OMEGA EP
System Operations Manual
Volume VII–System Description

Chapter 7: Experimental System

APPENDIX A: GLOSSARY OF ACRONYMS

Chapter 7
Experimental System

7.0 INTRODUCTION

The Target Experimental Systems provide a complete operating environment and support infrastructure for target-physics experiments. These systems position targets within the target chamber, generate and maintain the high-vacuum environment, and support a suite of target diagnostics.

The target area subsystems replicate existing OMEGA systems and operator interfaces wherever possible and utilize existing methodology where it was not. This approach minimizes retraining of personnel, reduces spare parts inventory, expedites design and implementation, and minimizes development costs.

The Experimental System is compatible with and shares much of the ten-inch manipulator (TIM)-based target-diagnostic inventory with the OMEGA system (e.g., x-ray framing cameras). Many diagnostic systems that are permanently installed are duplicates of or are based on existing OMEGA target-diagnostic systems (e.g., x-ray pinhole cameras). All diagnostics to be used on OMEGA EP will be explicitly qualified for use on the OMEGA EP Laser System following the Laboratory for Laser Energetics (LLE) 7700 procedure.

Target-area features necessary to support the operation of target diagnostics include configurable timing trigger and monitor systems, built-in data acquisition systems for charge-coupled device (CCD) and charge-injection-device (CID) sensors, network communications support, work areas to assemble and configure diagnostic instruments, a photographic darkroom, other post-shot data-processing facilities, and off-line storage areas. These facilities are similar to those deployed on OMEGA.[1]

The target area supports the future addition of a planar Cryogenic Target Handling System (CTHS). It is expected to be a replica of the system on OMEGA and be capable of irradiating solid deuterium targets to investigate physics issues related to cryogenic implosions and advanced ignition concepts. The system is not designed to support experiments requiring tritium.

The target area is also compatible with the possible future installation of a National Ignition Facility (NIF) diagnostic instrument manipulator (DIM)-compatible system. This system would have the capability to accept DIM payloads and would have a transport distance commensurate with the smaller-diameter OMEGA EP target chamber, providing the capability to perform full-function testing of NIF diagnostics.

7.1 TARGET CHAMBER

The target chamber (TC) is a 3.35-m-diam sphere of 7.9-cm wall thickness, constructed of 5083 aluminum. The TC design supports interchangeability of TC-mounted equipment with that used on the 60-beam OMEGA TC. The TC typically operates at a vacuum of $<10^{-5}$ Torr.

The TC has 90 bolted and O-ring sealed circular ports of 12-in., 18-in., 24-in., 26-in., and 36-in. diameter. The 18-in. and 24-in.-diam ports are identical in design to those used on the OMEGA TC. The standoff distance from the center of the TC to the flange faces is nominally 1.63 m. Port locations differ from those on the 60-beam OMEGA TC and are optimized for the OMEGA EP mission. Port locations are shown in Table 7.1. TC coordinates are described using a right-handed spherical coordinate scheme that is illustrated in Fig. 7.1.

Table 7.1: OMEGA EP target chamber port assignments[(a)] with port size and opposing port locations. [The angles (θ, ϕ) are polar coordinates described in Fig. 7.1.]

Port ID	Assignment	Port diameter (in.)	θ(°)	ϕ(°)	Opposite port
1	CTHS Cryo Upper	18	0	0	90
2	TIM-10	18	27	0	87
3	Unassigned	18	27	45	88
4	Unassigned	18	27	90	–
5	Unassigned	18	27	135	89
6	Unassigned	18	27	225	85
7	TPS	18	27	270	–
8	Unassigned	18	27	315	86
9	High-intensity parabola inserter	36	41	180	82
10	Unassigned	12	43	11.25	81
11	Unassigned	12	43	33.75	–
12	Unassigned	12	43	56.25	–
13	Unassigned	12	43	78.75	–
14	Unassigned	12	43	101.25	–
15	Unassigned	12	43	123.75	–
16	Unassigned	12	43	236.25	–
17	Unassigned	12	43	258.75	–
18	Unassigned	12	43	281.25	–
19	Unassigned	12	43	303.75	–
20	Unassigned	12	43	326.25	–
21	Unassigned	12	43	348.75	80
22	Beam 1, 48°	12	58	142	79
23	Beam 4, 48°	12	58	218	–
24	Diagnostic Port B3, 48°	12	58	322	77
25	Unassigned	18	60	0	73
26	Unassigned	18	60	60	74
27	X-TVS illuminator	18	60	90	75
28	Unassigned	18	60	120	76
29	Unassigned	18	60	240	–
30	Unassigned	18	60	270	71
31	Unassigned	18	60	300	72

[(a)] Port assignments can change due to changing experimental needs. Contact the OMEGA EP Experimental Subsystem Engineer for current port assignments.

Table 7.1: OMEGA EP target chamber port assignments[(a)] with port size and opposing port locations. [The angles (θ, ϕ) are polar coordinates described in Fig. 7.1.] (continued).

Port ID	Assignment	Port diameter (in.)	θ(°)	ϕ(°)	Opposite port
32	Y-TVS illuminator	12	69	180	68
33	Backlighter beam entry	26	70	37.5	–
34	Diagnostic Port B2, 23°	12	74	17	64
35	Unassigned	12	74	73	65
36	Unassigned	12	74	107	66
37	Beam 1, 23°	12	74	163	67
38	Beam 4, 23°	12	74	197	60
39	Unassigned	12	74	253	61
40	Unassigned	12	74	287	62
41	Diagnostic Port B3, 23°	12	74	343	63
42	Unassigned	18	75	135	59
43	Unassigned	18	75	225	–
44	Unassigned	18	75	315	57
45	TIM-12	18	90	0	51
46	Unassigned	12	90	30	52
47	Unassigned	18	90	60	53
48	TIM-14	24	90	90	54
49	Unassigned	18	90	120	55
50	Unassigned	18	90	150	56
51	Backlighter parabola OAPI	25	90	180	45
52	Unassigned	18	90	210	46
53	TIM-11	18	90	240	47
54	Side lighter parabola OAPI	25	90	270	48
55	Unassigned	18	90	300	49
56	Unassigned	18	90	330	50
57	Unassigned	18	105	135	44
58	Unassigned	18	105	225	–
59	Unassigned	18	105	315	42
60	Diagnostic Port B4, 23°	12	106	17	38
61	Unassigned	12	106	73	39
62	Unassigned	12	106	107	40
63	Beam 3 23°	12	106	163	41
64	Beam 2 23°	12	106	197	34
65	Unassigned	12	106	253	35
66	Unassigned	12	106	287	36
67	Diagnostic Port B1, 23°	12	106	343	37
68	Y-TVS	18	111	0	32
69	Sidelighter beam entry	26	116	54	–
70	Unassigned	18	120	27.5	–
71	TIM-15	18	120	90	30

Table 7.1: OMEGA EP target chamber port assignments(a) with port size and opposing port locations. [The angles (θ, ϕ) are polar coordinates described in Fig. 7.1.] (continued).

Port ID	Assignment	Port diameter (in.)	θ(°)	ϕ(°)	Opposite port
72	Unassigned	18	120	120	31
73	DIM	18	120	180	25
74	Unassigned	18	120	240	26
75	X-TVS	18	120	270	27
76	Unassigned	18	120	300	28
77	Beam 3, 48°	12	122	142	24
78	Beam 2, 48°	12	122	218	–
79	Diagnostic Port B1, 48°	12	122	322	22
80	TC Vacuum Gauges	12	137	168.75	21
81	Unassigned	12	137	191.25	10
82	High-intensity beam entry	36	139	0	9
83	Unassigned	24	145	90	–
84	Man access	24	145	270	–
85	Vacuum system	18	153	45	6
86	Unassigned	18	153	135	8
87	TIM-13	18	153	180	2
88	Unassigned	18	153	225	3
89	Unassigned	18	153	315	5
90	CTHS cryo lower	18	180	0	1

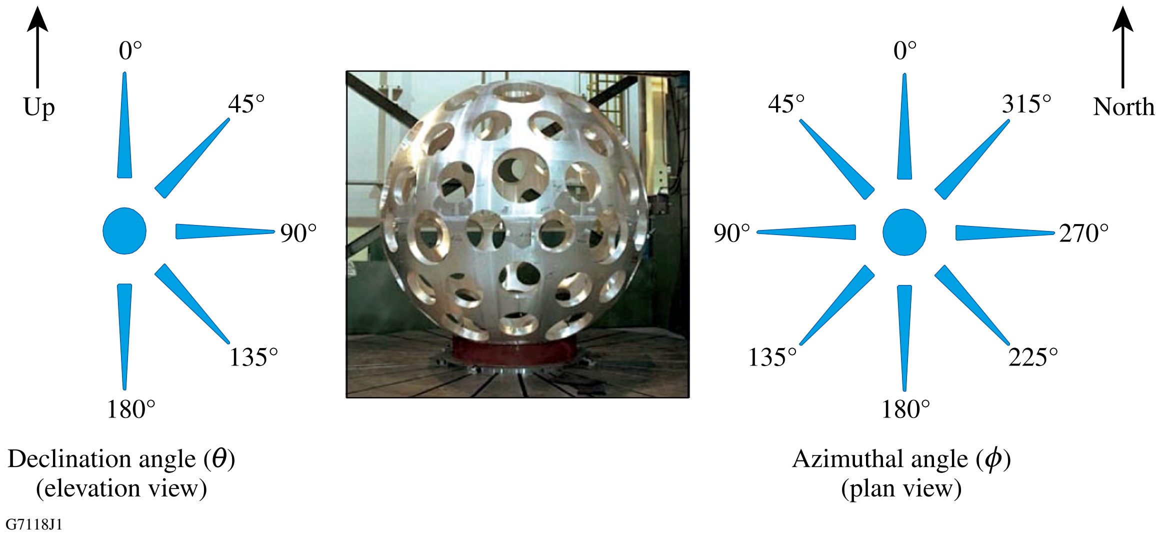


Figure 7.1
The TC is constructed from a 3.35-m-diam, 7.9-cm-thick sphere of type-5083 aluminum. The nominal 1.63-m target chamber center-to-flange radial distance supports the use of existing OMEGA equipment designs and hardware. The angle θ refers to the declination with 0° straight down. The angle ϕ refers to the azimuth with 0° due north and increases in a counterclockwise direction looking down on the TC.

A perspective view of the TC in its initial deployed configuration is shown in Fig. 7.2. Long-pulse focusing optics assemblies (FOA's) position the optics at the focal length of 3.4 m, approximately twice the radius of the TC. Spools are used to mate these assemblies to the TC.

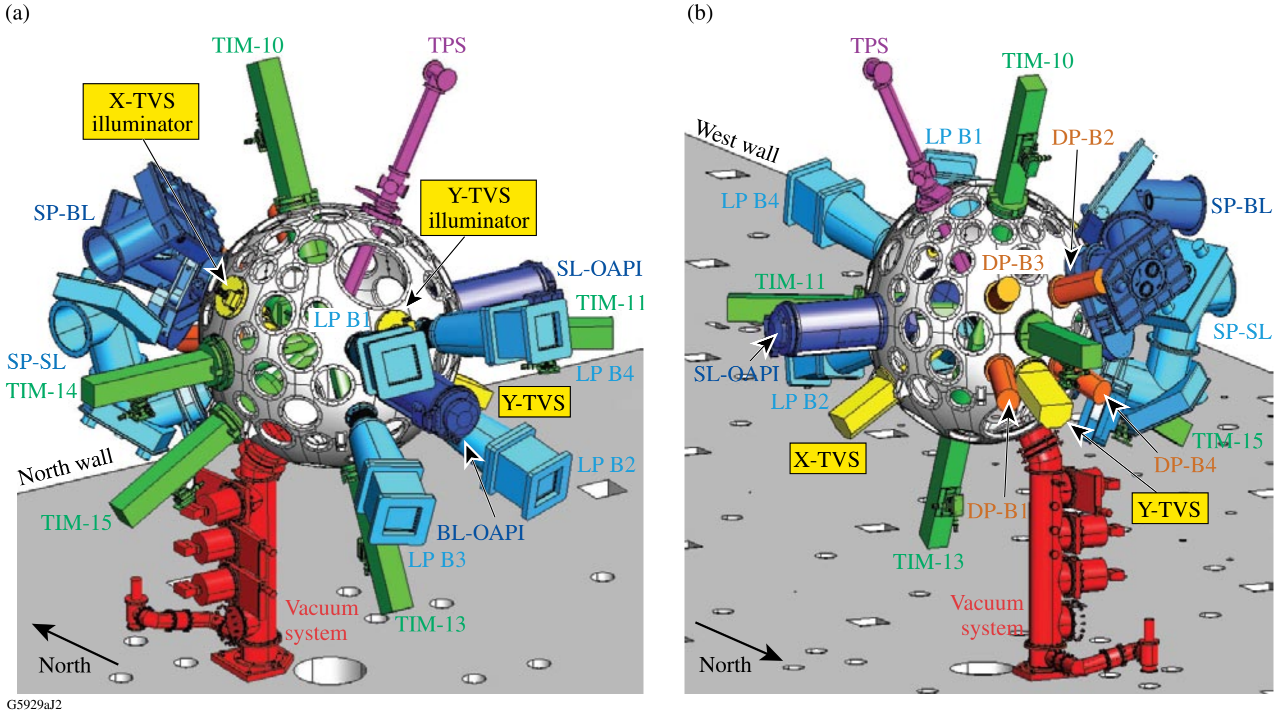


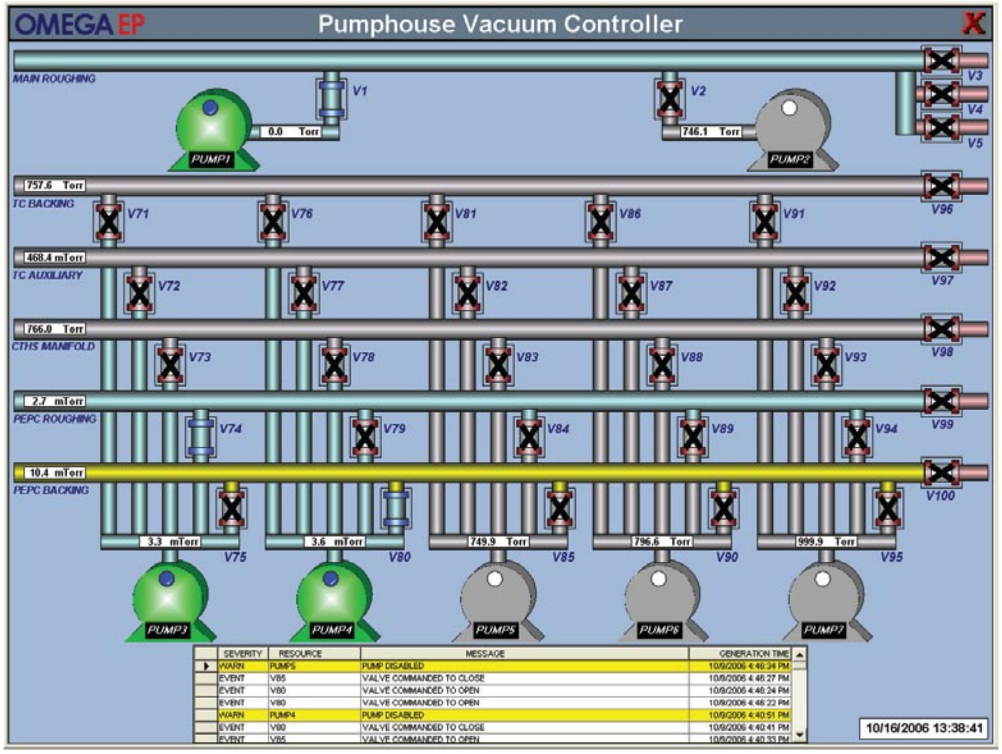
Figure 7.2
OMEGA EP target chamber viewed (a) from the southwest and (b) from the northeast. This drawing has been simplified to illustrate the functionality of the TC. Entry locations are shown for both short- and long-pulse beams. The short-pulse backlighter (SP-BL) and sidelighter (SP-SL) enter the TC from the GCC that is west and south of the TC. The four long-pulse beams enter the TC from the south. Also shown are target positioner (TPS), target viewing (TVS), the vacuum-distribution assembly, and some of the diagnostic attachments (TIM's, OAPI's, diagnostics ports). The TC is supported by the TAS (not shown; see Sec. 7.5). All of the current TC port assignments are described in Table 7.1 and illustrated in Fig. 7.24.

