S-AA-M-12

OMEGA
System Operations Manual
Volume I–System Description

Chapter 7: Experimental System

Table of Contents

Chapter 7
Experimental System

7.0 INTRODUCTION

The OMEGA Experimental System consists of mechanical, optical, and electrical subsystems designed to provide a flexible, robust environment for positioning targets for and diagnosing the results of inertial confinement fusion (ICF) experiments on the 60-beam OMEGA laser system. This chapter will discuss the following components of the experimental system:

7.1 Target Chamber
7.2 Target Vacuum System
7.3 Auxiliary Vacuum Systems
7.4 Tritium Recovery Subsystems
7.5 Target Chamber Access Systems
7.6 Target Positioner System
7.7 Target-Viewing System
7.8 Target Existence Detector
7.9 Experimental System Timing Subsystems
7.10 Diagnostic Support—Ten-Inch Manipulator
7.11 Diagnostic Support—Target Chamber Ports
7.12 Experimental System Control and Data Acquisition

7.1 TARGET CHAMBER

ICF experiments on OMEGA are conducted in a vacuum environment provided by the Target Chamber (TC). The TC conforms to the specifications listed in Table 7.1-1. Beamline focus lens

Table 7.1-1
OMEGA TC Specifications

Geometry	Spherical, ports in a stretched soccer ball configuration
Radius	65 in. (nominal 66 in. to diagnostic port face with required adapters)
Wall thickness	3.65 in. nominal
Material	5083 aluminum
Nominal internal volume	17,480 liters (550 cubic ft)
Vacuum seals	Viton O-rings
Port fasteners	For 18-in. ports: 7/16 in.-14 bolts For 24-in. ports: 1/2 in.-13 bolts
Beam ports	60 ports, nominal 18-in. bore
Diagnostic ports	12 ports, nominal 18-in. bore 20 ports, nominal 24-in. bore

assemblies (FLAS) are installed at each of the 60 beam ports. Blast window assembles installed between the actual focus lens and the TC port include transparent optics that form the vacuum barrier. Each of the twelve 18-in. diagnostic ports is in the center of a pentagonal arrangement of beam ports and each of the twenty 24-in. diagnostic ports is in the center of a hexagonal arrangement of beam ports. Experimental System equipment including vacuum pumps, target diagnostics, target positioners and diagnostic manipulators are mounted to flanges that seal the diagnostic ports.

The TC is maintained at pressures below 10^{-5} Torr for all shooting operations. This limits ionization at the high laser intensities encountered in typical ICF target shots, mitigates shockwave propagation, and provides a relatively long mean free path to allow diagnosis of short-wavelength and charged-particle phenomena. In practice, the TC operates in the 5×10^{-6} to 1.5×10^{-5}-Torr range.

7.2 TARGET VACUUM SYSTEMS

Mechanical vacuum pumps and cryogenic pumps are used in several combinations to support target operations. As is illustrated in Fig. 7.2-1, the target vacuum system consists of three CTI On-Board 400 cryogenic pumps and three mechanical pumps. The latter are Edwards EH1200/GV160 Rootes blower boosted claw type dry pumps. They are installed in an integral configuration that allows the use of any of the three pumps for Main Roughing, Auxiliary Roughing, or Turbopump Backing operations.

The cyropumps are attached directly to one of the TC diagnostic ports via a "trident" manifold. Each identical unit can be connected to or isolated from the main TC volume by means of a HVA 16-in. pneumatically operated gate valve. Each cryopump contains a collection surface that is cooled to below the freezing point of hydrogen (20°K) by a dedicated helium refrigeration circuit. The pumps produce high vacuum levels by freezing gas molecules to the collection surfaces. The mechanical pumps operate between atmospheric pressure and intermediate vacuum levels.

