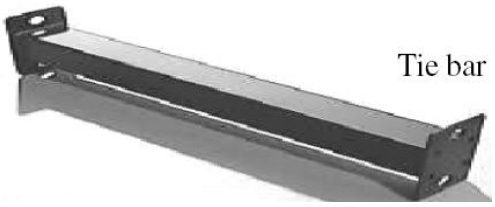
ATTENTION: Be aware that activities AIV-0135 and AIV-0136 will have to be performed in conjunction at some point of the preparation work, assembly, alignment, leveling and anchoring process. Activity AIV-0135 is a description for individual assembly of optical tables and the preparation for joining them together. Activity AIV-0136 is the WDTS that describes the procedure for installing the metrology table on the Inner-BCA technical slab.

Installation instruction for each VERE optical table (breadboard and stand):

Place the leg sections with cross bars vertically with the leveling feet on the floor. The inside of the leg section has the screws for attaching the tie bars.

DO NOT TIGHTEN ANY SCREWS UNTIL FINAL STEP! Entire assembly must be loose enough to align all holes. Attach top tie bars to the leg sections. DO NOT TIGHTEN SCREWS! Place breadboard on top of stand. Use #1/4-20 by 1" long button head screws and fender washer to securely attach the breadboard to the mounting plates attached to the leg tops. The washers go on the underside of the mounting plate.

You may now TIGHTEN ALL SCREWS, INCLUDING ANY PRE-INSTALLED SCREWS. Adjust the height adjustable leveling feet to pre-level the surface by rotating the foot to desire height and then tighten the nut to retain position.


Tie bar

- **Installation kit provided by VERE:**
  - 2x leg sections with cross bars;
  - 4x tie bars;
  - 16x #1/2-13x1" button head screws attached to inside of leg section;
  - 4x #1/4-20X1" button head screws; and
  - 4x fender washer.

- **Equipment required from MROI:**
  - Spirit level;
  - Tape measurement;
  - Hex key #5/16"; and
  - Hex key #5/32".

Important notes recommended by VERE:

Handling:
Handling the breadboards must be performed carefully to avoid pulling the skins from the core. When handling, always lift by the lowest skin. The breadboard may be safely moved on edge but do not drop. If dropped it may fracture the core. If the breadboard is to be lifted by a crane or forklift, use spreader bars or slings under it for lifting.

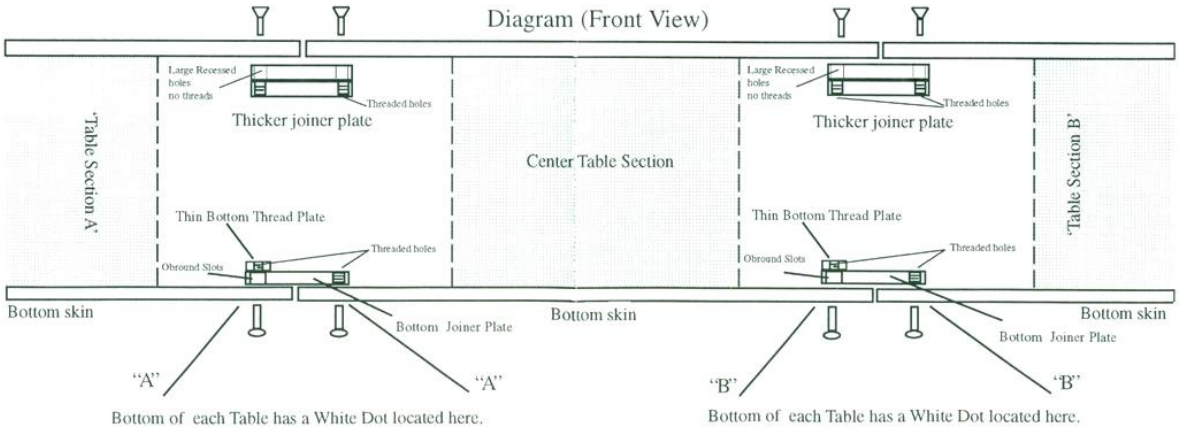
Care:
The black finish used on the breadboards is highly durable but will haze if cleaned with solvents. It is recommended that the boards be cleaned with a damp soft cloth or paper towel, using alcohol or mild detergent. Do not apply too much pressure when cleaning, as shiny areas may appear. The core is epoxy coated and is highly resistant to most chemicals but it is advisable to avoid spills into the core. Any liquid into the open hole would be contained inside a 9.53mm honeycomb cell exposed to the open threaded hole. Remove any liquid with a stiff tip syringe.

Mounting holes:
The mounting holes of the breadboards are sealed with a plastic film. Inserting a screw into the hole will punctuate this film and permit the screw to pass into the board, allowing the full depth of the board to be utilized. Up to a 3" length bolt/screw can be used.

When the three optical tables are assembled, they can be prepared to be joined together. The procedure for joining the optical tables together is the WDTS shown in INT-406-AIV-162. Joining the tables includes using the joiner plates, which instructions are summarized below (following the procedure recommended by VERE):

Instructions for assembling joiner plates:

Place each table section on their assembled support stands (see installation instructions for the stands). Reference to the "white dots" located at the bottom of each table, as shown in the figure below.



Joiner plates are attached to the underside of the table skins. Use the thickest joiner plate along the under edge of the top skin and the thinner joiner plate for the bottom skin. Use flat head screws in the counter sunk holes for the top skin, button head screws for the bottom skin. See diagram above. DO NOT TIGHTEN ANY SCREW UNTIL TABLE SECTIONS ARE JOINED AND TOP GRID IS ALIGNED.

Begin by attaching the joiner strips for Sections "A" and "Center". Start inserting the flat head screws (counter sunk holes) into this section of the table. TIGHTEN THE FLAT HEAD SCREWS AFTER ALIGNMENT OF GRID. TIGHTEN FIRST SCREW AT EACH END OF TABLE FIRST, THEN EVERY 10TH SCREW, THEN EVERY 5TH SCREW, ETC UNTIL ALL SCREWS ARE TIGHTENED. **DO NOT TIGHTEN THE BUTTON HEAD SCREWS ON THE BOTTOM SKIN UNTIL THE TOP SKIN IS ALIGNED AND LEVELED.** Follow the same tightening pattern as explained above. Slots are provided in the bottom skin and bottom joiner plate to assure moveability so the top skins surface is flat and continuous.

Instructions to align grid and level table top:

Use a straight edge to level the first two Sections "A" and "Center". Change by moving the adjustable foot on each leg of the table stand. This is done by turning the large nut near the bottom of the foot with a wrench. Also, lift or push down on top joined area and tighten counter sunk screws as directed above to finish alignment. Tighten bottom screws after alignment is accomplished. Then align and level Section "B" to the "Center" Section.