The TC is connected to the grating compressor chamber (GCC) via two 24-in.-diam, short-pulse beam transport tubes (BTT's) that are isolated by gate valves when short-pulse operations are not underway.

7.2 TARGET VACUUM SYSTEMS

7.2.1 Central Rough Vacuum System

The central vacuum system (see Fig. 7.3), located in the OMEGA pumphouse, complements the cryogenic and turbomolecular high-vacuum pumps that are integrated into each of the vacuum chambers in the facility. The rough vacuum system uses a network of stainless-steel pipelines to connect two sets of mechanical vacuum pumps to areas requiring a vacuum as low as 10^{-3} Torr. Vacuum chambers that are supported by these rough vacuum systems include the spatial filters, plasma-electrode Pockels cells (PEPC's), GCC, short-pulse beam tubes, target chamber, and target area antechambers. The rough vacuum system provides vacuum for rough evacuation of chambers, backing of turbomolecular pumps, and regeneration of cryogenic pumps.



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EVENT	V85	VALVE COMMANDED TO CLOSE	10/9/2006 4:46:27 PM
EVENT	V80	VALVE COMMANDED TO OPEN	10/9/2006 4:46:24 PM
EVENT	V80	VALVE COMMANDED TO OPEN	10/9/2006 4:46:22 PM
WARN	PUMP4	PUMP DISABLED	10/9/2006 4:40:51 PM
EVENT	V80	VALVE COMMANDED TO CLOSE	10/9/2006 4:40:41 PM
EVENT	V85	VALVE COMMANDED TO OPEN	10/9/2006 4:40:33 PM

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Figure 7.3
Pumphouse roughing system vacuum controller GUI.

Two separate vacuum-piping networks are installed: A low-flow system ~600 cfm using 3-in. or 6-in. id lines) to support the PEPC's and TC auxiliary components such as TIM's and a high-flow system (2000 cfm using 8-in. and 12-in. id lines) is used to evacuate the TC, GCC, BTT's, spatial-filter tubes, and to support cryogenic pump regeneration.

BOC Edwards Model GV 160 hook and claw dry pumps fitted with BOC Edwards model EH 1200 Rootes Blower booster pumps are used on the 600-cfm system. Five sets of pumps are installed on a shared manifold that feeds the five 600-cfm circuits. Each set can be connected to any of the pipelines, allowing for flexible deployment to facilitate continued operations during maintenance. Multiple pumps can be connected to a single manifold for support of higher load operations, although in these cases the actual flow is generally limited by the pipeline diameter.

Two BOC Edwards Model GV 600 hook and claw dry pumps fitted with both a BOC Edwards Model EH 2400 and a BOC Edwards Model EH 4200 Rootes blower type of booster pump are used on the 2000-cfm system. The 2000-cfm line is a single shared line that supports the GCC, TC, BTT's, and spatial filter vessels. One or both sets of pumps can be connected to the 2000-cfm line.

7.2.2 TC Vacuum System

Long-duration operation of the TC at vacuums of <10^{-5} Torr is achieved with three CTI On-Board 400 cryogenic pumps (see Fig. 7.4), each having a pumping speed of 10,000 l/s (nitrogen). These high-vacuum pumps are attached to the TC via a manifold at Port 85. Each cryopump is isolated via a

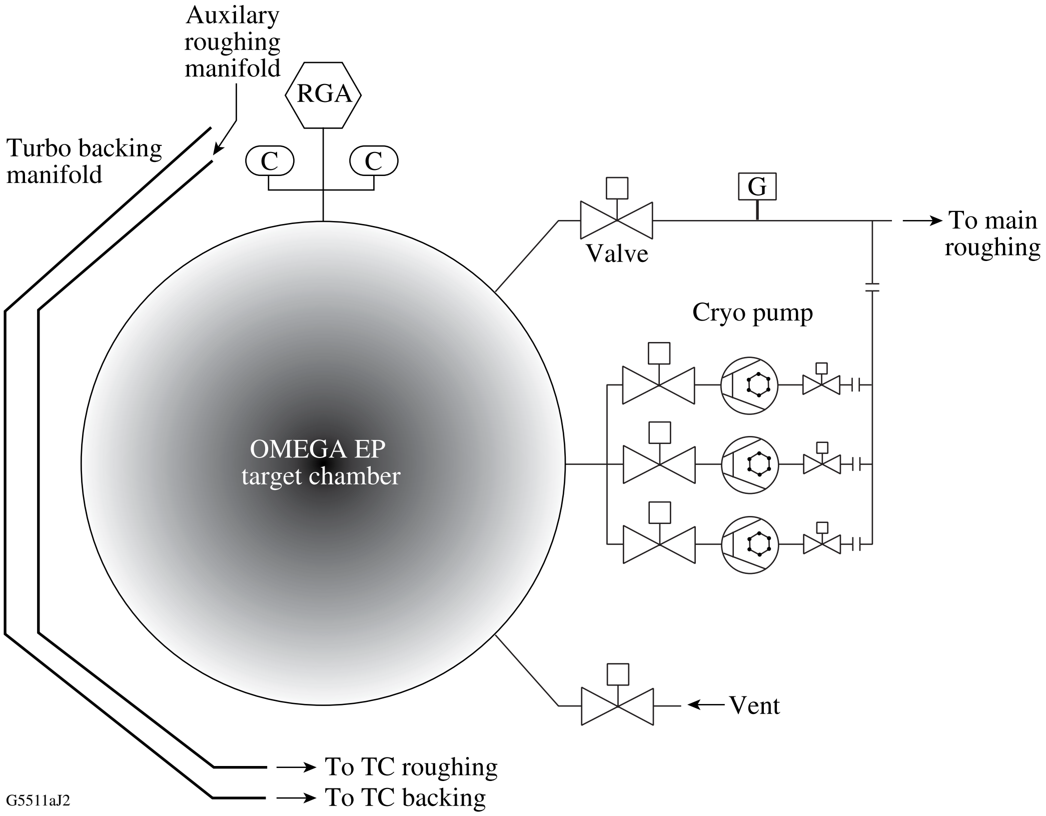

Figure 7.4
Schematic of the TC vacuum system. Seven sets of pumps (Fig. 7.3) supply a roughing and backing vacuum and three cryo pumps maintain high vacuum. [C: vacuum (thermocouple/ionization) gauge; RGA: residual gas analyzer; CTHS: Cryogenic Target Handling System].

16-in.-bore gate valve. A minimum of one pump is required to maintain a nominal 10^{-5} Torr vacuum. The remaining pumps are available for repair, regeneration, or may be brought on-line for additional pumping capacity. Plumbing interconnect diagrams provide more detailed information (Vacuum Interconnect Diagrams, D-AC-I-009 and D-AC-I-010).

The TC is pumped from atmospheric pressure to the crossover pressure (10^{-3} Torr) through the roughing valve installed in the same manifold as the cryopumps. Pump-down of the TC to operational vacuum levels is completed in less than 30 min.

TC vacuum performance is monitored with a pair of wide-range Granville Phillips Model 354 Micro-Ion Plus gauges and an MKS Model EVS -160-080 residual gas analyzer (0 to 100 amu) located in Port 80.

7.2.3 TC Auxiliary Vacuum Systems

Pressure in an antechamber [e.g., a TIM or target-positioning system (TPS)] is equalized with the TC pressure prior to opening the isolation valve. Antechambers are typically fitted with a vacuum system that includes a roughing valve and a turbomolecular high-vacuum pump. Vacuum for the initial evacuation of the antechamber and backing for the turbomolecular pumps is provided via two 3-in. ID manifolds installed on the target area structure (TAS); each is connected to a dedicated portion of the 600-cfm rough vacuum system.

Each antechamber connects to the auxiliary vacuum manifold for rough evacuation (atm to ~100 mTorr). Pressure in this manifold is allowed to fluctuate as high as 760 Torr with a base pressure near 15 mTorr. A device is granted exclusive connection to this circuit by the main vacuum control system. Antechambers ready for rough pumping are queued pending completion of the roughing cycle for higher-priority antechambers.

The turbopumps of all the antechambers discharge to the turbo-backing manifold that is maintained at less than 100 mTorr. Crossover pressure for an antechamber is specified so that this line remains at less than 100 mTorr during the crossover operation. No software arbitration is required for this circuit.

TC roughing and backing vacuum lines are integrated into the TAS (see Fig. 7.5). Additional information on the vacuum system can be found in Ref. 2.

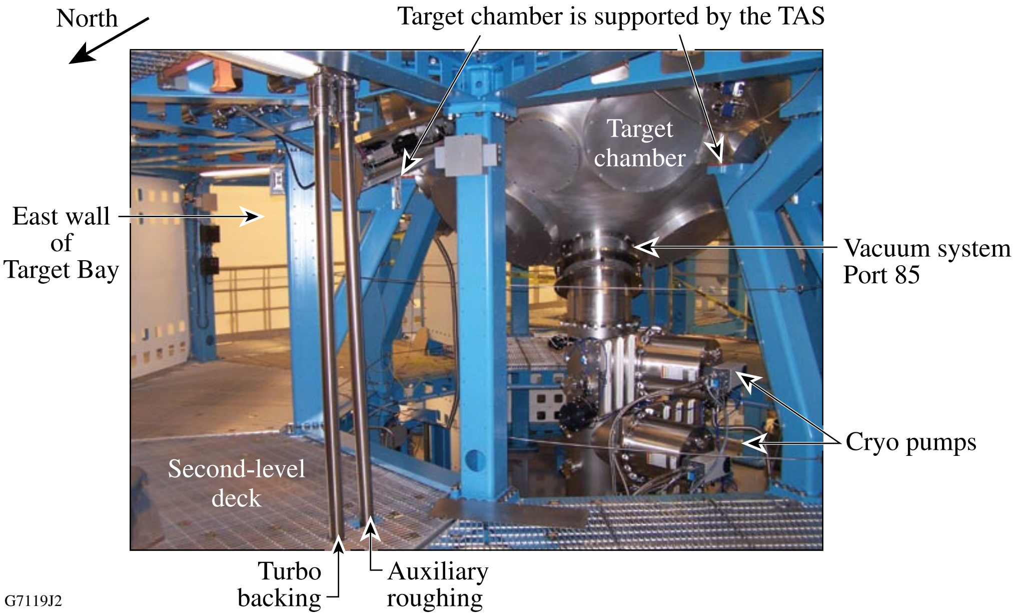

Figure 7.5
The TC is supported by the TAS at seven locations. This view, looking into the TAS from the northwest tower at level 2, shows the auxiliary roughing and turbo backing vacuum lines integrated into the deck support structure. Two of three cryo pumps that support the TC vacuum system are also visible.

7.3 BEAM TRANSPORT TUBES

Short-pulse beams are transported between the GCC and the OMEGA or OMEGA EP TC inside the BTT's. BTT's are maintained at a vacuum equivalent to the GCC and TC, typically on the order of 10^{-5} Torr. Electrical isolation (>5-kV dc) between the tube and the vessel is provided by a high-molecular-weight polyethylene insulator.

BTT's are pumped using one of the central rough vacuum systems and up to two Leybold Heraeus MAG W3200 CT turbo pumps. These turbopumps employ magnetically suspended rotors that require a controlled shutdown. One turbopump is required for high vacuum. The second turbopump allows for maintenance.

BTT's are fitted with 24-in. id pneumatically operated gate valves at either end to isolate them from the GCC and TC. A bellows at either end of each BTT provides vibration isolation between the two chambers. Vacuum performance on all BTT's is monitored using wide-range Granville Phillips Model 354 Micro-Ion Plus gauges.

7.3.1 Transport Tubes to the OMEGA EP TC

Two BTT's transport beams between the GCC and the OMEGA EP TC. The backlighter beam enters the TC through Port 33 and the sidelighter through Port 69. Figure 7.6 illustrates the vacuum configuration for these BTT's. The vacuum system provides roughing and backing for the turbopumps.

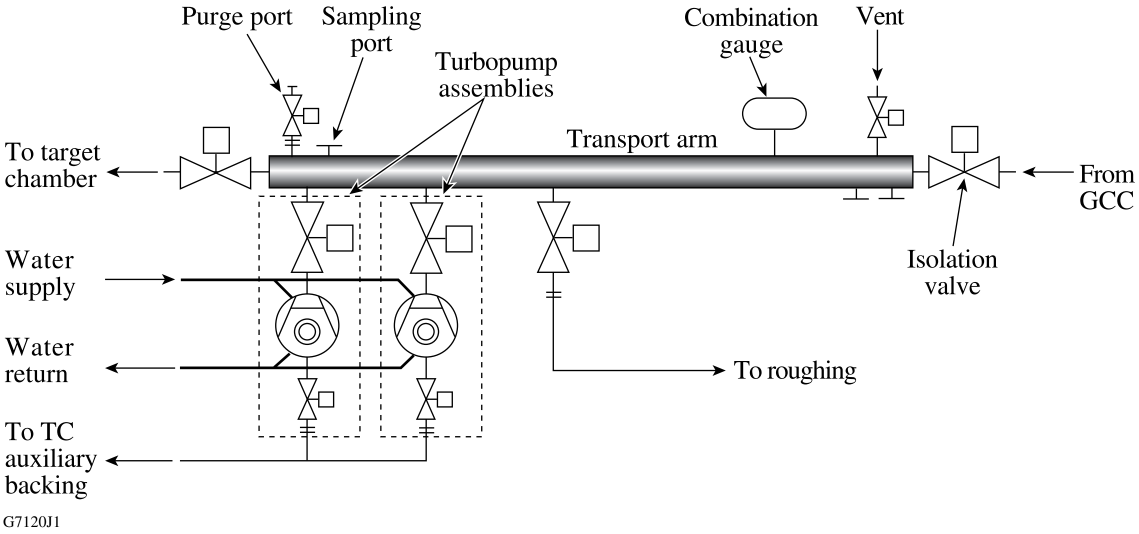

Figure 7.6
The vacuum schematic diagram for a BTT. The main roughing vacuum system (see Fig. 7.3) provides an initial vacuum of ~10^{-2} Torr. Turbopumps then reduce the vacuum to less than 6×10^{-5} Torr.