The TC is evacuated in two steps: one or more mechanical pump is used (via the Main Roughing manifold) to "rough" the chamber from ambient atmospheric pressure to the approximately 2×10^{-2} Torr level at which the cyropumps become effective. The mechanical roughing pump(s) is then isolated from the TC and the cryogenic pumps operate from $\sim 2 \times 10^{-2}$ to below 5×10^{-7} Torr. Shooting vacuum is normally achieved in less than 60 minutes after the start of roughing. The cyropumps can be cycled on-line to maintain high vacuum indefinitely. A minimum of one is required to pump the TC, and the others are backups. This allows for repair and regeneration of pumps while the TC is kept at high vacuum. The cyropumps: produce minimal vibration, are highly maintainable and reliable, and do transfer contamination to the TC.

TC pressure is monitored by a redundant set of nude Bayert-Alpert ionization gauges (IG in the figure) and Convectron™ gauges (C), controlled by a Granville Phillips type 316 controller. A Spectra residual gas analyzer (RGA) is be available for analysis of the TC contents.

The vacuum systems are complimented by a dry air TC refill system, which employs two 10 CFM Balston Instrument air dryers connected in parallel feeding four 0.5 PSIG/5 CFM Air Products regulators, also plumbed in parallel, via a 5-gal buffer tank. The TC and all of its fitting hardware is rated to contain 2 PSIG positive pressure. To ensure that this pressure is not exceeded, the TC is fitted (at the pressurized side of the vent valve) with two 12 CFM Circle Seal pressure relief valves set at 1 PSIG.