- **Equipment required from MROI:**

  - Spirit level;
  - Tape measurement; and
  - Hex key #5/32".

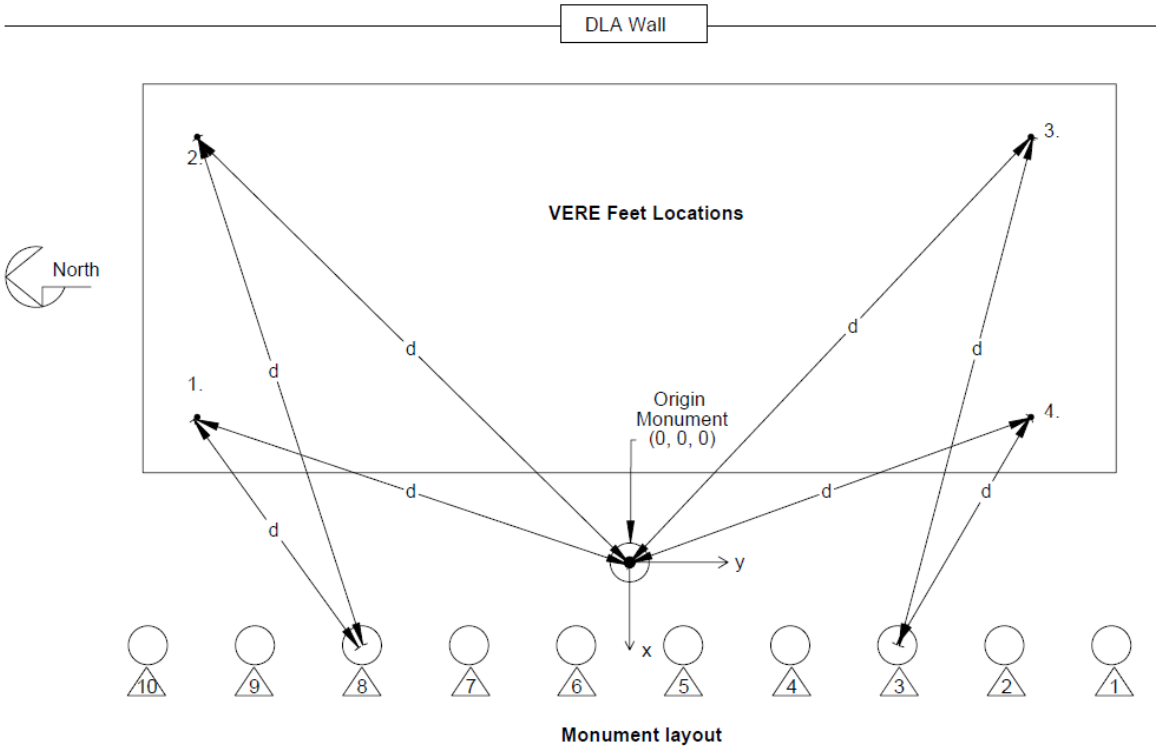
Care must be taken to not stress the breadboards when tightening the stands.

Miscellaneous tools for AIV-0136:

- Tape measure (25ft/ 8m);
- 4ft level;
- Spirit level;
- Bulls-eye bubble level;
- Allen wrench set (imperial/metric);
- Open end wrench set (imperial/metric);
- Large square (2ft or larger);
- Compass (3-1/2" radius capability);
- Utility knife w/spare blades;
- Flat scraper w/spare razor blades;

- Marking utensils (sharpies, china markers, pencils);
- Hammer;
- Hammer drill and 3/8” drill bit with spare drill bits;
- Roll of string;
- Vacuum cleaner;
- Trash bags (for removed debris);
- Mineral Spirits; and
- White cloths and broom/dust pan (for cleaning).

Location of VERE middle optical table feet:



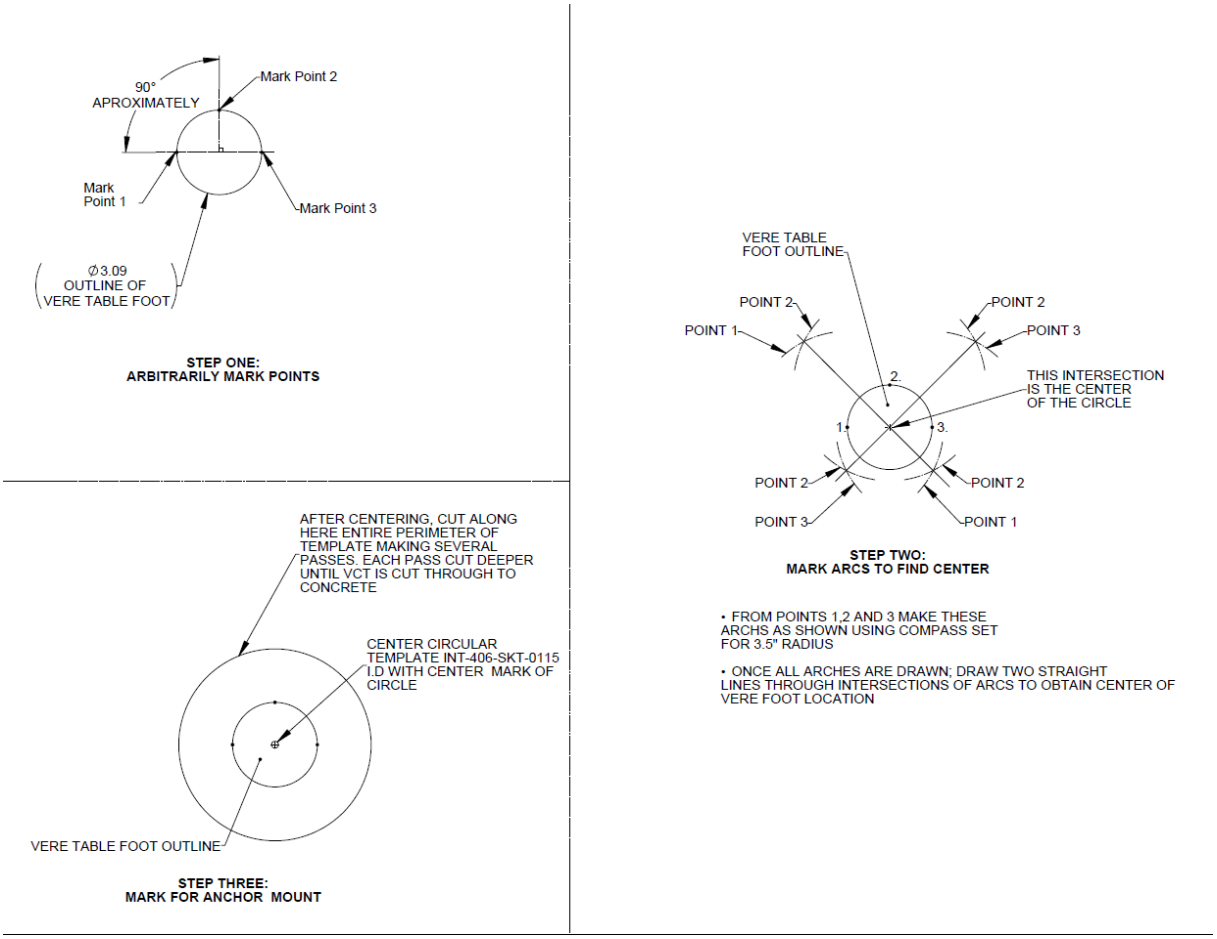
Monument layout

Locations are defined by the following distances:

	[mm]	[inch]
Monument 8 to coordinate 1	614.26	24.1835
Origin monument to coordinate 1	1115.50	43.9173
Monument 8 to coordinate 2	1185.76	46.6835
Origin monument to coordinate 2	1449.50	57.0669
Monument 3 to coordinate 4	614.26	24.1835
Origin monument to coordinate 4	1115.50	43.9173
Monument 3 to coordinate 3	1185.76	46.6835
Origin monument to coordinate 3	1449.50	57.0669

Prep. A:

1. Use the technique below to locate center of the “VERE foot out-line” to center the mounting plate (INT-406-DWG-2150):



2. Carefully cut along the 7" diameter using several passes, cutting deeper with each subsequent cut. Repeat this task until the VCT (Vinyl composite floor tile) material is cut through to the concrete substrate - Repeat 4x. For this task use the utility knife, changing the blades frequently.

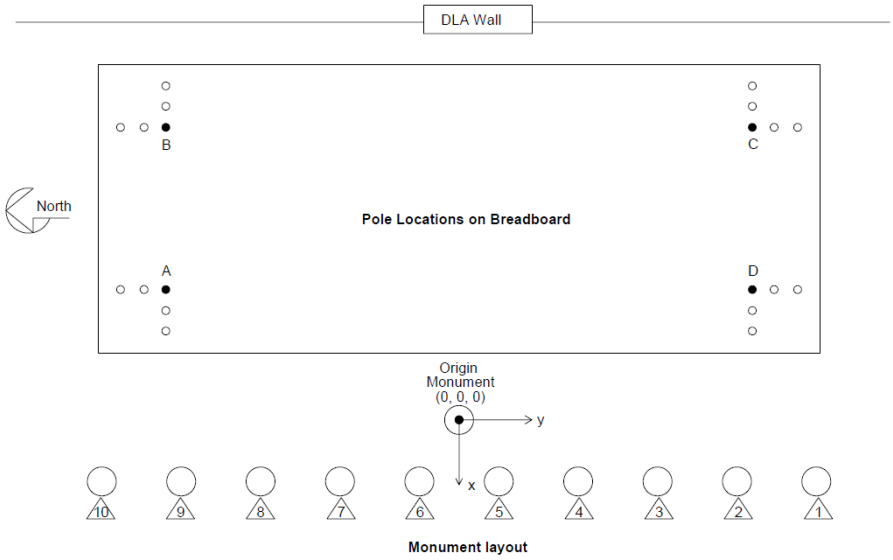
CAUTION: serious injury may occur from razor of utility knife, care is urged.

After the circular portion of the VCT has been completely cut through to the concrete; scrape the adhesive residue with a “standard one edge razor blade-flat scraper” until all adhesive is removed.

CAUTION: use care while scraping not to damage the remaining edges of the VCT, which will be visible and good aesthetics are desired at these locations.

Finally, use mineral spirits on a clean, white cloth and wipe down the exposed concrete; then allow area to dry.

Pole location on breadboard:

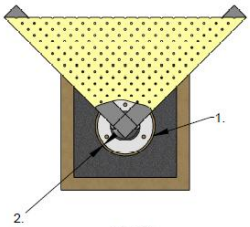


Coordinates for pole locations are:

	[mm]	[inch]
Pole location A	(-499.5, -1150, +1365)	(-19.665, -45.276, 53.740)
Pole location B	(-1099.5, -1150, +1365)	(-43.287, -45.276, 53.740)
Pole location C	(-1099.5, +1150, +1365)	(-43.287, +45.276, 53.740)
Pole location D	(-499.5, +1150, +1365)	(-19.665, +45.276, 53.740)

Prep. B:

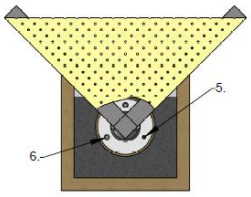
After complete anchor and fastener installation (#1/4-20 Hex head bolts with washers), hand tighten fasteners until snug; then re-check table alignment with total station.



STEP 1

1. REMOVE VCT WITH CARE NOT TO DAMAGE THE EDGES OF THE EXPOSED VCT.

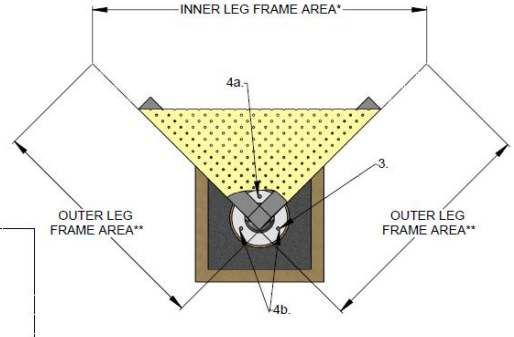
2. ASSURE A 1/4" SPACING BETWEEN THE TILE AND THE MOUNTING PLATE FOR EXPANSION.



STEP 3

5. AFTER THOROUGHLY CLEANING THE HOLES, PLACE THREE 1/4" X 3/8" REDHEAD RL-14 ANCHORS UNTIL FLUSH WITH CONCRETE SUBSTRATE.

6. THEN FASTEN 1/4" X 1" HEX HEAD BOLTS WITH MATCHING WASHERS AS SHOWN.



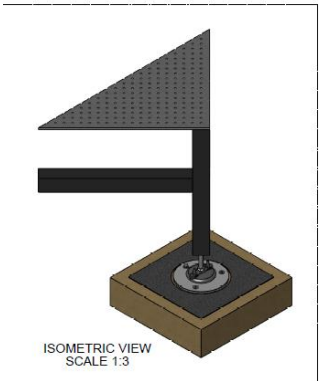
STEP 2

3. DRILL THREE 3/8" HOLES 1-1/8" DEEP INTO CONCRETE SUBSTRATE - USING THE ∅.40 HOLESOF THE MOUNTING PLATE AS A TEMPLATE.

4. FOR EASY ACCESS AND INSTALLATION OF ANCHORS AND FASTENERS, CONDUCT THE FOLLOWING TASKS:

• a) ORIENT THE PLACEMENT OF THE HOLES AS SHOWN WITH ONE HOLE POSITIONED WITHIN THE INNER LEG FRAME AREA*;

• b) POSITION THE THE OTHER TWO HOLES OUTSIDE OF THE OUTER LEG FRAME AREA**.