7.3.2 Backlighter Transport Tube to OMEGA

The configuration of the BTT to the OMEGA TC (Fig. 7.7) is different from the OMEGA EP BTT in order to mitigate tritium contamination. The OMEGA BTT makes use of OMEGA vacuum systems and the Tritium Recovery System (TRS).[3] The OMEGA vacuum system, serviced by the TRS, provides roughing and backing vacuum. Facilities are also included to allow an atmospheric pressure purge directly into the TRS. The vacuum components are controlled by the OMEGA vacuum system except for the isolation valve at the GCC. This valve is controlled by OMEGA EP's vacuum system and interlocked with OMEGA. The interlock requires "permission" from OMEGA before it can be opened from OMEGA EP.

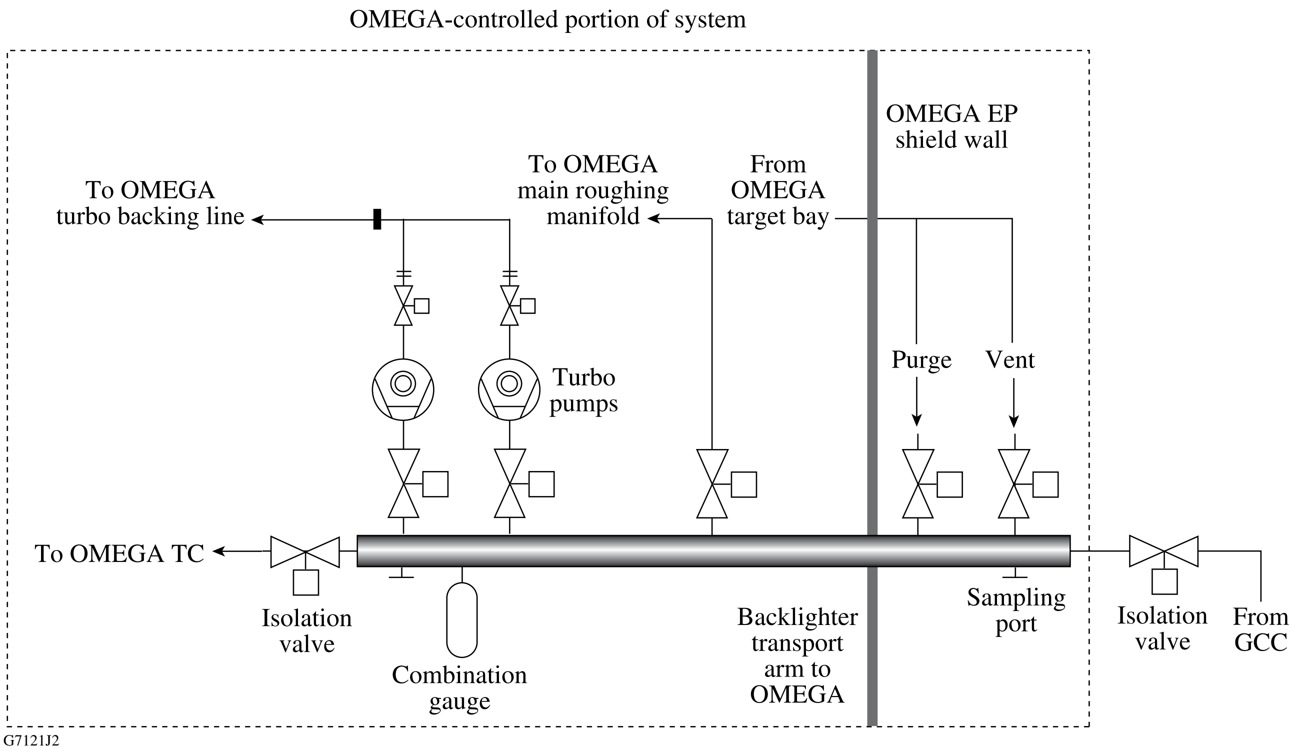

Figure 7.7
The vacuum schematic diagram for the BTT from the GCC to the OMEGA TC. The configuration enables isolation of the GCC from the OMEGA TC and permits removal of tritium.

7.4 OFF-AXIS PARABOLA INSERTER AND MANIPULATOR

This section describes the systems required to insert, manipulate, and retract the off-axis parabola (OAP) located in each TC. The OAP is the final optic in the short-pulse beam transport path (see Vol. VII, Chap. 5, Optomechanical System, S-AD-M-009), reflecting the incoming beam and focusing it to the target. The mission requires three OAP's: two in the OMEGA EP TC that are used for back- and sidelighting, and one in the OMEGA TC used for backlighting. The beams may also be used for other experimental programs such as "fast ignition" (see Vol. VII, Chap. 1, System Overview, S-AD-M-005). Figure 7.8 provides a cutaway illustration of an OMEGA EP off-axis parabola inserter/manipulator (OAPI-M) attached to the TC.

Each OAP is mounted onto a "manipulator" that controls its orientation after insertion into the TC. This device is called the off-axis parabola manipulator (OAPM). The OAPM is mounted on a "sled" that moves the manipulator in and out of the TC and also provides a controls interface. This device is called the off-axis parabola inserter (OAPI). The OAPI is inserted into a vacuum vessel whose function is to shuttle the OAPM into position and provide mechanical, vacuum, and electrical controls support. The entire assembly is referred to as the off-axis parabola inserter/manipulator or OAPI-M.

Figure 7.9 provides a cut-away view of each TC illustrating the beam entry points and the locations of the OAPI-M's. The OAPI-M for the OMEGA EP backlighter is located in Port 51 and the sidelighter is in Port 54. The OAPI-M for the OMEGA backlighter beam is located in Port H7.

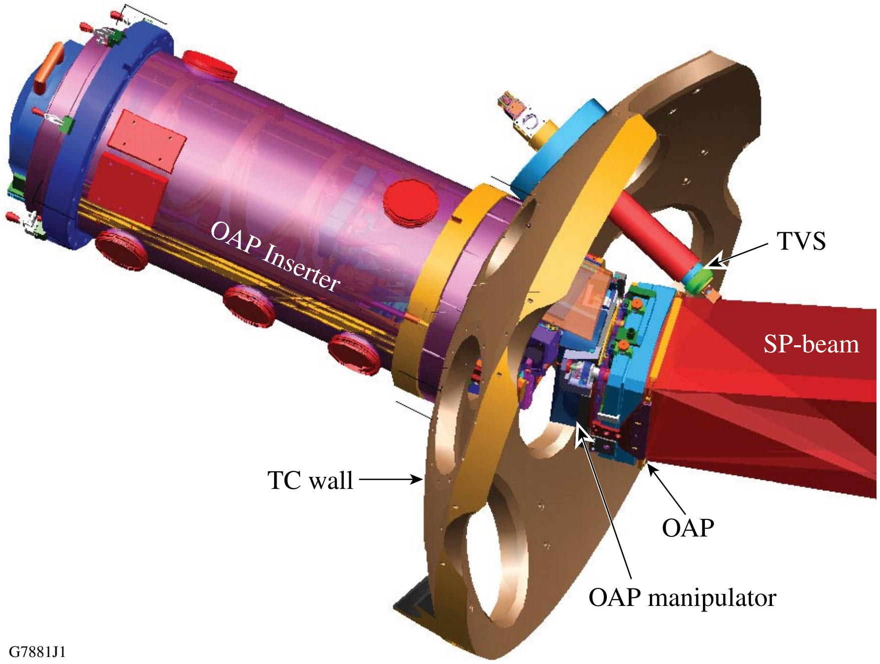

Figure 7.8
The OMEGA EP backlighter OAPI-M is shown attached to the TC (Port 51). The short-pulse beam is shown reflecting off the OAP that focuses the beam to target. One of the target viewing system (TVS) illuminators is located above the OAP.

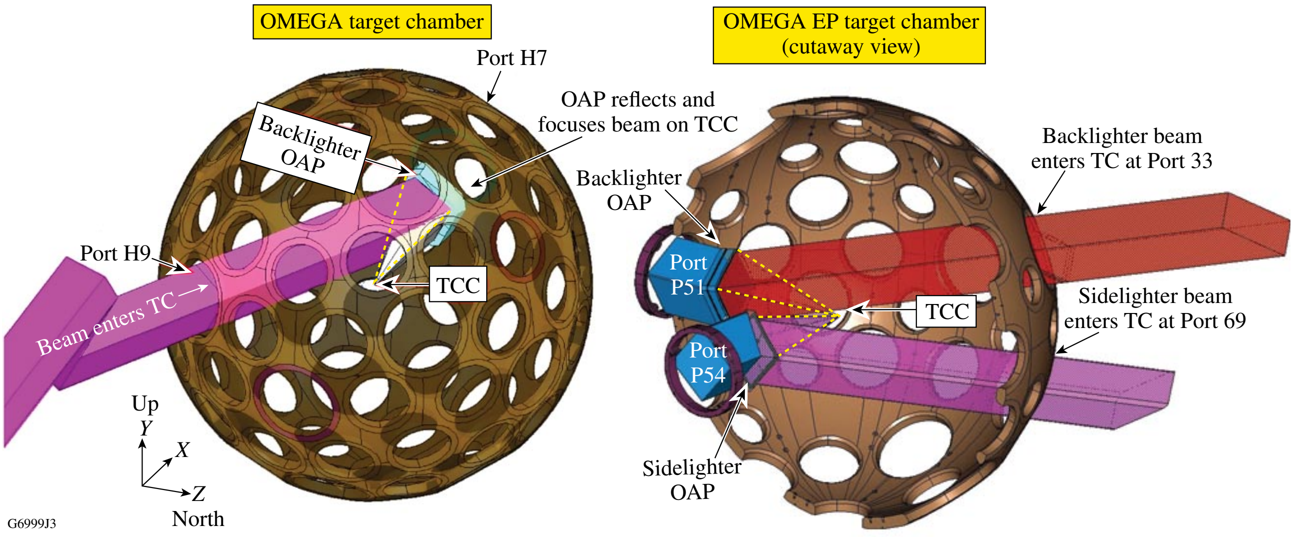

Figure 7.9
Two OAP's are used in the OMEGA EP TC (backlighter at Port 51 and sidelighter at Port 54) and one OAP for the OMEGA TC (backlighter at Port H7).

7.4.1 Off-Axis Parabola Inserter

The OAPI is contained in a vacuum vessel and is used to insert the OAPM into position in the TC. It includes mechanical, vacuum, and electrical controls support. The OAPI is mounted radially on a TC port flange. The OMEGA OAPI-M is shown in Fig. 7.10. The OAPI-M has a stainless-steel cylindrical TC attachment that supports vacuum operation to 10^{-6} Torr. A 24-in. gate valve on the OMEGA OAPI-M provides vacuum isolation of the antechamber from the TC.

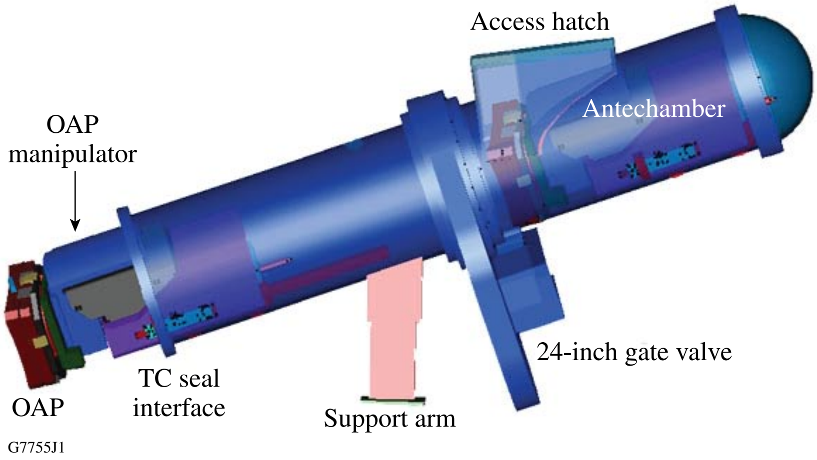

Figure 7.10
The OMEGA OAPI-M is located on Port H7. The two OMEGA EP OAPI's are not equipped with vacuum gate valves or the antechamber extension at the right, requiring the TC to be vented for OAPM insertion or removal. The manipulator aligns the OAP to the target after insertion.

The OMEGA OAPI-M has an antechamber vacuum vessel isolated by a gate valve. This allows the OAPI-M to be removed to the antechamber for service without breaking TC vacuum. The OMEGA EP OAPI-M's do not have an antechamber and require the TC to be vented to remove the OAPI-M onto a rail sled for service. The OMEGA EP OAPI's do not preclude future installation of a gate valve or an antechamber.

On the OMEGA OAPI, a hatch located on the antechamber is opened to provide payload access to the interior. The payload of the OAPI is the OAPM that encompasses the associated actuator hardware necessary for precise alignment. When closed, the hatch completes the outer vacuum seal. The OAPI's internal transport mechanism supports the payload and can move it from the antechamber, through an isolation valve, to the desired position within the TC. The OMEGA OAPI includes the vacuum components necessary to pump its internal volume to the TC operating pressure so that the isolation valve may be opened and the payload inserted. These elements also vent the volume back to ambient pressure after the payload has been retracted and the isolation valve closed. Cable entry via vacuum feedthroughs travel through an umbilical cable carrier to the OAPM to provide power, signals, and communication as needed throughout the full range of travel.

Within the basic enclosure, the OAPM is attached to the saddle of the inserter drive that moves along a set of rails via a linear rack drive at 10 to 12-in. per minute. After the OAPM is driven to its full forward position, docking clamps attach the OAPM to a docking ring inside the vessel. Figure 7.11 provides an illustration of the OAPM.

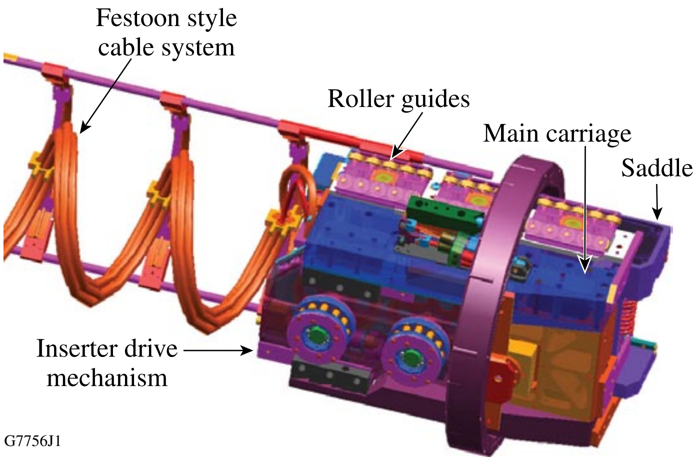

Figure 7.11
The design model of the OAPM. The OAP, on its mount, attaches to the Saddle. The OAPM drives itself into a "docked" position at which point the OAP is inserted. The festooned cable management system provides power and control signals to the OAPM and OAPI from the vacuum controls interface box.

The insertion/retraction and docking processes are separate from the OAP alignment process and are discussed in more detail in Sec. 7.4.3. Insertion and retraction processes are performed locally via a touch-panel interface. The OAP alignment processes are performed in the OMEGA EP Control Room. The inserter motion, clamping, and vacuum controls are programmable logic controller (PLC)-based controls with a local control panel and remote operation through UNIX-based software applications.