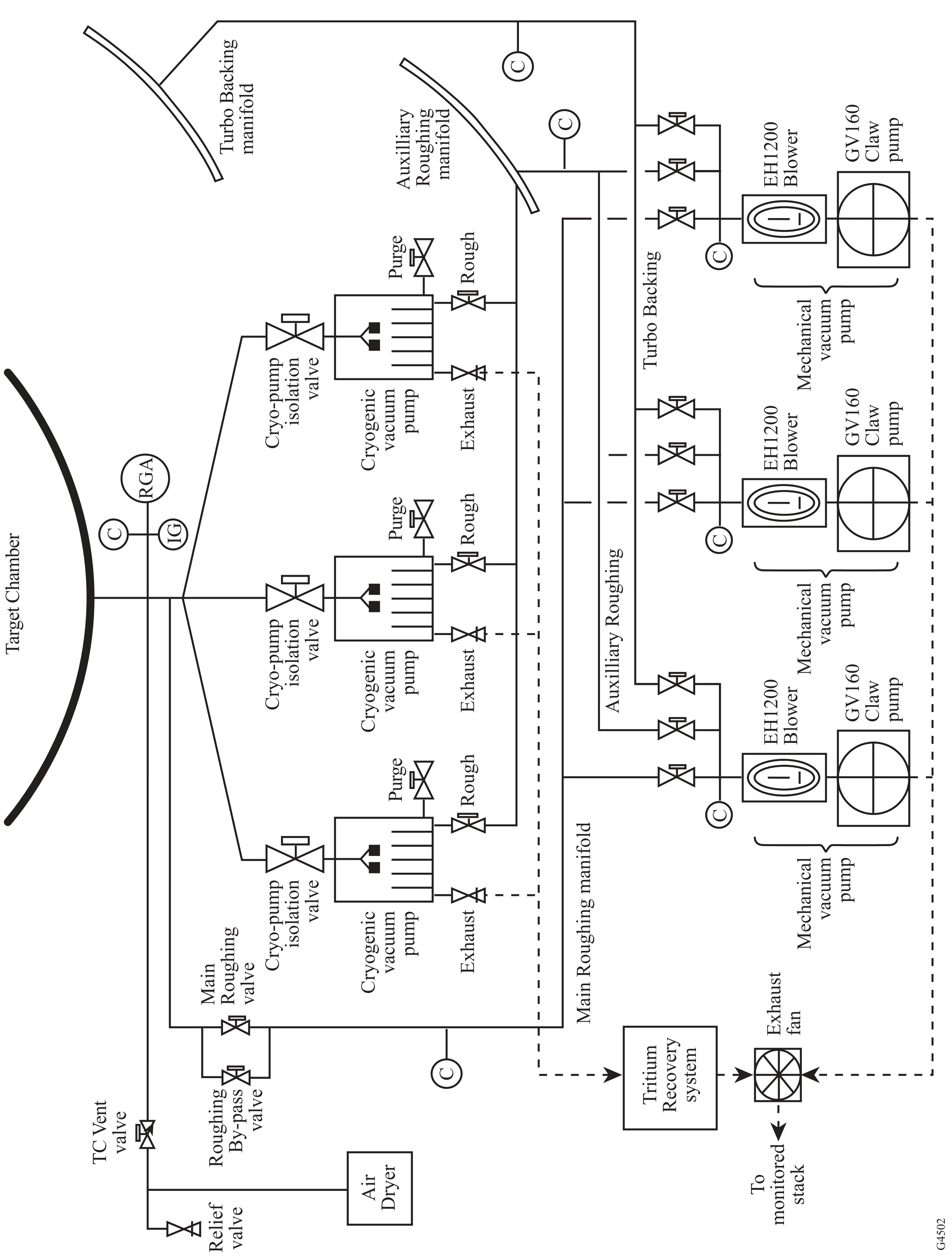


Fig. 7.2-1
Schematic of the target vacuum system.

When the system is shooting room temperature targets, the exhaust from the mechanical pumps flows through a 1500 CFM blower and up a 40-ft tall exhaust stack installed on the East outer wall of the Target Bay. The cryopump relief valves vent directly to the atmosphere via the exhaust stack and a bypass around the Tritium Scavenger. The TC pressure relief valve vents directly to atmosphere. During operations with cryogenic targets, mechanical pump exhaust will processed by an oxidizer/molecular sieve system to remove tritium prior to being discharged via the exhaust stack.

The cyropumps need to be regenerated periodically because their operation becomes less efficient as frozen gas accumulates on the collection surfaces. During regeneration, the gate valve is closed to isolate the cryopump from the TC and the collection surface is warmed to allow the gases to thaw. The released gases flow through the cryopump relief valves and exhaust to the 1500 CFM exhaust stack via a Zirconium Iron scrubber system to remove tritium. This emissions control system is discussed in Sec. 7.4.

7.3 AUXILIARY VACUUM SYSTEMS

The general layout of the auxiliary vacuum systems is depicted in Fig. 7.3-1. The target positioner and many of the target diagnostics feature air lock-type systems which are cycled to move equipment from ambient conditions into the TC vacuum and vice versa without cycling the TC vacuum itself. These antechambers must be pumped to a vacuum nearly equivalent to that of the TC before they are connected to the TC. This requires a two-stage pumping system: The volumes are initially roughed by mechanical pumps (via the Auxiliary Roughing manifolds) to a medium vacuum, typically 0.1 Torr. At that point a dedicated high-vacuum system, typically a turbomolecular pump, is engaged to pump the antechamber to high vacuum ($<1 \times 10^{-4}$ Torr). Mechanical vacuum pumps are used to “back” the turbopumps via the Turbo Backing manifold, scavenging their exhaust up to atmospheric pressure. (The turbopumps themselves are considered to be part of the diagnostic subsystem.) When high vacuum is achieved, the device isolation valve is opened, connecting the antechamber to the TC. The turbo isolation valve is then closed and the turbopump turned off.

Separate manifolds are employed for roughing and backing because the auxiliary roughing line pressure varies between atmospheric pressure and vacuum as loads are connected and pumped down, while the turbo-pump backing line must remain below about 0.1 Torr to support the 50 to 300 l/s turbopumps. The auxiliary roughing manifold has 35 NW40 fittings, while the turbo backing line has 35 NW25 fittings for connection to diagnostics. For configuration management purposes, the auxiliary vacuum system ends at the manifold. The isolated stainless steel bellows hoses, valves, and turbopumps are considered part of the diagnostic and are controlled by that diagnostic support subsystem.