When table alignment and leveling are achieved, hand-tighten the fasteners with an extra quarter turn.

INT-406-AIV-0136 - Assembly of full metrology table at Inner-BCA

Type of Task Sheet: WDTS
Owner: FS, SJ

Work Definition Task Sheet (WDTS)	
WBS	**Task Name**
INT-406-AIV-0136	Assembly full metrology table at I-BCA

MROI Sub-Project (WBS - Name)		
4.06.00 - Delay Line System		
Preparation Task	**Start Date**	**Task Duration**
Individual assembly of breadboards and stands	When dirty work is concluded at I-BCA	1 day

TASK OUTPUT

DLS metrology table installed (aligned, leveled and achored) in the I-BCA

REQUIREMENTS

Specialists		**Facility**		**Test/special equipment**	
1	MROI-DLS staff	1	NMT/MROI BCF - I-BCA	1	Survey equipment
2	FSI staff	2		2	Portable lights
Pre-requisites		**Applicable documents**		3	Miscellaneous tools (AIV-0135)
1	INT-406-AIV-0028	1	INT-406-VEN-0113	4	
2	INT-406-AIV-0135	2	INT-406-VEN-0010	5	
		3	INT-406-VEN-0012	6	

TASK PROCEDURE

Phase	Step	Description	Comments/Illustrations
Measurement	1	To start, the middle table shall be installed as follows: Facing the DLA wall, use the monuments installed inside the Inner-BCA to mark linear coordinates (positions) for the locations of the VERE table feet: 1, 2, 3 and 4.	Refer to INT-406-AIV-0135 for the location of VERE middle optical table feet.
Prep-A	2	Use provided tile cutting template (INT-406-SKT-0115) to mark and circularly cut the tile at the four footing locations; then clean adhesive residue. Put middle optical table into position on the concrete slab.	Refer to INT-406-AIV-0135 Prep-A 1 & 2 for suggested circular center location; and VCT cutting and adhesive removal technique.
Set-up	3	Set-up total station on the origin monument of MROI (coordinate (0,0,0) - refer to AIV-5140).	Each optical table will be aligned and leveled using a total station and poles with precision targets installed at known points on each table top (mounting holes).
Alignment	4	Align and level the middle optical table by looking at the four defined targets with the total station. The mounting holes to be used for the four poles location are determined by 3x3 holes from each corner. Make the adjustment using leveling feet. Nominal height is 1265mm.	Refer to INT-406-AIV-0135 for reference schematic on pole locations. Adjustment should be performed until the maximum accuracy provided by the total station has been obtained.
Installation <-- Prep-B	5	Orient each metrology table anchor as shown in the INT-406-AIV-0135 Prep-B. Drill three holes 3/8" x 1-1/8" deep for each leveling foot (twelve holes in total). Vacuum each hole to remove dust and install the red-head in each hole.	Refer to INT-406-AIV-0135 Prep-B for suggested installation technique.
	6	Proceed to install and align the south table to the anchored middle table. After table is in place via total station, circle (mark) each table foot (4x) completley around it's perimeter. When all feet are outlined remove table for clear working space.	Refer to INT-406-AIV-0135 Prep-A 2 for suggested VCT cutting, adhesive removal (for the south and north tables).
Repeat	7	Replace South table at circular "cut-out" locations and repeat step 5. For the North table installation, repeat steps 5 and 6.	Refer to INT-406-AIV-0135 Prep-A 2 for suggested VCT cutting, adhesive removal (for the south and north tables).

NOTES

1	Perform a final alignment/level check on all three tables via total station.
2	Wipe parts and floor with alcohol after removing tile and drilling holes. Clean up debris after completion.

INT-406-AIV-0137 - Assembly of Agilent laser head to nominal position

Type of Task Sheet: WDTS
Owner: DK

Work Definition Task Sheet (WDTS)	
WBS	**Task Name**
INT-406-AIV-0137	Assembly of Agilent laser head to nominal position

MROI Sub-Project (WBS - Name)		
4.06.00 - Delay Line System		
Preparation Task	**Start Date**	**Task Duration**
Assembly of DLS metrology laser head	When metrology table is assembled	1/2 day

TASK OUTPUT
Agilent laser beam aligned parallel to the holes in the metrology table at 100mm above surface of the table.

REQUIREMENTS					
Specialists		**Facility**		**Test/special equipment**	
1	Dan Klinglesmith	1	NMT/MROI BCF - I-BCA	1	Laser targets
2	Fernando Santoro	2		2	
Pre-requisites		**Applicable documents**		3	
1	Metrology table aligned/leveled	1	INT-406-AIV-0028	4	
2	Metrology table anchored	2	MROI-216, 217, 218, 219	5	
3		3		6	

TASK PROCEDURE

Phase	Step	Description	Comments/Illustrations
PREPARATION	1	Test power connections to laser head. Computers are not needed at this stage.	
	2	Install laser head feet (drawing MROI-233).	
	3	Assemble laser beam compressor following instructions on drawing MROI-224.	See INT-406-DWG-2011: Laser Beam Compressor Assembly
	4	Create and mount a laser beam target for installation at North end of metrology table.	
SETUP	5	Attach laser base plate (INT-406-DWG-2012-rev01) to optical table at South end with laser facing North. Beam compressor mount needs to be installed first.	
	6	Locate Agilent laser head feet (MROI-231) on base plate on kinematic mounts (grooves). Clamp laser feet with laser head clamps (drawing MROI-218).	
MEASUREMENT	7	Determine height of laser beam at the end of each table. Should be 100mm above the top surface of the metrology table. Distance from east edge of the table should be XXXmm and distance from South edge should be about xxmm.	

NOTES	
1	Phase Measurement - Step #7: beam distance from east edge of metrology table determined by placement of laser head mount on table top.
2	There does not appear to be any way to rotate the laser beam to be parallal to optical table holes.

INT-406-AIV-0138 - Assembly/integration of Metrology System for a DL

Type of Task Sheet: WDTS
Owner: DK

This is an important sub-activity as it is first necessary to align the metrology system for the first block so that the beam from the beam expander is aligned to the DL before the Trolley in put in the pipe. This is performed by placing a target over the metrology window and another target at the far end of the DL on the same axis and then aligning the beam so its center passes through the center of each target. This ensures that the incoming beam will be in the correct position so that when the Trolley is installed into the DL, the outgoing beam should appear at the outgoing metrology window.