7.4.2 Off-Axis Parabolic Manipulator

The OAPM includes the mount and the mechanical controls for adjusting the position and orientation of the OAP. An illustration of the OAPM is shown in Fig. 7.12. While attached to the OMEGA TC, the OAPI may be loaded with the OAP and its manipulator while the TC is maintained at vacuum. Alignment of the OAP requires six degrees of freedom provided by a six-axis motorized head that is part of the OAPM (Fig. 7.12). The OAPM has the capability to meet the reinsertion position tolerances of ±25 μm (x, y, z) and ±1 mrad (tip/tilt). These stages are powered by vacuum-compatible, brush-type dc motors coupled via transmissions to encoders for position-sensing feedback. The stages employ flexures to achieve precise motion over a limited range. The OAPM motion stages are driven by a stand-alone

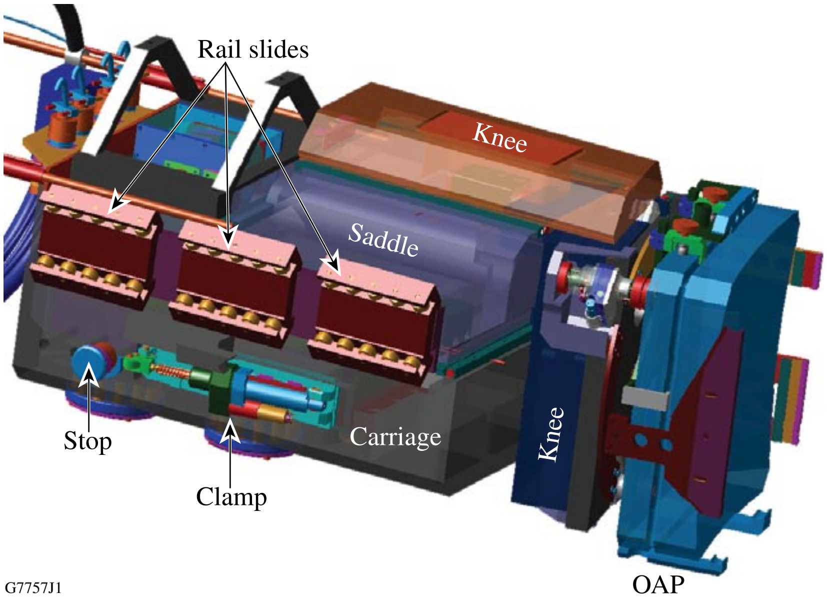

Figure 7.12
An illustration of the OAPM. The carriage supports the knee, saddle, and OAP and drives itself in and out of the target chamber on an internal rail. Clamps and hard stops position the OAPM to within ±25 μm of its docked position.

Galil[(a)] motion controller that, with the exception of some hard-wired handshaking, is independent from the OAPI controls. The OAPM also includes support for a disposable debris shield (DDS) to protect the OAP from target debris.

Additional information on the OAPI-M and associated components can be found in the technical requirement documents and design reviews.[3]

7.4.3 Off-Axis Parabola Controls

The OAPI graphical user interface (GUI) on the OMEGA EP vacuum control system (EP-VAC) is used to control the insertion and removal of the OAPM. The OAPI includes the vacuum components necessary to pump its internal volume to the TC operating pressure so that the isolation valve may be opened and the OAPM inserted. These components also vent the volume back to ambient pressure after the payload has been retracted and the isolation valve closed. PLC logic control monitors the pressure within the antechamber and provides actuation and interlock functions of the gate valve, hatch, and auxiliary vacuum pumping facilities. The PLC-based controllers have a local touch-panel interface in the target areas. An electrical disconnect box isolates the controls equipment rack prior to a shot.

The OAPM GUI, located at the Beamlines Workstation in the OMEGA EP Control Room, controls the alignment and focusing of the three OAP's. The OAPM software provides for tip, tilt, and translation of the OAP in three dimensions. Alignment of the OAP is accomplished using the six axes of motion (Fig. 7.13) provided by motorized stages of the OAPM. The OAPM PLC-based Galil motion controllers share the local touch-panel interfaces in the target areas with the OAPI-PLC controllers. There are hardwired interlocks between the OAPI and OAPM controllers. Additional information on the OAP controls can be found in the technical requirement documents and design reviews.[4]

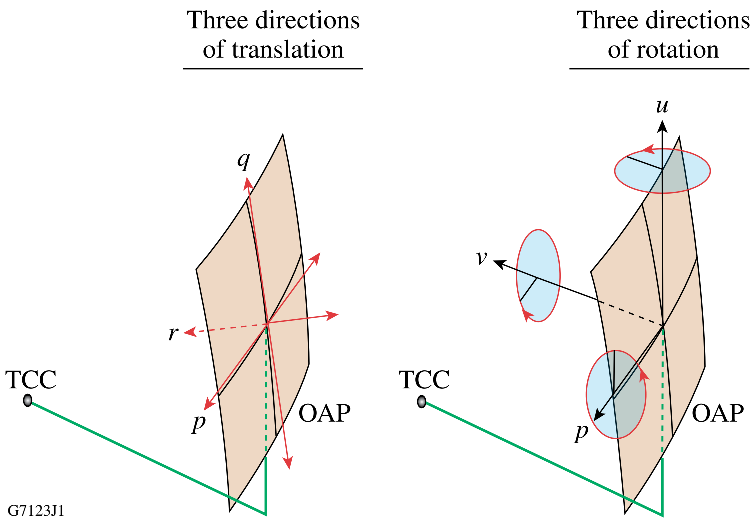

Figure 7.13
The six degrees of freedom of the OAP are shown. There are three directions of translation (*r*, *q*, and *p*) and three directions of rotation (θ_p, θ_u, and θ_v). The OAPM design allows the OAP to translate ±1 cm in each dimension. The OAPM can tip the OAP about θ_p and θ_u by ±1°.

[(a)] See www.galilmc.com.

7.5 TARGET SYSTEMS

7.5.1 Target Positioning System

A large variety of ambient-temperature targets can be installed into and supported by the six-axis TPS. Figure 7.14 illustrates the elements of this subsystem, which is a single-load, computer-controlled, target supporting system. The TPS is located in Port 7 ($\theta = 27°$ and $\phi = 270°$).

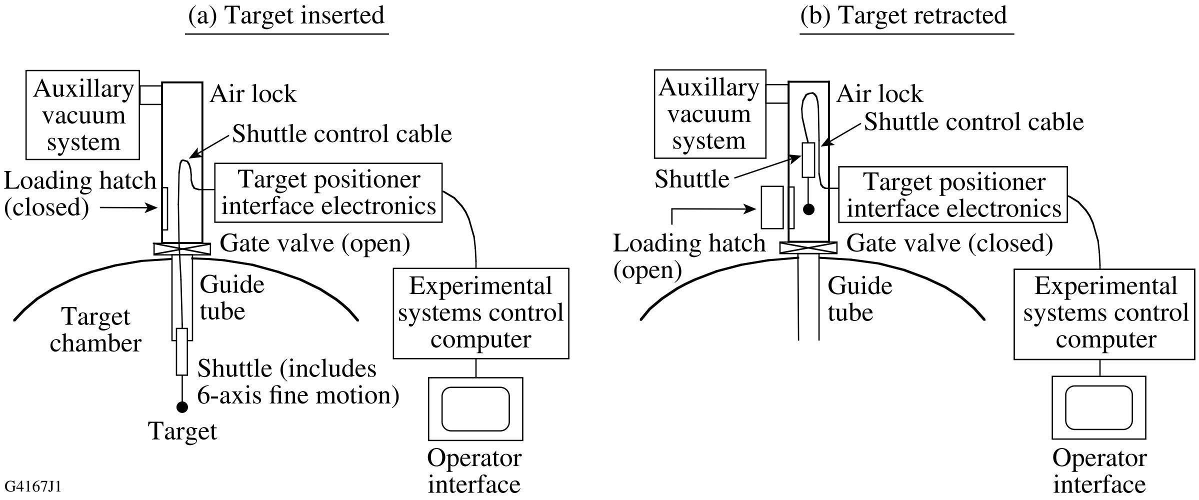

Figure 7.14
Target positioning system (a) with the target in the center of the chamber and (b) with the target retracted.

The TPS is identical to that used on OMEGA.[5,6] It meets the requirement of locating the target to within ±5 μm of a designated location near the center of the TC. The TPS positions targets in six axes: x, y, z, ω, θ, and ϕ. A seventh axis, designated the transport (t) stage, runs parallel to the z axis (which runs along the TC radius) and has greater range and lower resolution than the z axis. The t axis is used to move the target from the antechamber to near the center of the TC. The other axes are used to align the target once it is near the TC center. These axes are depicted in Fig. 7.15(a). To reduce the requirement for compound axial control to perform simple axial movement, stages are arranged as shown in Fig. 7.15(b).

TPS Axes Specifications
The specifications for motion along the seven axes are:

***t* axis**

- Full travel: 80.22 in. (2.0376 m)
- Estimated travel time over range: ~5 min
- Encoder resolution: 1.3 μm/count, 1.6×10^6 counts full travel
- Positioning accuracy required:
- Insertion: Within capture range of the target viewing system ~±750 μm, and in the event of insufficient static motor inertia, to a mechanical hard stop to limit gravity-induced drift.
- Retraction: Depends on home position sense.
- Expected backlash: ~4.6×10^{-2} in. (1170 μm) due to gear head only

x axis

- Full travel: ±1.0 in. (50,800 μm)
- Encoder resolution: 0.8 mm/count, 6.35×10^4 counts full travel
- Incremental jog: ±3 counts
- Expected backlash: ~2.9×10^{-2} in. (736 μm) due to gear head

y axis

- Full travel: ±1.0 in. (50,800 μm)
- Encoder resolution: 0.8 mm/count, 6.35×10^4 counts full travel
- Incremental jog: ±3 counts
- Expected backlash: ~2.8×10^{-2} in. (710 μm) due to gear head

z axis

- Full travel: ±1.0 in. (50,800 μm)
- Encoder resolution: 0.76 mm/count, 6.7×10^5 counts full travel
- Incremental jog: ±3 counts
- Expected backlash: ~4.2×10^{-4} in. (10.6 μm) due to gear head

ϕ axis

- Full travel: ±5.0°
- Encoder resolution: 5.9×10^{-7} degrees/count, 2.9×10^5 counts full travel
- Incremental jog: ±30 counts
- Expected backlash: ~5.3×10^{-4} degrees due to gear head

θ axis

- Full travel: ±5.0°
- Encoder resolution: 5.1×10^{-7} degrees/count, 3.4×10^5 counts full travel

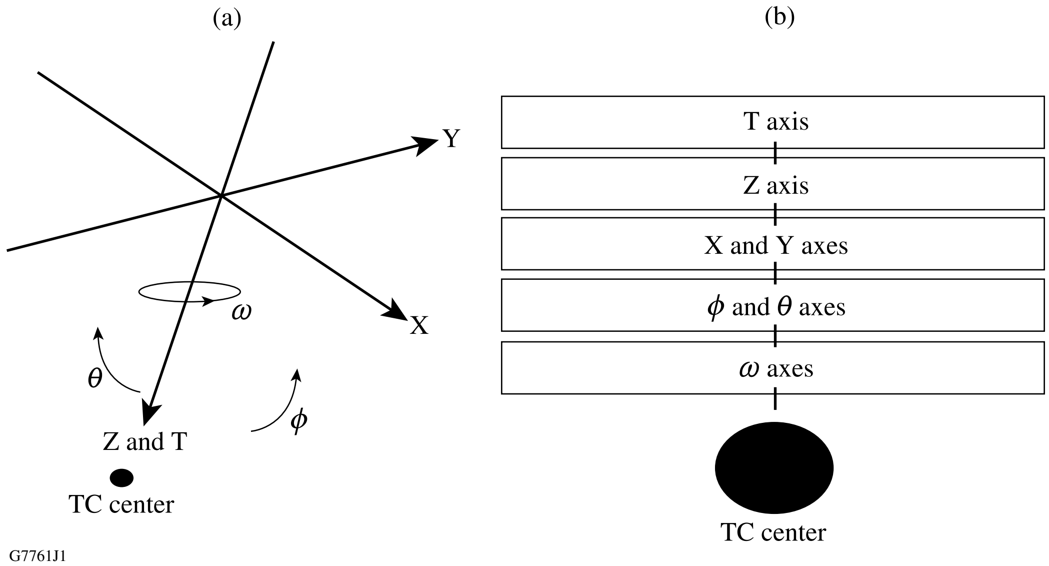

Figure 7.15
(a) Target chamber axes and (b) relative positions of target positioner axial stages.

- Incremental jog: ±30 counts
- Expected backlash: ~4.6×10^{-4} degrees due to gear head

ω axis

- Full travel: ±180°
- Encoder resolution: 3.0×10^{-3} degrees/count, 1.07×10^{5} counts full travel
- Incremental jog: ±30 counts
- Expected backlash: ~2.7 degrees due to gear head

7.5.1.1 TPS loading

The TPS allows loading and unloading of one target at a time without interruption of TC vacuum. To implement this, it features an antechamber and an auxiliary vacuum system. Targets attach to the TPS using a spring located pin.

7.5.1.2 TPS controls

The target-positioning-control software program runs on a Sun workstation (*uranus*) in the Control Room and communicates to a Galil motion controller located in an electronics rack located under the TAS. TPS Controls are described in Sec. 7.9.2.2. The GUI provides the operator with the means to operate each of the fine-positioning axes.

The PLC-based controls interface is provided by a local touch-screen panel. An electrical disconnect box located on the TAS, adjacent to the TPS, isolates the controller during shot operations.

7.5.1.3 TIM-based target positioning

A TIM(b)-based target positioning system (T-TPS) is available to support certain special-purpose targets such as gas-filled hohlraums,(c) CH gas bags, and backlighter foils positioned independently of their main targets. The T-TPS uses the TIM's alignment axes to position its target within 30 μm (the TIM radial positioning resolution) of the designated location and incorporates a yaw axis to rotate the target about the TIM center line. As a TIM-based diagnostic, the T-TPS uses the TIM's transport and vacuum systems for load-and-lock capability and operates within the TIM's 23-min cycle time.

The T-TPS is equipped to support the fill system and pressure-monitoring equipment required for gas-filled targets. Targets are attached to the T-TPS using a magnetic base developed for the Nova target positioner at LLNL.

7.5.2 Target Viewing System

The primary means of determining target position is the TVS. This system is comprised of a pair of back-lighted refractive telescopes situated with a nominal 90° relative angular separation (Fig. 7.16). Each TVS arm includes an illumination source with imaging optics, an *f*/13 refractive telescope assembly that includes a beam splitter, two cameras, and one three-channel video frame grabber. Both the illuminator output lens and the telescope input lens have blast shutters to protect the respective arms from blast and optical radiation damage. The location of the TVS TC ports in shown in Table 7.2.

(b)The TIM is a diagnostic shuttle system that is described in Sec. 7.6.1.

(c)A hollow cylindrical metal structure used in the "indirect drive" approach to inertial confinement fusion.