The mechanical pumps are located in a separate pump house to eliminate pump-related vibration on the laser/target bay floor. They connect to the manifolds via a 3-in. diameter stainless steel pipe. Vacuum is monitored by Granville–Phillips Convectron gauges and Model 316 controllers.

The auxiliary vacuum systems, up to and including the manifolds, are controlled by the same GE Fanuc Series 50 PLC-based control system that controls the Main Vacuum system.

7.4 TRITIUM-RECOVERY SUBSYSTEMS

Because operations with targets filled with up to 40 atm of deuterium and tritium gas (DT) are planned, elaborate hardware and procedures are installed in the OMEGA experimental system to limit DT release to that allowed by the Laboratory’s discharge permit.

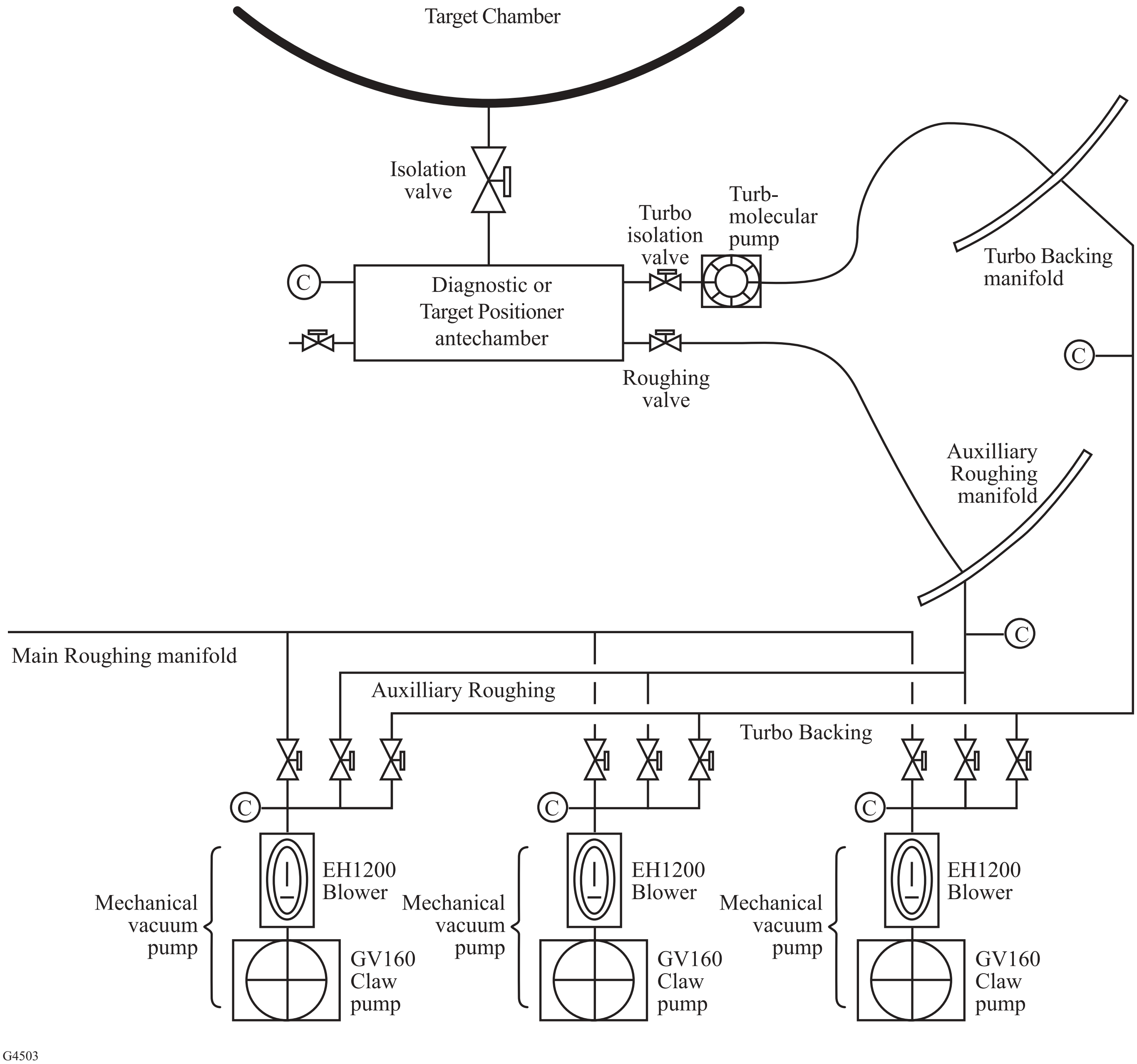


Fig. 7.3-1
Vacuum layout of target positioner in the current configuration (without tritium recovery capability) with central auxiliary roughing manifolds shown. Note that these manifolds also service diagnostic antechambers.

The current tritium-recovery subsystem consists of a high-activity circuit (Fig. 7.4-1). The low-activity circuit is also shown but will not be installed until the end of FY00.

Target Loading

Tritium enters the system from DT targets filled from the tritium-fill station (TFS) via the TPS. The tritium-filled target is delivered to the experimental area in a sealed container and is manually loaded into the TPS.