Suggestions from John Seamons:

Don't forget the Agilent E1709A remote receiver alignment (AC/DC ratio). Perform after optical alignment is done. See chapter 4 of operating manual. Also see "8.receivers pg 8-29" doc that jks has.

Cabling between metrology table and electronics rack:
(1) Label both ends of firewire and optical fiber cables (especially on rack side) for future identification in case cables are disconnected at some point (they will all look the same.)
(2) 20m optical fiber from E1706A remote sensor on table to E1709A remote receiver in rack. Contingency slack: maybe coil a few meters on the optical table (warning: 6” coil radius min., see below.) Then coil remainder of 20 meters on a fiber tray in rack? Ron will have good advice about this since he deals with fiber all the time.
(3) Minimum bending radius of optical fiber for excessive attenuation protection. E1705E-400 spec: 47mm (1.7") min. (L&O vol 1, pg 130), 6" coil min. (8.receivers, pg 8-23). So put fiber inside one of those orange corrugated cable looms that has limited bending radius? (so e.g. it doesn't get pinched going over rung of cable tray.) Secure ends of loom at ? in the Inner-BCA and inside the Outer-BCA rack. This is assuming fiber isn't already in some sort of cable jacket that has radius protection.

INT-406-AIV-0139 - Integration of shear camera to the Metrology System

Type of Task Sheet: WDTS
Owner: DK

Suggestions from John Seamons:

See suggestion for INT-406-AIV-0515. That 15m FireWire cables are now

available that would be easier to use than a 10m plus 4.5m and active repeater. Must get MF approval.

INT-406-AIV-0140 - Integration of Metrology System to a Trolley

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0141 - Integration of shear camera to a Trolley

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0142 - Final alignment of Metrology System to Trolley

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0143 - Final alignment of shear camera to Trolley

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0144 - Verification of Metrology System for a DL

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0145 - Verification of shear camera system for a DL

Type of Task Sheet: WDTS
Owner: MF

INT-406-AIV-0146 - Integration and verification of Controls for ISF

Type of Task Sheet: Description
Owner: JS

Activities consist of tests to ensure operation of the Trolley controls before transport of the Trolley to the Ridge. This is accomplished by Cambridge performing the pre-defined test plan. There are several preparation steps required: Power must be provided to the Trolley via a standalone 48V DC power supply (same one as used in the DL local enclosure). 2.4 GHz WiFi wireless

network access must be provided to the Trolley. The workstation must have a Linux operating system (e.g. Ubuntu) installed; be configured for the ISF network and have the Cambridge production DL workstation software installed, configured and tested prior to the arrival of the Trolley.

Reference documents:

Identifier	Description	MROI-CAM P/N
AIV-6004	Standalone 48V DC power supply cabling	INT-409-DWG-65xx
AIV-5065	DL workstation configuration instructions	-
AIV-5066	Cambridge software installation and testing instructions	
AIV-5067	Test Plan	INT-409-VEN-0108

INT-406-AIV-0147 - Integration and verification of Controls for a DL

Type of Task Sheet: Description
Owner: JS

Activities consist of tests to ensure proper operation of the Trolley controls in the DL as defined by the Cambridge test plan. This is accomplished by Cambridge performing the pre-defined test plan. In addition further tests will be performed to further characterize and assess the performance of the Trolley possibly by using the Delay Line Analysis GUI. A framework for software site acceptance testing is outlined in INT-406-VEN-1009 section 4.

Reference documents:

Identifier	Description	MROI-CAM P/N
AIV-5067	Test Plan	INT-409-VEN-0108
AIV-5065	DL workstation configuration instructions	-
AIV-5066	Cambridge software installation and testing instructions	-
AIV-4035	Delay Line Analysis GUI Functional Description	INT-406-VEN-1006
AIV-4037	Verification plan for the MROI production DL software	INT-406-VEN-1009

INT-406-AIV-0500 - PREPARATION TASKS BREAKDOWN STRUCTURE

Type of Task Sheet: Description
Owner: FS

As for the major activities and sub-activities outlined in the DLS-AIV Planning, there is a need to identify tasks that are not related to the high-level inputs but which are still **required** to allow the AIV Project Plan to be undertaken. We refer to these as "Preparation tasks". These are independent engineering activities not part of the DLS work package which nevertheless must be executed on an appropriate schedule.

INT-406-AIV-0501 - Monumentation

Type of Task Sheet: Description
Owner: FS

Monumentation is a network of primary control points developed to ensure the relative location and orientation of each interferometer subsystem, and to

monitor over time the absolute and differential tilt and subsidence of the interferometer stations, piers and slabs. For MROI, monumentation is an observatory-level preparation task and it is part of the BCF subproject. As far as the DLS AIV plan is concerned, the monumentation required for the DLS subproject is specified in INT-402-TSP-0100-monumentation-requirements. Those called survey monuments in the DLA and Inner-BCA are used to set-up a laser theodolite and target that mimics the DL virtual axis of each pipe run. Alignment jigs provides reference to align pipes and supports during installation (see activity INT-406-AIV-0014 and INT-406-AIV-0131).

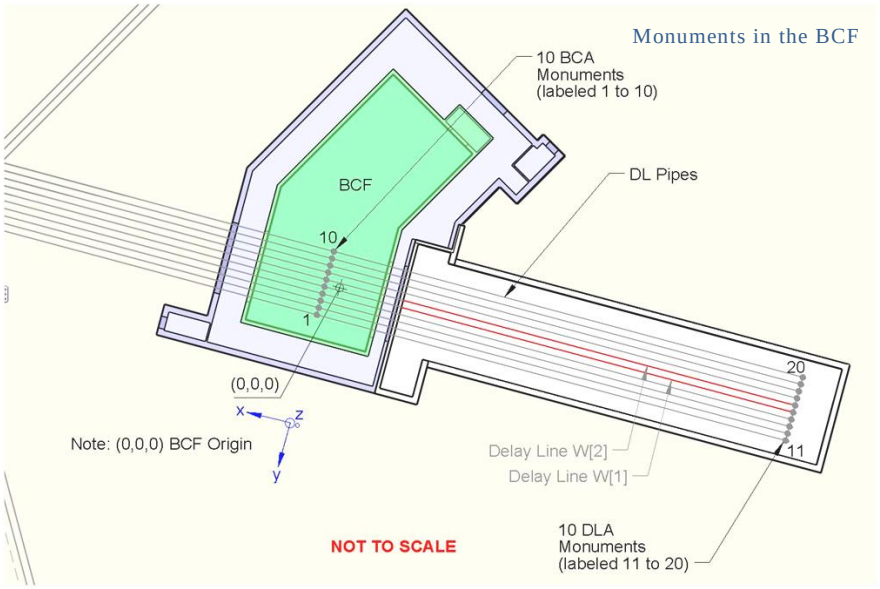
The reader should refer to the following documents:

Identifier	Description	MROI-CAM P/N
AIV-5100	Installation of Survey Monuments in the MROI-BCF	INT-406-TSP-0100
AIV-5101	Alignment Tasks for the MROI-BCF and Array Infrastructure (Date: 2007-0520)	-
AIV-5102	Monumentation for the MROI-BCF (Date: 2006-1215)	-

INT-406-AIV-0502 - To prepare scope of work for monumentation at the BCF

Type of Task Sheet: Description
Owner: RS

A detailed statement of work is required for the installation of the survey monuments within the BCF. This statement of work must include not only the installation of the monuments in the Inner-BCA and DLA, but also a series of reference marks to assist in the installation of the DLA anchor bolts. The installed location of each new reference monument must also be accurately measured as part of this effort. All new monuments should be installed relative to the centerline of the best-fit rectangle on the DLA technical slab. This centerline was defined previously during the slab characterization performed by the professional survey company EDM Works after facility construction. The monument positions shall be recorded in an agreed to coordinate system.



The reader should refer to:

Identifier	Description	MROI-CAM P/N
AIV-5103	Monumentation Phase I Statement of Work	INT-412-CON-0100
AIV-5104	DLA technical slab characterization report (EDM Works)	-

INT-406-AIV-0503 - To secure-monitor-close a contract for successful delivery of the BCF monuments

Type of Task Sheet: Description
Owner: RS

A contract must be let based on the statement of work defined in AIV activity INT-405-AIV-0501. The DLS-AIV team must monitor the contractor's progress and verify that the scope of work is completed to the team's satisfaction. The final deliverable from the contractor will include a close-our report with the recorded installed positions of each new reference monument. Direct measurements and visual inspection will be applied by the DLS-AIV team to check on consistence with the requirements.

The reader should refer to:

Identifier	Description	MROI-CAM P/N
AIV-5075	Installation Report by Summit Engineering	-

INT-406-AIV-0504 - To procure proper tools needed to install & align the DLS

Type of Task Sheet: Description
Owner: RS

A number of tools are required to install and align the DLS based on the Work Definition Task Sheets contained in this AIV plan. A full inventory of the existing tools available to the project must be developed and the additional tools required must be identified. All required tools must be procured prior to the commencement of the AIV task that requires the specified tool.

The reader should refer to:

Identifier	Description	MROI-CAM P/N
AIV-5076	Survey Equipment List	INT-412-CON-0200
AIV-5077	Derived Tool List for AIV at BCF	INT-412-CON-0300

INT-406-AIV-0505 - Measurements

Type of Task Sheet: Description
Owner: FS

INT-406-AIV-0506 - To measure the shape & flatness of the DLA technical slab

Type of Task Sheet: Description
Owner: RS

The shape and flatness of the technical slab must be characterized. This is required for both the final design of the delay line supports as well as the definition of the delay line axis. The delay line axis must be parallel to the centerline of the best-fit rectangle on the DLA technical slab. This will maximize the distance between the anchor bolts for the supports and the slab edge. This will mitigate the risk of slab failure at the perimeter of the slab during the installation of the anchor bolts.

The reader should refer to:

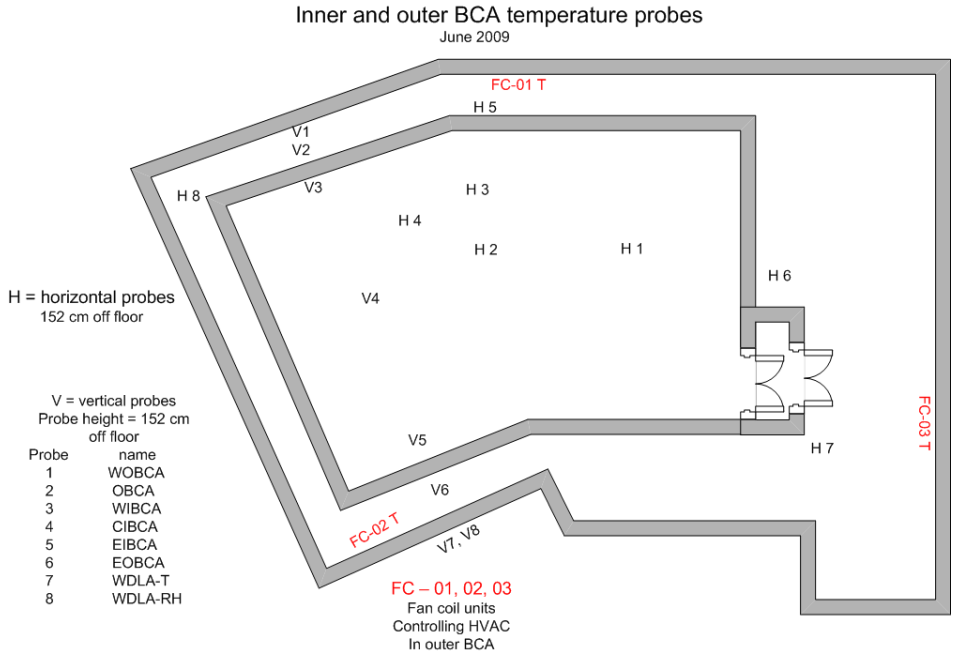
Identifier	Description	MROI-CAM P/N
0506-(a)	SOW by FS	-
AIV-5104	DLA technical slab characterization report (EDM Works)	-
AIV-5074	DLA Floor Slab - shape measurements - v0.1 - Oct2007	-

INT-406-AIV-0507 - To measure any temperature gradient along the DLA

Type of Task Sheet: Description
Owner: DK

This task is concerned with measuring the temperature gradients along the light path from the point at which it enters the BCF via the beam relay pipes through the outer and Inner-BCA and then on through the DLA and back to the Inner-BCA. We have located 14 temperature probes and 2 relative humidity probes along this path at a height of 152cm (60 inches) above MROI grade. The drawing of the inner and Outer-BCA shown locates the first 8 probes marked V1-V8. The probes in the DLA are spaced 100ft apart starting at the first slab break and are labeled 300 west, 200 west, 100 west, center, 100 east, 200 east and 300 east. The center location has both a temperature and humidity probe.

Measurements are made every 5 minutes and recorded on a daily basis. This effort has been ongoing since December 2007.



We are seeing diurnal gradients on the order of -1.5ºC per day in the DLA and 0.05-0.2ºC per day in the Inner-BCA. The Outer-BCA areas see 1.5-2.0ºC variations per day. This experiment will continue as more and more equipment is placed both in the BCA and DLA.