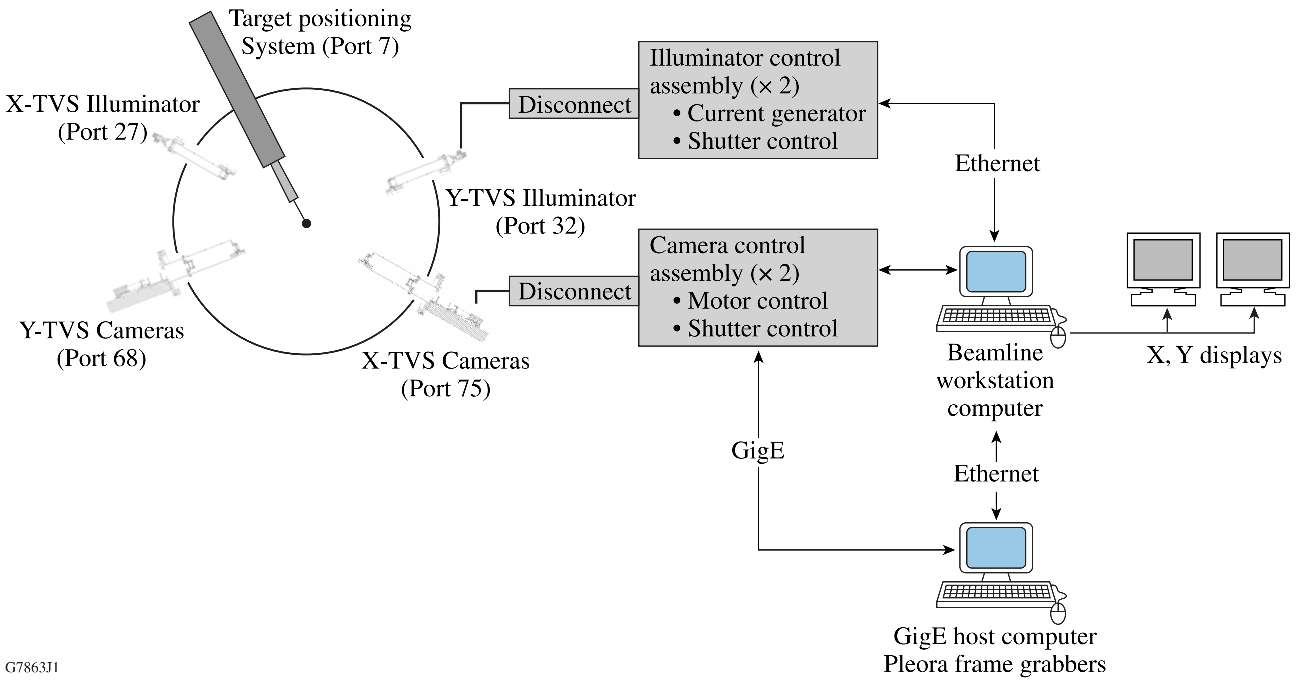

Figure 7.16
A schematic view of the TVS and its control system. Dual wavelength illuminators assist in providing wide and narrow FOV's to the operators in the Control Room from two orthogonal views of the target. Blast shutters protect the optics and are closed prior to the shot. Electrical disconnect boxes protect the sensitive electronics from EMI/EMP. Only one set of camera and illuminator control assemblies are illustrated.

Table 7.2: TVS port locations.

Device	Port ID	$\theta(°)$	$\phi(°)$
X-TVS illuminator	27	60	90
X-TVS cameras	75	120	270
Y-TVS illuminator	32	69	180
Y-TVS cameras	68	111	0

The light sources use incoherent light to illuminate the target (to reduce optical noise from constructive interference effects). Light-emitting diode's (LED's) provide independent illumination for each camera at wavelengths of 525 nm [wide field of view (FOV)] or 620 nm (narrow FOV). The intensities of the lamps are controlled remotely.

Each telescope is equipped with a beam splitter, two optical paths, and two CCD cameras. The optical paths have different magnifications, resulting in a higher-resolution image (~5 μm/pixel) with a 5-mm-diam "narrow" FOV and an image with slightly lower resolution (~15 μm/pixel) and a 30-mm-diam "wide" FOV. The cameras adhere to the Camera Link standard and use 12-bit digital progressive scan sensors; the narrow-FOV camera has a 1000 × 1000 pixel array, whereas the wide-FOV camera has 2048 × 2048 pixels.

Each camera uses a dedicated camera link to Gigabit-Ethernet (GigE) converter (frame grabber) to interface to a common host computer via a dedicated GigE network. Live target images, along with software-generated reticle overlays, are displayed on two digital displays at the Experimental System control station. Target images are archived in the system database prior to each shot.

Each TVS illuminator and sensor is fitted with a blast shutter that is closed as part of the final preparations for the target shot. This shutter protects the optics and cameras from damage caused by target debris.

The use of two cameras located on orthogonal axes facilitates the location of any point in space within the FOV of both axes. Absolute TC coordinates are calculated using software interfaced through a web browser that generates reticles, which are superimposed onto the images viewed by the control system operator. This enables the target to be aligned accurately and quickly.

The TVS is also used to align diagnostics. Its ability to accurately identify a point in space specified by spherical coordinates relative to the TC center is used to locate a retractable or removable bore-sighted pointer attached to the diagnostic. OMEGA EP will use many of the operational algorithms employing the TVS that have been developed on OMEGA. The image performance build-to design specifications are provided in Table 7.3.

Table 7.3: OMEGA EP TVS image performance specifications.

Parameter (units)	Narrow FOV	Wide FOV
Imaging area (mm Ø)	5.0	30
Optical resolution (μm/px)	5	15
Magnification	1.48	0.49
Image format (μm/px)	1000 × 1000	2048 × 2048
Spatial resolution (line pairs/mm, 50% MTF)	TBD	TBD
Two-camera, full-frame, 8-bit frame rate (fps)	30	12
Measurement accuracy *(μm, w/specified target Ø)	<1* (1 mm Ø target)	<3* (3 mm Ø target)
Illuminator-to-imager Pointing accuracy (°)	≤1	≤1

The OMEGA EP TVS is a hybrid of the current OMEGA TVS optomechanical design and the OMEGA TVS-II[d] cameras and controls. The control hardware and software are designed to meet all of the requirements of both systems. This provides a common look and feel to the operators and simplified design and maintenance. A subset of the full functionality will be used in each of the laser systems. An example of a graphical user interface is shown in Fig. 7.17. More detailed information may be found in the design reviews.[7]

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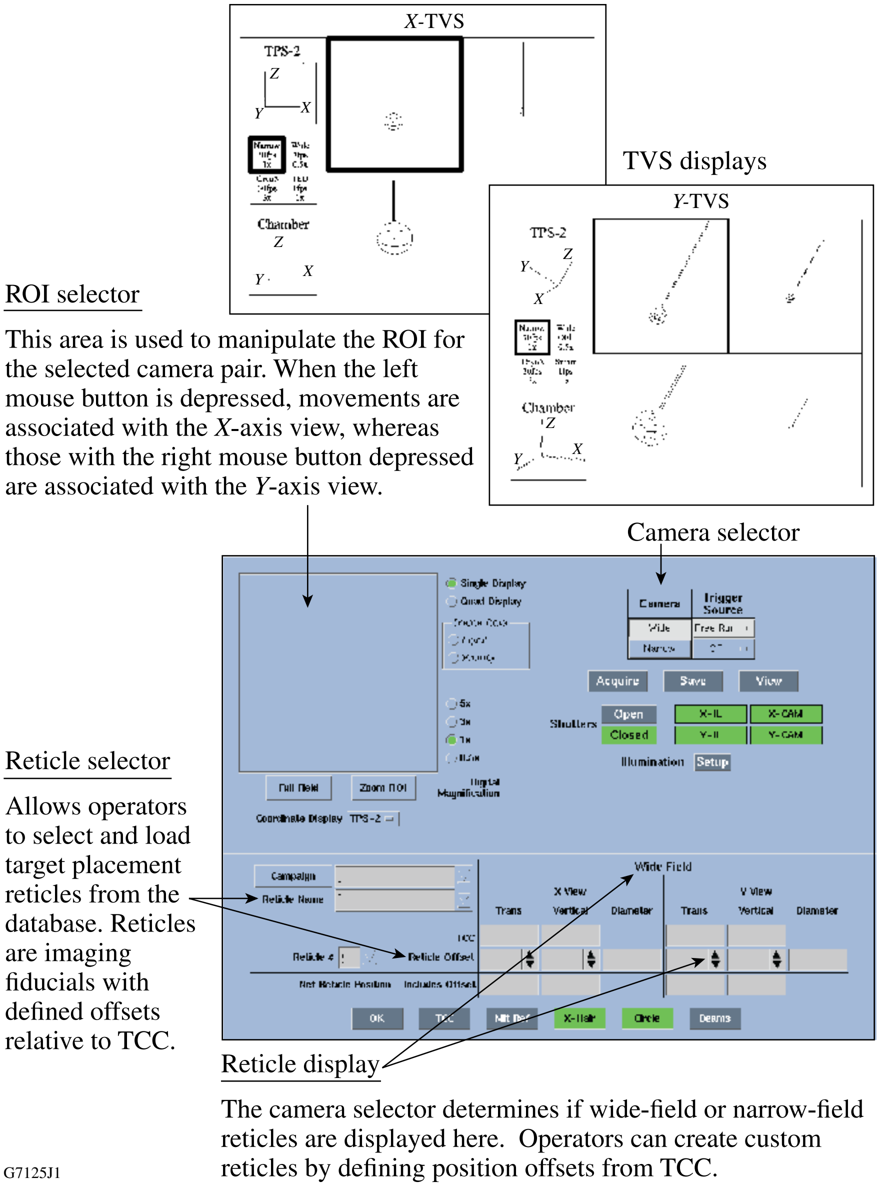
[d] TVS-II is a redesign of OMEGA TVS.



ROI selector

This area is used to manipulate the ROI for the selected camera pair. When the left mouse button is depressed, movements are associated with the *X*-axis view, whereas those with the right mouse button depressed are associated with the *Y*-axis view.

Camera selector

Reticle selector

Allows operators to select and load target placement reticles from the database. Reticles are imaging fiducials with defined offsets relative to TCC.

Reticle display

The camera selector determines if wide-field or narrow-field reticles are displayed here. Operators can create custom reticles by defining position offsets from TCC.

Figure 7.17
The TVS GUI runs on a Sun workstation and is similar to that of OMEGA TVS. Two digital displays are used to show images from the orthogonal viewing axes; each display is capable of showing images from up to four cameras simultaneously. The region of interest (ROI) selector facilitates zoom and pan operations for the cameras. Target placement reticles are retrieved from the database or created by an operator and then overlaid on live images.

7.5.3 Compatibility with Cryogenic Targets

OMEGA EP includes features to support the installation of a planar cryogenic target handling system. The most important of these features are

- 18-in. ports installed at the top ($\theta = 0°$) and bottom ($\theta = 180°$) of the TC,
- clearance below the TC for a cryostat cart installed in Diagnostic Bay #2, including a hole in the Laser Bay floor to allow for installation of a transport tube between the Target Bay and Diagnostic Bay #2, and

- clearance above the TC for an upper pylon used to remove the cryogenic shroud from the target prior to the shot.

7.6 TARGET AREA STRUCTURE

The TAS (Fig. 7.18) supports optical assemblies, vacuum vessels, and diagnostic instrumentation and provides personnel access to service and maintain equipment in the OMEGA EP Laser Bay. Its primary function is to provide a support structure for the TC and the associated optical assemblies that transport and diagnose the beams. These optical assemblies include

- Transport of the four long-pulse beams from the transport spatial filters (TSF's) to the TC that consists of IR transport mirrors, periscope mirror assemblies (PMA's), frequency conversion crystals (FCC's), diagnostic pickoffs, ultraviolet (UV) transport mirrors, distributed phase plates, and a target-focusing optic;

- Short-pulse (SP) beam transport of both the backlighter and the sidelighter beams from the GCC to the TC, including beam-transport tubes, turning mirrors, and the off-axis parabola (OAP);

- Four UV diagnostic packages (UVDP's) that provide for UV alignment and measure beam energy, pulse shape and contrast, near- and far-field images, and assess damage to the optics; and

- Diagnostics mounted to the TC, e.g., TIM's, TPS, TVS, CID's, etc.

Also integrated into the design of the TAS are electronic racks and the distribution of utilities that include power, lighting, Ethernet, cooling water for the turbopumps, vacuum, and nitrogen.[8] For example, Fig. 7.5 provides a view showing how the roughing and backing vacuum lines are integrated into the TAS.

Structural stability was an important design consideration for the TAS. The structural stability design guidelines were based on the OMEGA upgrade finite element analysis,[9] the tolerance allocation from the Optical Pointing Budget (S-AC-X-005), and floor vibration inputs (see Table 7.4).

Additional information on the TAS can be found in the design reviews and related technical requirement documents.[10]

Table 7.4: OMEGA EP structural-stability-design input and guidelines.

Parameter	Value
Mirror angular displacement at resonance (mount plus structure)	<0.15 μrad
Mirror mount SDIP angular displacement at resonance (structure only)	<0.075 μrad
Foundation vibration inputs from 0 to 100 Hz	Function of frequency*
Structure internal damping	1%
Angular displacement due to structural thermal growth from a 1°F temperature rise	<9 μrad

*Charts 24–26, Target Area Structures FDR; Part 2 of 3, B-DM-M-264

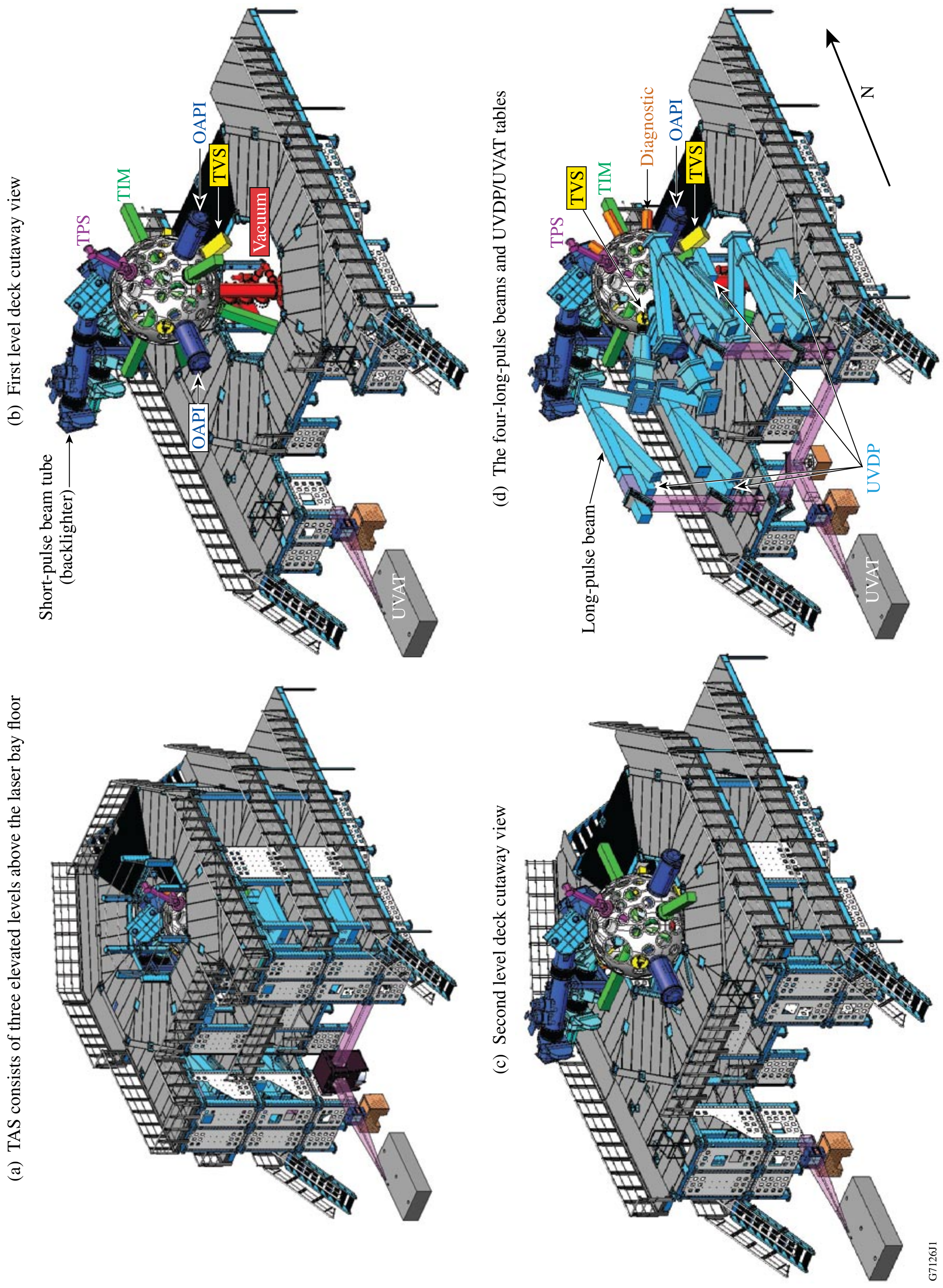


Figure 7.18

The TAS consists of three levels (a) above the laser bay floor. The first level deck cutaway view (b) shows the target chamber with some of its devices. The second level deck provides access to the OAPI's and three of the TIM's (c). The four long-pulse beams occupy a substantial volume on the SE and SW towers (d). The ultraviolet alignment table (UVAT) is on the floor south of the TAS.