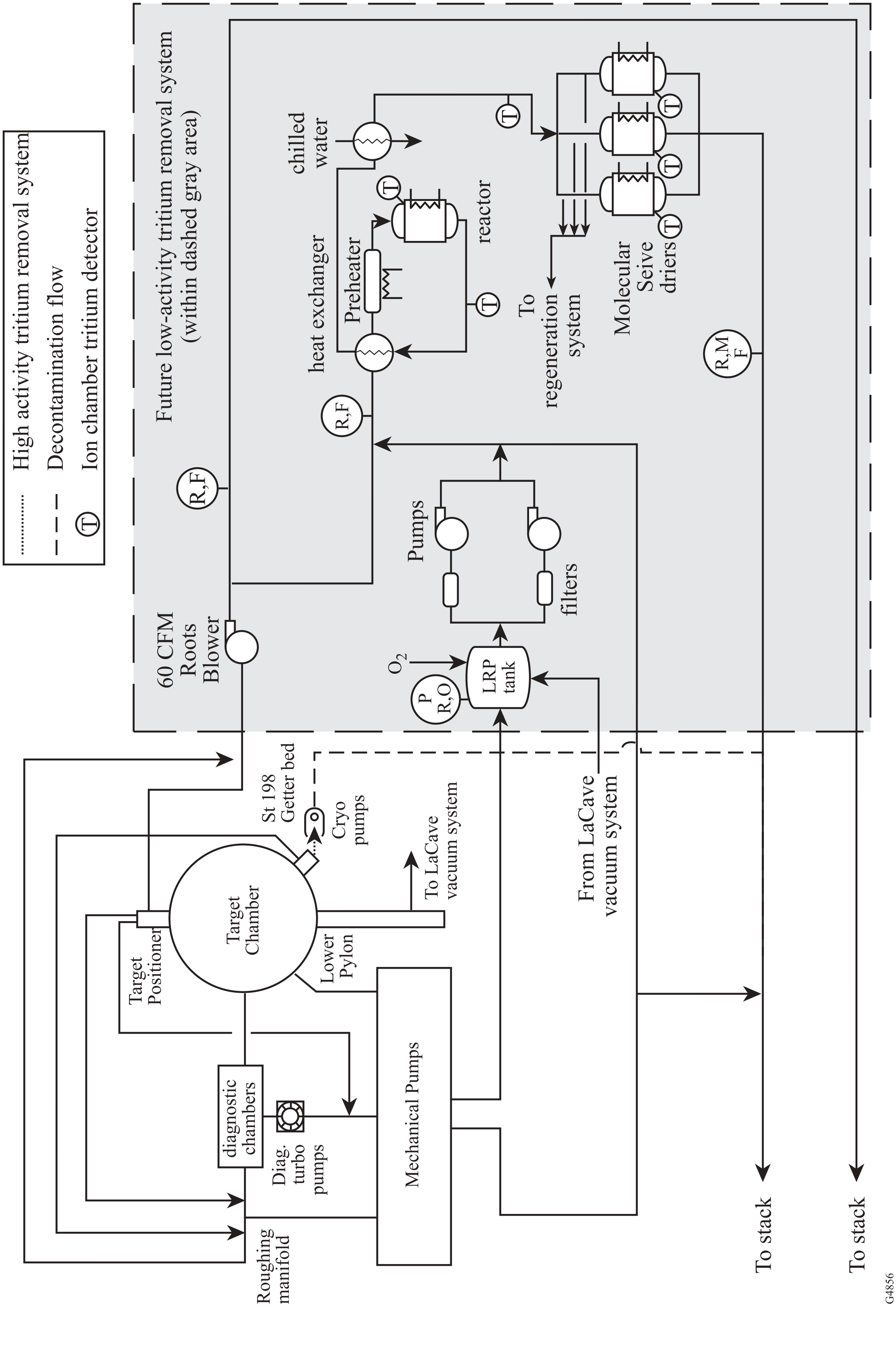


Fig. 7.4-1
Tritium recovery system schematic showing tritium flow paths.

With the target secured on the TPS transport arm, the TPS antechamber is evacuated to $<10^{-4}$ Torr using the auxiliary roughing system and a 200-liter/s turbo pump. The gate valve to the TC is then opened, and the target is positioned at the center of the TC. Only about 1% of the tritium contained in an implosion target is actually consumed. Most of the remainder accumulates on the second-stage cryo array of the operating cryopump. To increase capacity for tritium (and other non-condensables) the cryopump second-stage arrays are operated at ~15°K to maximize surface migration of hydrogen isotopes.

Cryopump Regeneration

Each cryopump is typically operated for three to four weeks prior to regeneration. To regenerate a cryo array it is warmed toward room temperature and the gas load is exhausted from the cryopump using a 2-CFM argon gas flow at room temperature. This exhaust flows through an Ontario Hydro zirconium/iron/tritium scrubber system before being sent up the 1500-CFM exhaust stack. The Ontario Hydro tritium scrubber unit is comprised of a molecular sieve (to remove H_2O/HTO), a Ni bed (to break down hydrocarbons), a SAES 198 zirconium iron getter bed, and inlet and outlet ionization chamber tritium detectors to assess performance. The complete cryopump regeneration procedure is included in Section SS 5 of the OMEGA System Operations Manual Volume II –System Operation Procedures (S-AA-M-13)