INT-406-AIV-0508 - To install anchor bolts in the DLA main slab

Type of Task Sheet: WDTS
Owner: FS, SJ

Work Definition Task Sheet (WDTS)	
WBS	**Task Name**
INT-406-AIV-0508	To install anchor bolts in the DLA slab

MROI Sub-Project (WBS - Name)		
4.06.00 - Delay Line System		
Preparation Task	**Start Date**	**Task Duration**
Monumentation and measurements of DLA slab	At least 1 week prior to installation of supports	3 days per 100m

TASK OUTPUT

DLA slab marked and anchor threaded rods installed for DL pipe supports

REQUIREMENTS

Specialists		**Facility**		**Test/special equipment**	
1	MROI-DLS staff	1	NMT/MROI BCF - DLA	1	INT-406-SKT-0101 rev01 (jig)
2	SFI staff	2		2	Tape measurement (25ft./8m)
Pre-requisites		**Applicable documents**		3	Portable lights
1	INT-406-AIV-0013	1	INT-406-VEN-0119 - Sec.1	4	Diamond core wet-drilling system
2	INT-406-AIV-0500	2	Types of anchors for anchoring to concrete	5	Cleaning rags/towels
3				6	Vacuum cleaner
4		3	HILTI - 4.2.6	7	Miscellaneous

TASK PROCEDURE

Phase	Step	Description	Comments/Illustrations
Preparation	1	Use the MROI anchor jig (INT-406-SKT-0101) to determine the position of the two remaining locations of the anchors on the DLA technical slab. Have them marked. This shall include support stands and anchor support.	Align the top left target hole with the pre-determined cross-hairs (white mark) and the bottom right target with it's predetermined cross-hairs (white mark).
	2	On the DLA technical slab use allocated diamond core wet-drilling system to drill 5/8' diameter holes 4" deep at the marked locations (4x).	After all holes are drilled, thoroughly clean and dry in preparation of epoxy set.
Installation	3	Refer to HILTI - 4.2.6 HIT-RE 500-SD Epoxy Adhesive Anchoring System (section 4.2.6.5 Installation Instructions) for complete installation process of the adhesive anchoring system.	Specific instructions within section 4.2.6.5 are highlighted. This should be followed for this particular installation. Refer to step 4 in conjunction with epoxy manufacturer recommendations for setting and cure time of epoxy.
	4	To assure anchor rods are aligned and leveled for setting in epoxy, use the MROI anchor jig (INT-406-SKT-0101).	Refer to datailed instructions on alignment and leveling of anchor rods. CAUTION: epoxy has one hour setting time; alignment and leveling are time dependent.
	5	While MROI anchor jig (INT-406-SKT-0101) is in use (four anchor rods set in epoxy for one hour) repeat steps 1 - 4 with second alignment jig. Repeat with third aligment jig if time permits.	

NOTES

1	Read section 1 of INT-406-VEN-0119 - Proposed Delay Line Tools, Jigs and Handling Procedures.
2	Support location on the DLA main slab should be marked out accurately (INT-406-VEN-0119).

INT-406-AIV-0509 - Controlling of interfaces
Type of Task Sheet: Description
Owner: FS

INT-406-AIV-0510 - To manage the ICD: DL to SCS

Type of Task Sheet: Description
Owner: JS

The production delay line software is required to interface with the Interferometer Supervisory Control System (SCS) and the Fringe Tracker subsystem. This ICD must be kept up-to-date to reflect that interface as it is developed.

Reference documents:

Identifier	Description	MROI-CAM P/N
AIV-5068	ICD: Delay line to ICS	INT-406-VEN-0002
AIV-5069	ICD: Delay line to Fringe Tracker	TBD UofC / MROI

INT-406-AIV-0511 - To manage the ICD: DL to Beam Relay System

Type of Task Sheet: Description
Owner: FS

INT-406-AIV-0512 - To manage the ICD: DL to BCF infrastructure (building)

Type of Task Sheet: Description
Owner: FS

INT-406-AIV-0513 - To manage the ICD: DL to Metrology System

Type of Task Sheet: Description
Owner: FS

INT-406-AIV-0514 - To manage the ICD: DL to Vacuum System

Type of Task Sheet: Description
Owner: FS

INT-406-AIV-0515 - To manage the ICD: Metrology System to BCF

Type of Task Sheet: Description
Owner: FS

Suggestion from John Seamons:
ICD INT-406-VEN-0012 v0.4 section 9.3 “Cabling” Table 2 and 10.2.2 “Shear Camera”. Since 15m FireWire 400 cables are now routinely available it would be easier to use one of them rather than a 10m cable plus a 4.5m cable and active repeater. Must get MF approval.

INT-406-AIV-0516 - To manage the ICD: Metrology System to BRS

Type of Task Sheet: Description
Owner: FS

INT-406-AIV-0517 - Signals and Services in the BCF

Type of Task Sheet: Description
Owner: RS

The signals and services required specifically for operation of the DLS are described in document 0517-(a). Other requirements which may be necessary for installation and maintenance are not addressed. There are some signals and services are required at the near end of each DL, i.e. near to the BCA, and some that are required at the far end of the DLs. These are: **1./** at the near end: vacuum manifold and pressure sensor, vacuum control valve, pressure sensor and datum sensor & module; **2./** at the far end of each DL there are three signals to inject into the pipe each with low voltage power requirements. For each DL the signals are injected into the pipe from modules mounted on the pipe end plate. These are the inductive power supply, the wireless network RF link and the low-latency analogue RF link.

The reader should refer to:

Identifier	Description	MROI-CAM P/N
AIV-5070	Delay Line Signals and Services in the DLA (by MF)	-

INT-406-AIV-0518 - Determine the signal & service requirements for the anticipated DLs

Type of Task Sheet: Description
Owner: JS

Before any AIV activities for the DL control systems can take place the appropriate power and network cabling should be installed. This is necessary because of the long lead times associated with installation of power and network services. The installation of the signaling cables may also need to be included here if there is significant time needed to install them along the ceiling path. Signal cable termination can be part of the normal AIV process. Ron King has developed a phased approach to DLA network distribution (copper now, fiber later) to lower costs.