7.7 DIAGNOSTIC INTERFACE SYSTEMS

Diagnostics are either TIM-based or fix-mounted to a TC port location. Diagnostics include fixed x-ray pinhole cameras, TIM-based x-ray pinhole cameras, x-ray framing cameras, streaked x-ray spectrographs, x-ray spectrographs, VISAR (velocity interferometry system for any reflector), and imaging x-ray streak cameras. These diagnostic devices are triggered by the hardware timing system.

7.7.1 Diagnostic Support—Ten-Inch Manipulators (TIM's)

The TIM is a diagnostic shuttle system that is used to position a variety of diagnostics near the center of the TC. Each TIM can mount to an 18-in. or 24-in. port and provides mechanical, vacuum, and electrical control support and positioning for a diagnostic payload.

Six TIM's are operational on OMEGA and support an extensive diagnostics suite. The OMEGA EP design also includes a provision for six TIM's that are identical in design to those on OMEGA and are to be installed in an arrangement (Table 7.1) that provides flexible and comprehensive diagnostic coverage of target experiments, including orthogonal side-on and face-on diagnostic views of targets. Three of the six TIM's are installed and the others will be added as future upgrades.

Mechanically, the TIM (shown in perspective view in Fig. 7.19) is an aluminum box mounted on a TC diagnostic port via a gimbaled flange. A flexible bellows provides an external vacuum seal and allow *x*, *y* positioning of the TIM. A 10-in. flapper valve isolates the TIM from the TC to allow loading

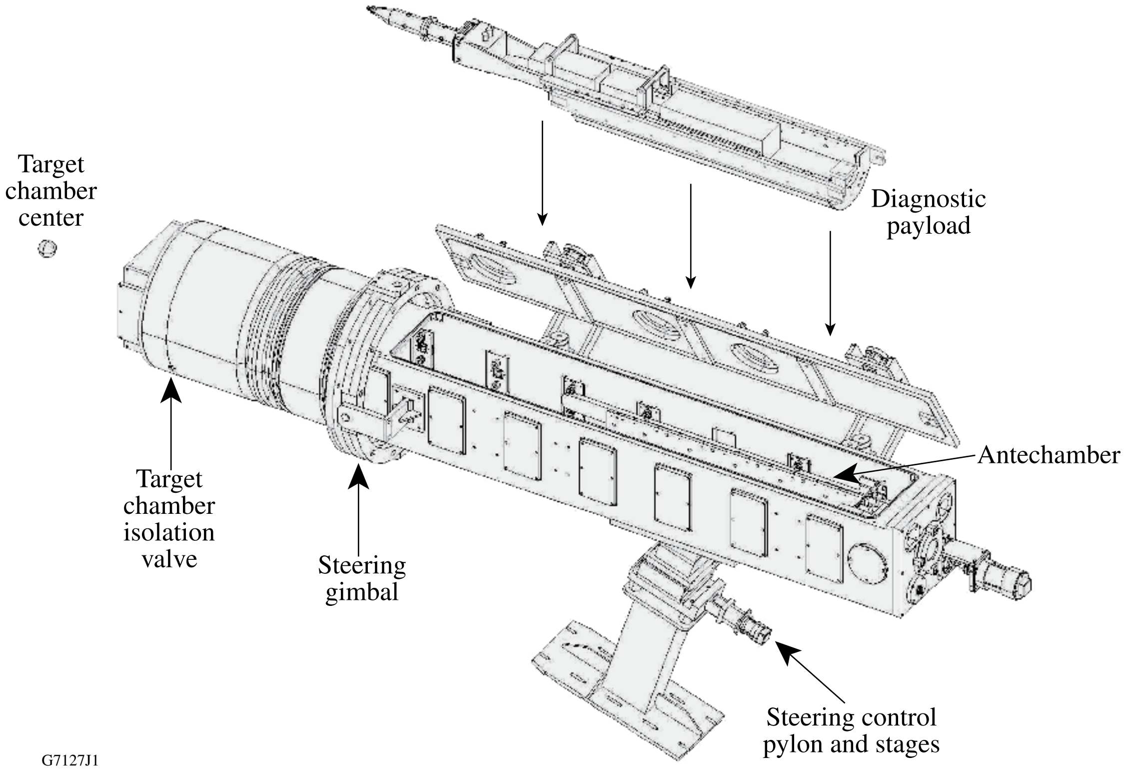


Figure 7.19
TIM used to field vacuum re-entrant diagnostics.

and servicing the TIM payload via the TIM door. A pedestal fitted with remotely controlled two-axis actuators supports the rear end of the assembly and allows *x*, *y* precision pointing adjustments around the gimbal axes.

The TIM's internal transport mechanism supports an instrument payload and permits it to be moved from the accessible space under the cover, through the flapper valve, to a position at or near the TC center. The TIM includes the vacuum components necessary to pump its internal volume to TC vacuum so that the flapper valve may be opened and the payload inserted into the TC. The TIM vacuum control configuration is shown in Fig. 7.20. These controls also vent the internal TIM volume back to ambient pressure after the payload has been retracted and the flapper valve closed. Feedthroughs and a traveling umbilical cord provide the payload with power, control signals, communications, and cooling throughout the range of travel. Table 7.5 lists some of the characteristics of the TIM.

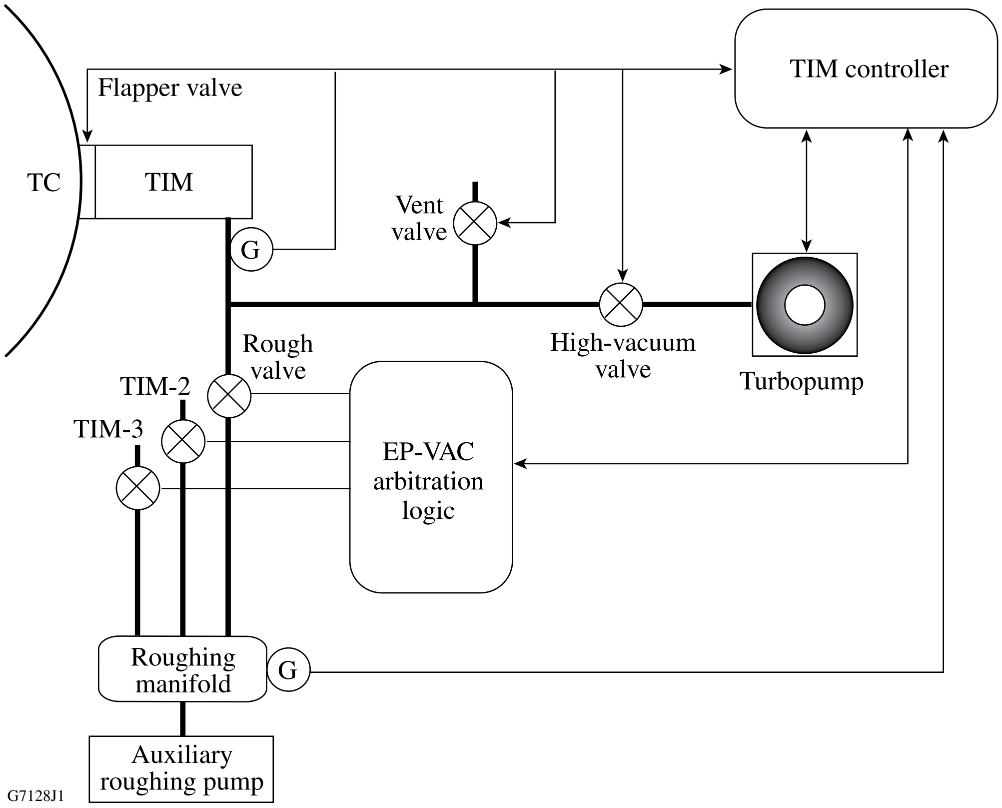


Figure 7.20
The TIM vacuum control configuration. The flapper valve allows isolation of the TIM from the TC. The TIM's are evacuated to the same pressure as the TC before being opened to the TC, as described in Sec. 7.2.3. A Granville Phillips Mini-Convectron® Model 275 gauge (G) that does not require a dedicated controller installed in the TIM control chassis is used to sense pressure. The TIM vacuum controller is external to the TIM and also controls insertion and retraction of the payload via a touch screen panel.

A diagnostic moment load of up to 800 lb-in. about the front roller can be satisfactorily supported.[11] Front and side views of the envelope of the payload are shown in Fig. 7.21.

Table 7.5: TIM characteristics.

Steering resolution	<10-μm resolution
Radial positioning	<30-μm resolution
Insertion-to-insertion repeatability	<50 μm (in all directions)
Cycle time (transport and vacuum)	23 min
Payload capability	22 cm OD × 152 cm overall, 45 kg max.

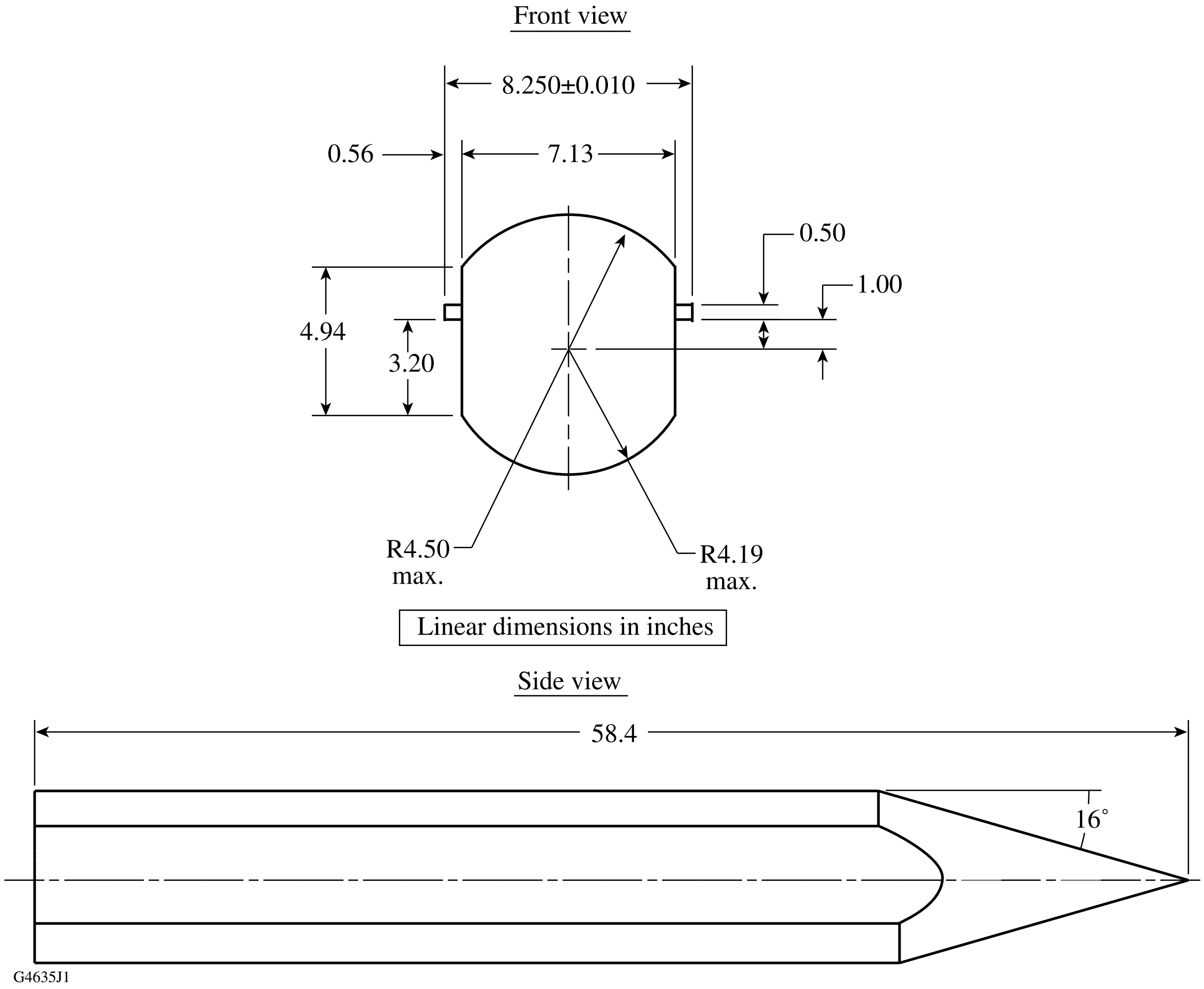


Figure 7.21
Payloads must fit within the constraints of this window and may weigh up to 45 kg.

The boat is shown in Fig. 7.22 along with the adapter that allows an instrument designed for a LLNL six-inch manipulator (SIM) to be accommodated in the TIM without modification.