A worst-case estimate of the gas loading and resulting gas assay for a cryopump under the planned operation and regeneration schedule is shown in Table 7.4-1. In arriving at these values, the following assumptions were made:

1. All of the air that is in the TC at crossover ($\sim 2 \times 10^{-2}$ Torr) is trapped on the cryopump. The assumed constituent gases are the components of air (N_2, O_2, etc.) in ratios similar to that of air at atmospheric pressure. Negligible water is included because it is assumed that the dry air vent system prevents its introduction.

Table 7.4-1
Estimated Cryopump Gas Loads for Four-Week Regen Interval

Component	Volume in Torr Liters
N_2	2216
H_2O (from outgassing)	0.000146
DT	6.86
CH_2/CH_3 (from stalk/shell)	5.5
O_2	585.9
H_2	0.001
He	0.015
CH_4	0.006
Ar	26.01
O_3	0.000196
CO_2	0.923

2. Out-gassing from the TC and diagnostic surfaces is included. A modest out-gas rate of 10^{-10} Torr liters/s cm^2 (composed of 80% to 90% water) is assumed to evolve from the empty TC surface area.

3. Diagnostics are vented with dry N_2 and are pumped to 10^{-4} Torr before crossover into the TC.

4. The gas pumped from the target positioner may be contaminated, so the whole volume of the target positioner antechamber is counted as a separate source during roughing stages.