Reference documents:

Identifier	Description	MROI-CAM P/N
AIV-5067	ICD: Delay line to ICS	INT-406-VEN-0002
AIV-5068	ICD: Delay line to Fringe Tracker	TBD UofC / MROI
AIV-6004	DLA AC Power Distribution Requirements	INT-412-DWG-6481
AIV-6004	DLA Network Distribution Requirements	INT-409-DWG-65xx
AIV-5070	Delay Line Signals and Services in the DLA (by MF)	-
AIV-5072	DLA Power System - Scope of Work (July 2009)	INT-406-ENG-000x

INT-406-AIV-0519 - To design & install the required electrical service

Type of Task Sheet: Description
Owner: RS

The DLA as designed by M3 and constructed by KLH had limited electrical services within the DLA. The building initially included only service receptacles along the south wall of the DLA. These receptacles were on a limited number of 20A circuits and were insufficient to operate all ten delay lines. The existing receptacles are also spaced such that their locations do not correspond to the anticipated delay line lengths (30m, 100m, 150m and 190m). For these reasons, additional electrical services must be supplied to the electronics at the end of the DLA at the locations defined in AIV activity INT-406-AIV-0518. Supplemental lighting may also be required at the far eastern end of the DLA. A statement of work, detailed design and subsequent installation are required.

The reader should refer to:

Identifier	Description	MROI-CAM P/N
AIV-6006	BCF construction drawings by M3	-
AIV-5078	DLA Electrical Systems Statement of Work	INT-412-CON-0500
AIV-6005	Requirements for Electrical Services	INT-412-DWG-6481A
AIV-6005	Delay Line Area Electrical DWG E-1	INT-412-DWG-0501E1
AIV-6005	Delay Line Area Electrical DWG E-2	INT-412-DWG-0501E2

INT-406-AIV-0520 - To design & install the required data communications service

Type of Task Sheet: Description
Owner: RS

The DLA as designed by M3 and constructed by KLH had very limited provisions for data communications. A cable raceway is provided to the western end of the DLA, but there are no conduits or cable routes to the DLA electronics. Cable conduits and/or raceways must be provided to the electronics racks as well as the requisite communications cables and ancillary electronics. Points of connection are defined in AIV activity INT-406-AIV-0518. Cable trenches for data communications are provided on the southern walkway slab within AIV activity INT-406-AIV-0519.

The reader should refer to:

Identifier	Description	MROI-CAM P/N

AIV-6005	BCF construction drawings by M3	-
AIV-5078	DLA Electrical Systems Statement of Work	INT-412-CON-0500
AIV-6005	Requirements for Electrical Services	INT-412-DWG-6481A

INT-406-AIV-0521 - To set requirements needed for operations & maintenance

Type of Task Sheet: Description
Owner: RS

Once new electrical and data communications systems are installed, these must be included in the operations and maintenance plan for the building. This presently includes daily and weekly inspections in addition to monthly and quarterly maintenance activities. The systems within the DLA must be inspected and maintained as suggested by the relevant equipment manufacturers. Spare parts required for system maintenance must also be added to the existing facility spare parts inventory.

INT-406-AIV-0522 - Supplies in the DLA

Type of Task Sheet: Description
Owner: RS

Supplies will be required within the DLA to support the AIV process. These supplies may include material handling tools, assembly tools, fasteners and consumables. The requisite supplies must be procured and made available prior to the commencement of the AIV activity.

INT-406-AIV-0523 - To setup a limited furnished shop with tools and fasteners in the DLA

Type of Task Sheet: Description
Owner: RS

The tools procured under AIV activity INT-406-DWG-0504 must be made available within the DLA. In addition, a supply of fasteners and other consumables must be made available. Some organization of these supplies will also be required. Workbenches and storage cabinets will be required. The preferred workspace configuration will allow 360-degree access to the work bench. The bench must have integrated storage for seals, bands, and other larger components.

The reader should refer to:

Identifier	Description	MROI-CAM P/N
AIV-5077	Derived tool list for AIV at the BCF	INT-412-CON-0300
AIV-5079	Provisional list of tools and test equipment for DL and Trolley installation and testing at MROI	-
AIV-6005	Survey Equipment List	INT-412-DWG-0200

INT-406-AIV-0524 - Temporary work areas

Type of Task Sheet: Description
Owner: RS

A number of temporary work spaces will be required to support the AIV activities. These include assembly spaces, storage spaces and a shipping & receiving space. Spaces are defined by the functional needs of the AIV tasks to be performed. A number of these work areas can be included within the DLA, however some activities may be performed in other portions of the BCF.

INT-406-AIV-0525 - To arrange workspace in the BCF

Type of Task Sheet: Description
Owner: RS

Temporary work spaces must be identified and reserved for AIV activities.

An AIV workspace will be reserved at the far eastern end of the DLA. The necessary work benches and other furnishings identified in AIV activity INT-406-AIV-0523 must be placed in this area. Supplemental lighting will also be required to ensure an effective and safe environment.

A temporary workspace with a work bench and portable light can also be arranged near the end of a piping run being installed; whenever shorter than 190m (other possible anticipated scenarios are 30m, 100m and 150m).

(Insert image of work space in the DLA)

A shipping & receiving space is also required. The preferred location is the east end of the DLA due to the access provided by the East DLA doors. The AIV work space must not impede forklift access. The BCF shipping & receiving room may also be used as a temporary loading & unloading area.

(Insert images of S&R space in the DLA & ICA)

Temporary storage will be provided along the walkway slabs that flank the DLA technical slab. The technical slab itself may also be used for temporary material storage so long as a clear path is maintained for the full length of the DLA.

(Insert image of storage space in the DLA)

Workspace for servicing the Trolleys is reserved in the optical lab. The necessary optical table and supplies for Trolley alignment will be provided in this space only.

(Insert image of optical lab in the ICA)

Some AIV tasks may also be performed in the Electro-Mechanical lab. Tools and supplies may be shared between the Electro-Mechanical Lab and the AIV workspace at the eastern end of the DLA.

(Insert image of mechanical lab in the ICA)

INT-406-AIV-0526 - To arrange workspace and workbenches at ISF

Type of Task Sheet: Description
Owner: CS

Workspace available for the open test track includes two optical benches and a computer desk. The computer desk can be used to hold the DL Trolley workstation computer and the optical benches provide space to set up the open test track. There is also a 4' x 10' optical table with a removable, overhead cable tray that can be used for additional workspace. The optical table and benches are spaced far enough apart to allow for easy maneuvering of the floor crane when moving the trolley.

INT-406-AIV-0527 - To provide tools and handling hardware at ISF

Type of Task Sheet: Description
Owner: CS

Tools and handling hardware for the open test track and DL Trolley will be provided by MROI (same as INT-406-AIV-0523). The tools provided will be based on the "Provisional list of tools and test equipment for DL and trolley inspection, installation and testing at MROI" (see AIV-5077 and AIV-5079). Additional tools can be provided by MROI if necessary. Handling hardware includes the floor crane and nylon slings in addition to the lifting equipment for the Trolley provided by Cambridge.

5.3. MROI-DLS AIV PROJECT PLAN CHART

Work flow chart from Microsoft Project

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