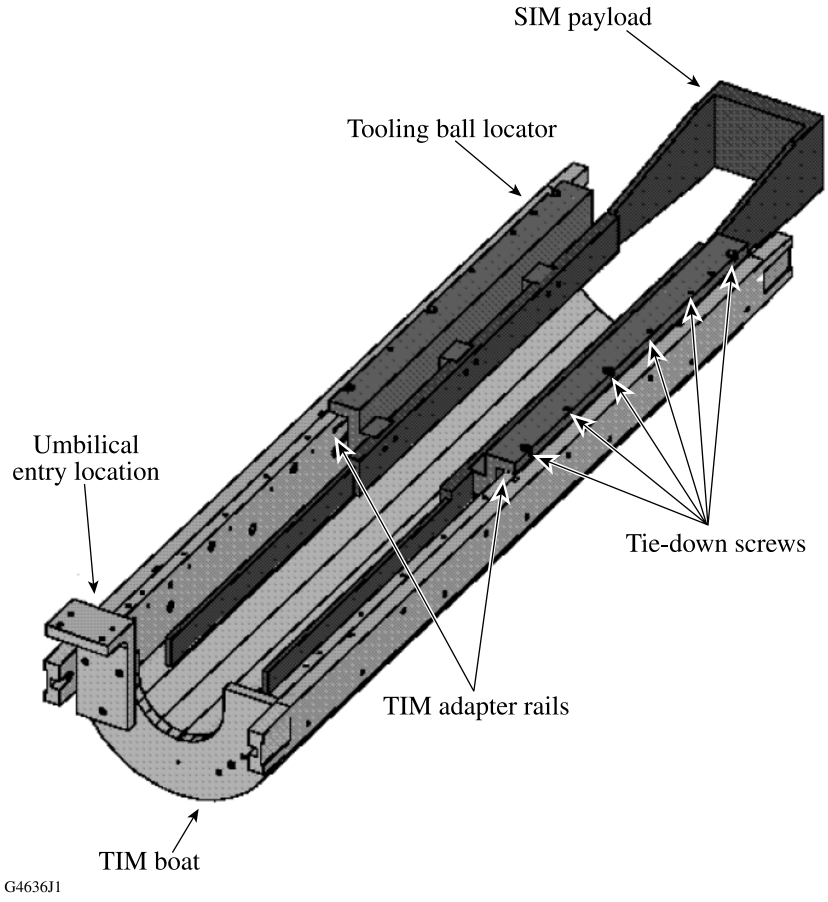


Figure 7.22
The TIM "boat" provides the mechanical interface for payloads. Standard adapters accommodate LLNL's SIM payloads.

The TIM umbilical carrier has a 0.8-in. × 0.87-in. cross section. Up to-four standard 1.98-in.-diam feedthrough flanges are available. Table 7.6 gives a typical umbilical configuration.

Table 7.6: Typical TIM umbilical configuration.

One 15-conductor (22 AWG) payload power cable
Two coaxial (RG-188) signal cables
One optical fiber (400 mm, 4ω, monomode with SS jacket)
One 28-conductor (22 AWG) CCD control cable
Two 1/4-in.-diam (Teflon with SS braid) coolant hoses

The TIM meets the following positioning requirements listed below:

- Transport axis:
  - Range of motion of ~95-in.
  - Nominal speed of travel of 0.6-in./s
  - Positioning command resolution of 0.001-in.
  - Programmable acceleration and velocity from a touch panel

- ϕ and θ axes:
  - Range of motion ±1.0-in.
  - Nominal speed of travel of 0.6-in./s
  - Positioning command resolution of 0.001-in.
  - Programmable acceleration and velocity from a touch panel

In addition, the total pointing offsets at the target chamber center (TCC) are 30-mm in the horizontal and vertical directions.

The TIM control logic operations are similar to OMEGA with respect to

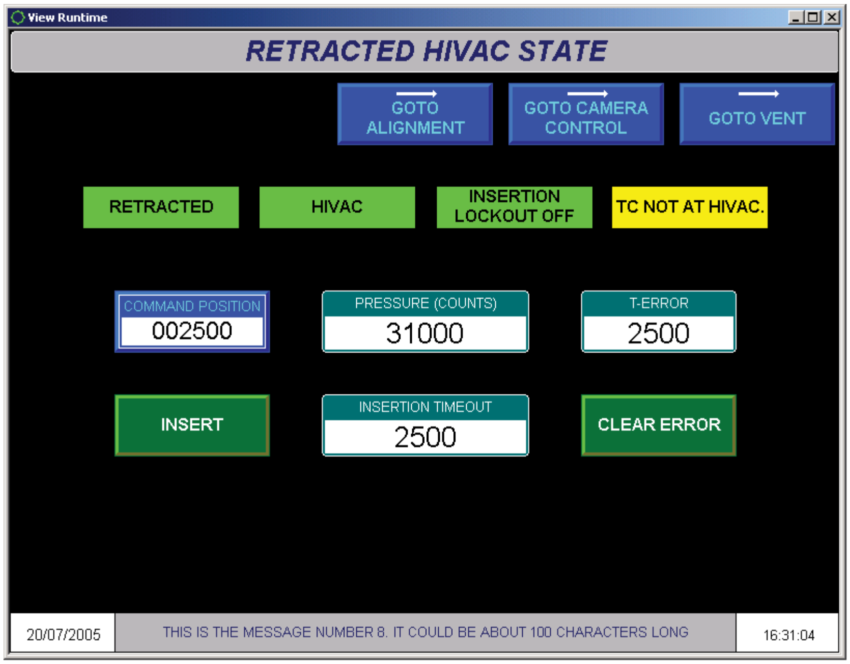
- interlocks and state transition permissives
- sequencing, and
- recovery operations.

The control design supports an operator-selectable nonstandard operating mode. Instrument payloads are compatible with those on OMEGA. The TIM controls are designed for safety, ease of access, and serviceability.

- The TIM controls chassis is rack-mounted and is remotely located in the SE and SW wings in the Diagnostic Bays.[8]

- A 12-in. color touch panel is the operator interface local to the TIM (Fig. 7.23).

- The motor drive controls incorporate locally programmable torque limit via touch-panel set points.



RETRACTED HIVAC STATE

COMMAND POSITION 002500

PRESSURE (COUNTS) 31000

T-ERROR 2500

INSERTION TIMEOUT 2500

20/07/2005 THIS IS THE MESSAGE NUMBER 8. IT COULD BE ABOUT 100 CHARACTERS LONG 16:31:04

G7129J1

Figure 7.23
The top bar of the TIM GUI indicates whether it is inserted, retracted, vented, or at high vacuum. Selector (blue) buttons enable the operator to go to other control screens that include alignment, camera control, vent, etc. Green backlit indicator lights indicate that the TIM is retracted and at high vacuum but not inserted. The yellow message indicator indicates the target chamber is not at high vacuum. Other readings are also displayed. The darker green buttons effect insertion and clear errors.

- The motor drive controls also provide retentive memory of stage position (encoder counts) such that position information is retained during power outages and reset only during “homing” routines.
- Logic has been incorporated in the “retracted door open vented” state to enable motion of the transport drive to facilitate payload positioning.
- Vacuum sensing utilizes a vacuum gauge that requires no dedicated controller. The vacuum level set point is within the PLC logic.

Additional information can be found in the design reviews for the TIM controls upgrade project.[12]

7.7.2 Diagnostic Support—Target Chamber Ports

Seven 12-in., ten 18-in., and one 24-in. ports are assigned to diagnostics (see Table 7.1). Additional unassigned ports include twenty-three 12-in. ports, thirty 18-in. ports, and a second 24-in. port. These ports may be subdivided into several smaller ports using relatively lightweight (<50-kg) adapter flanges. The flanges also serve to protect the TC flange surface from mechanical damage during diagnostic installation.

The flange surface of the TC is precision machined and serves as a reference surface for the instrument being attached as well as the vacuum seal surface. Diagnostic ports are located in a regular pattern around the TC. Ports that are not in use are sealed with blank port covers.

As indicated in Table 7.1, 36 of the 90 ports on the OMEGA EP target chamber have been assigned. Twenty-two of the 36 assigned ports support target diagnostics. Some of these ports are dominated by the installation of a single piece of equipment, but many provide for installation of smaller ports and may support multiple instruments. Table 7.7 lists the diagnostic ports. Beam entry and focusing ports are listed in Table. 7.8. Figure 7.24 shows their locations on the TC.

Table 7.7: OMEGA EP target chamber ports supporting target diagnostics or target handling.

Port ID	Assignment	Port ID	Assignment
1	CTHS cryo upper	60	Diagnostic Port B4, 23°
2	TIM-10	67	Diagnostic Port B1, 23°
7	TPS	68	X-TVS
24	Diagnostic Port B3, 48°	71	TIM-15
27	Y-TVS illuminator	73	DIM
32	X-TVS illuminator	75	Y-TVS
34	Diagnostic Port B2, 23°	79	Diagnostic Port B1, 48°
41	Diagnostic Port B3, 23°	84	Man access
45	TIM-12	85	Vacuum system
48	TIM-14	87	TIM-13
53	TIM-11	90	CTHS cryo lower

Table 7.8: Ports assigned for beam entry and focusing.

Port ID	Assignment
37	Beam 1, 23°
22	Beam 1, 48°
64	Beam 2, 23°
78	Beam 2, 48°
63	Beam 3, 23°
77	Beam 3, 48°
38	Beam 4, 23°
23	Beam 4, 48°
33	Backlighter beam entry
51	Backlighter parabola OAPI
69	Sidelighter beam entry
54	Sidelighter parabola OAPI

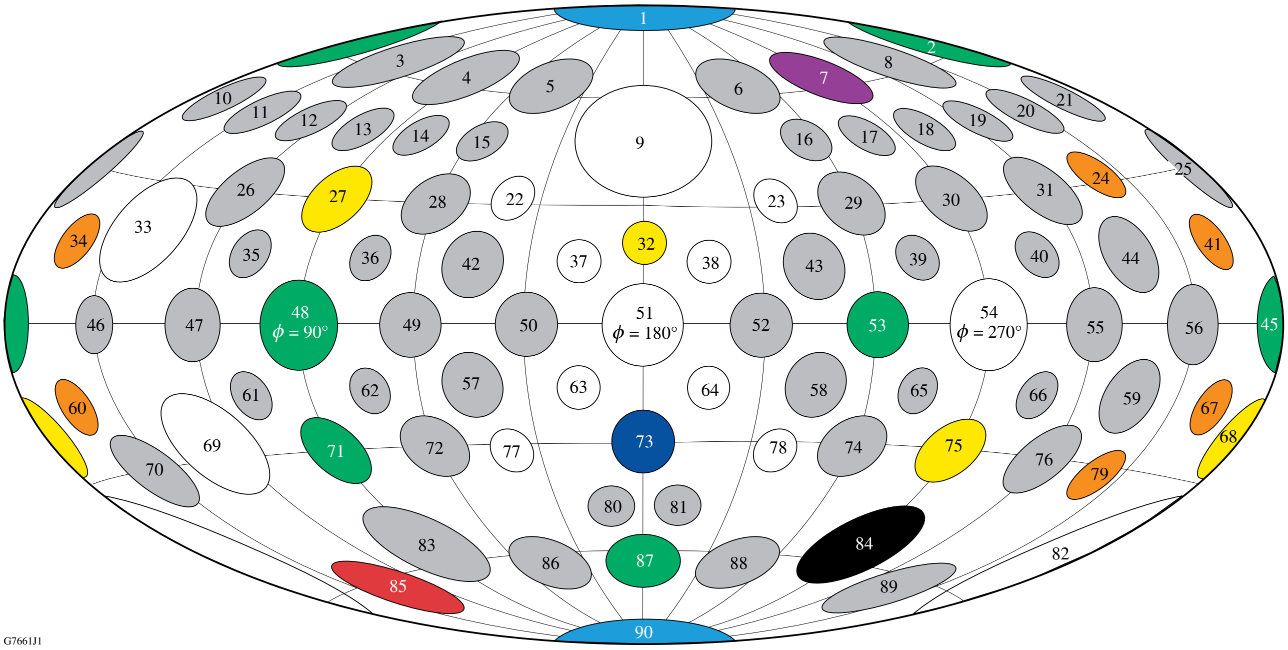


Figure 7.24
OMEGA EP target chamber with ports assigned for target diagnostics and target-handling equipment. In this Aitoff projection, the azimuth angle ϕ of 180° is south (90° west and 270° east). Unassigned ports are shown in gray (see also Table 7.1).

7.8 DIAGNOSTIC CAPABILITY: CURRENT, FUTURE, AND COMPATIBILITY WITH OMEGA

OMEGA EP includes a baseline target diagnostics package and the capability to support existing and future target diagnostic instruments. A list of available diagnostics is shown in Table 7.9. In general, OMEGA TIM-based instruments are supported. Fixed diagnostics (i.e., those mounted directly to TC flanges) will be integrated as required.

Table 7.9: Diagnostics available on the OMEGA EP target chamber.

Diagnostic	Data obtained	Deployment
Fixed x-ray pinhole cameras	Time-integrated x-ray images	Two initially, up to 10 possible
X-ray pinhole cameras*	Time-integrated x-ray images	Fully supported, shared with OMEGA
X-ray framing cameras*	Time-resolved, 2-D x-ray images	Fully supported, shared with OMEGA
Streaked x-ray spectrographs*	Time-resolved, x-ray spectra	Fully supported, shared with OMEGA
X-ray spectrographs*	Time-integrated x-ray spectra	Fully supported, shared with OMEGA
VISAR	Shock-breakout interferometry	To be added in FY08
Imaging x-ray streak cameras*	Time-resolved, 1-D x-ray imaging	Fully supported, shared with OMEGA

*TIM-based diagnostics.

Time-integrated x-ray pinhole cameras are regularly used to assess laser performance by measuring the target self-emission. Beam alignment and intensity can be inferred from this data. OMEGA EP includes a pair of flange-mounted x-ray pinhole cameras for this purpose. A computer-based data acquisition and control system provides support for the electronic CID sensors used on these instruments.[13] This system includes 12 channels to support the CID devices used for the x-ray pinhole cameras and other TIM-based diagnostics.

Instruments required for experiments that involve substantial specialized equipment, such as the VISAR used to measure shock speeds and breakout times will be added later.

7.9 EXPERIMENTAL SYSTEM CONTROL AND DATA ACQUISITION

The Experimental System controls utilize a variety of software applications running on five major platforms linked by the LLE Ethernet. A PLC network, consisting of more than a dozen PLC's, complements this system and implements the basic vacuum control and interlock functions. Figures 7.25 and 7.26 provide diagrams of this architecture. The overall control system is closely integrated with the Beamlines controls. For example, OAP alignment and spatial filter vacuum are controlled by the Beamlines Operator (BLO).

The operator interface consists of GUI's that are displayed on Sun workstations or PC's in the Control Room. The Experimental Systems Operator (ESO) controls the TPS, TVS, and diagnostic

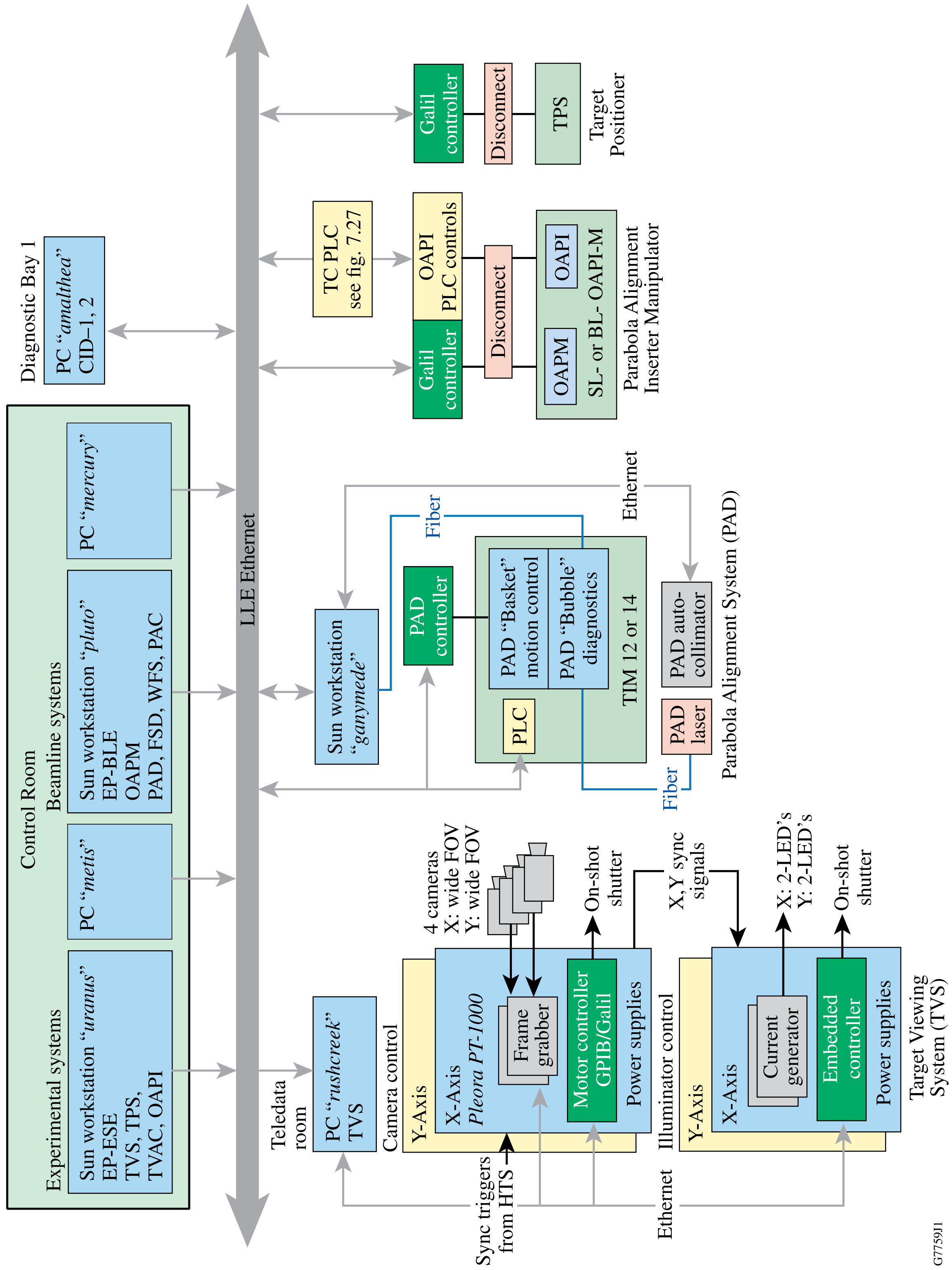


Figure 7.25
The Experimental System controls use a variety of software applications running on software platforms linked by the Ethernet LAN. For the EP-VAC, the EP-SE (OIP server) communicates through the OIP clients, EP-ESE, and EP-BLE to the PLC's that control the vacuum devices shown in Fig. 7.27. The TVS-, TPS-, and TIM-based diagnostic devices are controlled by GUI's located at the Experimental Workstation. The OAPM is aligned through the beamlines' GUI using the PAD. The TVS camera and illuminator controls direct four cameras that image the target.

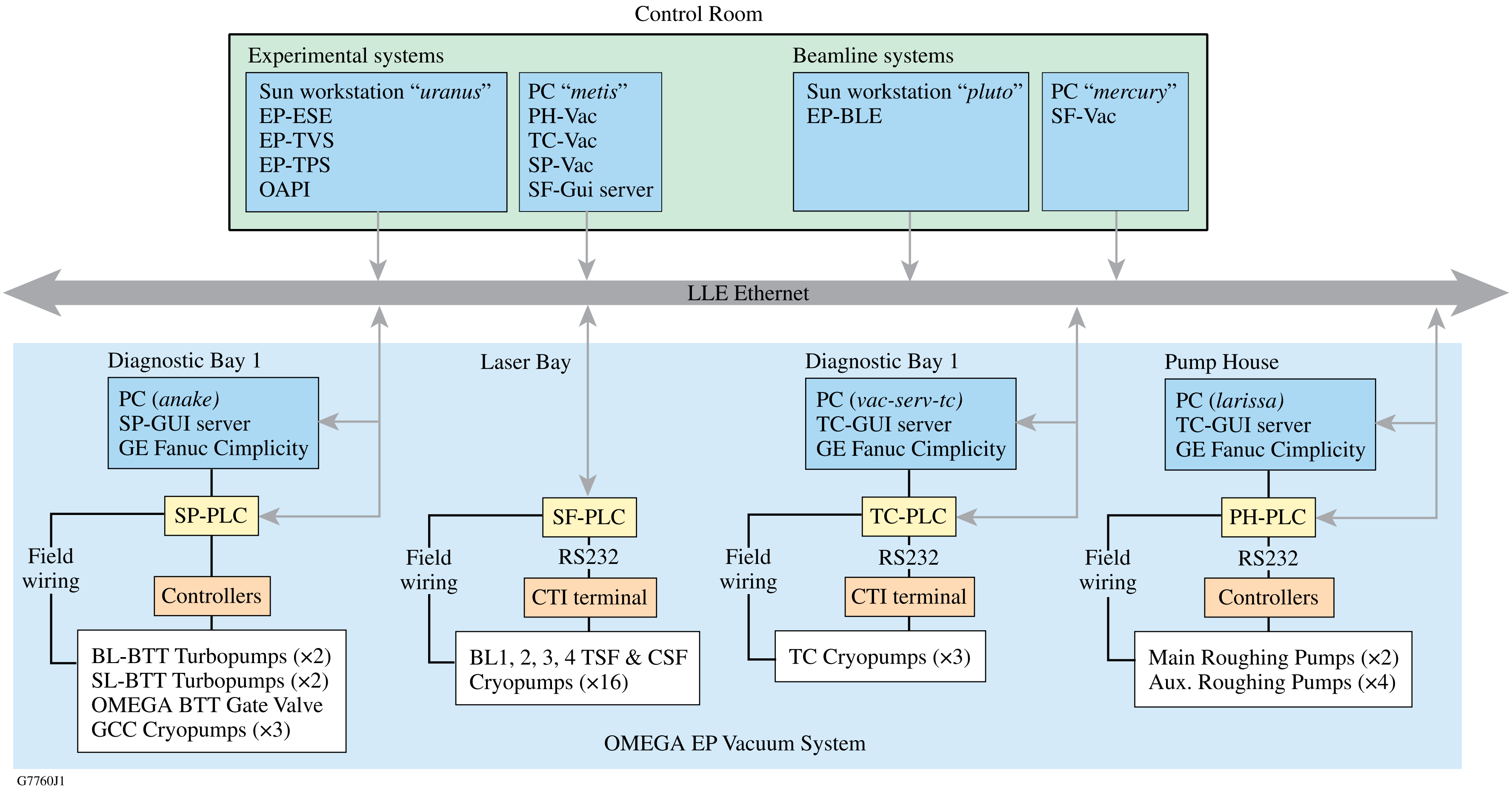


Figure 7.26
Three EP-VAC GUI's used to monitor and control the vacuum system are accessible in the Control Room. There are four secondary operator control interfaces controlled by EP-VAC controls: two in the Diagnostic Bay, one in the Laser Bay, and one in the pumphouse (PH). The PH PLC also directs the insertion of diagnostic devices (TIM's, OAPI's) into the Target Chamber.

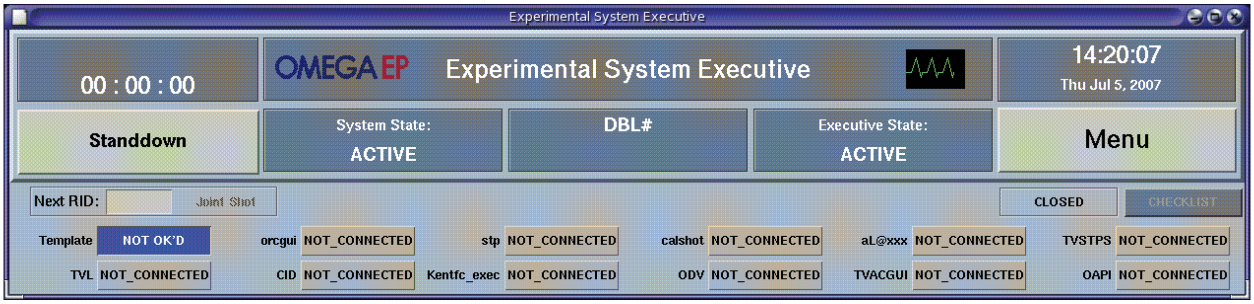
instruments that are inserted by the TIM's. The EP-VAC can be controlled by GUI's located in the Control Room. EP-VAC PLC based control systems are dispersed: one in the Laser Bay, one in the OMEGA pump house (PH), and two are in Diagnostic Bay 1. The EP-VAC GUI's commands are transmitted across the LLE ethernet to the PLC's that control the vacuum devices.

7.9.1 Experimental System Executive

The control system uses executive programs to coordinate and monitor the shot-cycle actions of the subsystems. The Experimental System Executive (EP-ESE) is a client of the Shot Executive (EP-SE) and monitors the status of the experimental subsystem components for the following clients:

- Target chamber vacuum
- Short-pulse vacuum system (GCC and BTT's)
- TVS
- TPS
- TIM-based instruments (TVAC)
- OAPI's
- CID cameras
- Applications started via an auto-launch program such as oscilloscopes

These functions are provided by a GUI that displays the status of the overall OMEGA EP experimental system and each of the primary software clients to the ESO. The EP-ESE serves as the messaging hub that distributes OMEGA Intercommunication Protocol (OIP) messages to these clients. A graphic of the EP-ESE is shown in Fig. 7.27.



Experimental System Executive

00 : 00 : 00

14:20:07
Thu Jul 5, 2007

System State: ACTIVE
DBL#
Executive State: ACTIVE

Next RID:

Template NOT OK'D
TVL NOT_CONNECTED
orcgui NOT_CONNECTED
CID NOT_CONNECTED
stp NOT_CONNECTED
Kentfc_exec NOT_CONNECTED
calshot NOT_CONNECTED
ODV NOT_CONNECTED
aL@xxx NOT_CONNECTED
TVACGUI NOT_CONNECTED
TVSTPS NOT_CONNECTED
OAPI NOT_CONNECTED

G7758J1

Figure 7.27
The EP-ESE is shown with a preliminary set of experimental system clients. This executive is itself, a client of the EP-Shot Executive.

7.9.2 Software Elements

Elements of the Experimental System control and data acquisition systems are discussed in this section.

7.9.2.1 Vacuum control system

The EP-VAC is a distributed I/O system that monitors and maintains the vacuum environment inside the vacuum vessels. It also protects vacuum-related equipment and instruments from exposure to inappropriate pressures. The system is based upon the GE Fanuc VersaMax® PLC's integrated into the LLE LAN Ethernet. The GE Fanuc Cimplicity and HMI/SCADA software provides the HMI/GUI interface. These GUI's enable Control Room personnel to perform vacuum-related operations and obtain information regarding the status of the vacuum vessels. Each controller is an OIP client of the appropriate executive software package. The four major independent software systems are listed below:

- Pumphouse vacuum controller
- Spatial-filter vacuum controller (including beamline environmental enclosures)
- Short-pulse vacuum controller (GCC and BTT's)
- Target chamber vacuum controller

7.9.2.2 Target positioning and viewing controls

While TVS and TPS were historically controlled on OMEGA with the same control hardware and operated together using a common software interface, new, more capable, TVS software has been separated from the target-positioning functions. Both TVS and TPS are clients to the EP-ESE. TPS receives target-image information from TVS and uses the target autopositioning system (TAPS) software to position the target. In addition to supplying information to the TPS, the TVS software controls image acquisition and display as described in Sec. 7.4.2, and is also able to access and input a database to configure its hardware and provide device settings. The TVS software also allows configuration by "expert" input. The TPS vacuum and target insertion functions are controlled via the separate EP-VAC control system.

7.9.2.3 Autolaunch/acquire

System and target-diagnostic data acquired by oscilloscopes are handled by a series of Unix programs that run on a Sun workstation and communicate with the oscilloscopes via the General Purpose Interface Buss (GPIB). The programs monitor the system's sequencing broadcast messages that are relayed over the Ethernet by the EP-ESE and arm the scopes so that they acquire data when triggered by a precision external trigger. The precision triggers are provided by the Hardware Timing System (HTS). These programs also function to acquire the data records from the scopes and transfer them into the Unix file system where they are available for review and archiving. Instances include.

7.9.2.4 Target diagnostic configuration

An application called TCGUI is run by the ESO to set up a list of the active diagnostics to be logged to the database as part of the shot record.

7.10 REFERENCES

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Appendix A

Glossary of Acronyms

BLO	Beamlines operator
BTT	Beam transport tube
BWA	Blast window assembly
CCD	Charge-coupled device
CDR	Conceptual Design Review
CH	Carbon-hydrogen
CID	Charge-injection device
CTHS	Cryogenic Target Handling System
dc	Direct current
DDS	Disposable debris shield
DIM	Diagnostic instrument manipulator
EMI	Electromagnetic interference
EMP	Electromagnetic pulse
EP-ESE	EP Experimental System Executive
EP-SE	EP Shot Executive
EP-VAC	EP vacuum control system
ESO	Experimental Systems Operator
FCC	Frequency-conversion crystal
FDR	Final Design Review
FOA	Focusing optics assembly
FOV	Field of view
GCC	Grating compression chamber
GigE	Gigabit Ethernet
GPIB	General purpose interface bus
GUI	Graphical User Interface
HTS	Hardware Timing System
HMI	Human Machine Interface
I/O	Input/output
ID	Internal diameter
IR	Infrared
kV	Kilovolt
LAN	Large-area network
LED	Light-emitting diode
LLE	Laboratory for Laser Energetics
LLNL	Lawrence Livermore National Laboratory
LP	Long pulse
MTF	Modulation transfer function
NIF	National Ignition Facility
OAP	Off-axis parabola
OAPI	OAP inserter
OAPI/M	Off-axis parabola inserter/manipulator
OAPM	Off-axis parabola manipulator

OD	Outside diameter
OIP	OMEGA intercommunication protocol
PC	Personal computer
PDR	Preliminary Design Review
PEPC	Plasma-electrode Pockels cell
PH	Pump house
PLC	Programmable logic controller
PMA	Periscope mirror assembly
RGA	Remote gas analyzer
ROI	Region of interest
SCADA	Supervisory Control and Data Acquisition
SIM	Six-inch manipulator
SL-OAPI	Sidelighter OAPI
SP	Short pulse
SP-BL	Short-pulse backlighter
SP-SL	Short-pulse sidelighter
SRF	Shot Request Form
T-TPS	TIM-based Target Positioning System
TAPS	Target autopositioning system
TAS	Target area structure
TBD	To be determined
TC	Target chamber
TCC	Target chamber center
TIM	Ten-inch manipulator
TPS	Target Positioning System
TRS	Tritium Recovery System
TSF	Transport spatial filter
TVAC	TIM-based instruments
TVS	Target Viewing System
UV	Ultraviolet
UVAT	Ultraviolet alignment table
UVDP	Ultraviolet diagnostic package
VISAR	Velocity interferometry system for any reflector