5. The four-weeks of operation prior to regeneration consist of: two pump-downs/week, 5 days/week operation, 100 diagnostic antechamber crossovers/day, 20 target-loading operations/day, and 10 DT shots/day using 40-atm targets.

6. The entire target support and shell structure is vaporized and collected as $CH_{3/2}$.

Desorption of Residual Tritium

The bulk of tritium remaining after a target shot collects on the second-stage array of the cryopump. However, some tritium is also adsorbed onto the surfaces of the TC and diagnostics, much of it in the form of tritium oxides (primarily HTO). This residual tritium is removed prior to maintenance operations by flushing the antechamber or TC with room air and exhausting the effluent to the monitored exhaust stack.

Following a vent/flush cycle, some tritium, primarily in the form of tritium oxides (especially HTO), may continue to desorb from the walls of the vacuum vessel and interconnecting plumbing.

In the future, during periods of substantial tritium activity, the mechanical roughing pump exhaust will feed through an oxidizer (to convert elemental tritium and tritiated organic compounds to oxides of tritium) and then through the molecular sieve (to collect oxides of tritium) prior to routing to the 1500 CFM monitored exhaust stack.

Tritiated Debris

Following a series of DT target shots some tritium-bearing debris (primarily residue from the target shell, target stalk, and diagnostic nose cones) will be present on the interior surface of the TC and on the surfaces of diagnostic instruments. This debris is mechanically removed by technicians using a special vacuum cleaner prior to conducting maintenance operations. Potentially contaminated work areas and devices are then checked using wipe sample collection surveys and a liquid scintillation counter before the maintenance operations are performed .

Tritium Monitoring and Procedures

The systems, instruments, and procedures for monitoring and controlling tritium are detailed in LLEINST 6610 (S-AA-M-16) OMEGA LLE Radiological Controls Manual. In particular, Part II, Sec. 2004 describes the environmental monitoring provisions. Part III details the applicable operating requirements and procedures. The procedures that are periodic in nature are treated as maintenance items and are included in Sec. 7 of OMEGA System Operations Manual Volume III–Subsystem and Component Maintenance (S-AA-M-14). This section provides an overview of the topics.

Several different classes of tritium monitors are employed to assure satisfactory performance of tritium-recovery equipment and containment procedures. These include survey and process ionization chamber detectors, and liquid scintillator counting using swipe-, aliquot-, and bubbler-type collection methods.

Process ionization chamber monitors are installed in the intake and exhaust lines of the tritium scrubber to assess performance of this collector device. These monitors are sensitive to activities of the order of 1 μCi/m^3. The output of these detectors are read and recorded by a stand-alone data recorder. If the exhaust sensors detect significant tritium activity, the attached system is shut down and an operator is alerted of the failure.

Compliance with the NYS Department of Environmental Conservation Permit Limits is monitored by liquid scintillator counter (LSC) assays for elemental and oxides of tritium taken on samples generated by a bubbler-type collection system.

Real-time monitoring of the atmosphere in the vicinity of maintenance operations, such as diagnostic manipulator payload reloading or entry of personnel into the TC, is performed using portable tritium survey monitors. These hand-held survey instruments are read directly by the operator and are sensitive to activities as low as 1×10^{-6} μCi/mil. When appropriate, data is logged manually.

Surfaces of hardware to be worked on, such as diagnostics or the TC wall, are monitored by swipe sampling of 100-cm^2 areas and LSC of the resulting sample.

Oil in roughing pump sumps is monitored regularly by aliquot and LSC.

7.5 TARGET CHAMBER ACCESS SYSTEMS

To perform service/maintenance operations on diagnostics and other support systems, personnel access to the exterior and interior of the target chamber is required.

External TC Access

The exterior of the TC is accessed primarily via the target mirror structure and personnel platform decks.

Internal TC Access

The interior of the TC is accessed by an access hatch with internal and external ladders fitted to port H16. The debris baffles for the cryopump intake port is designed to double as a personnel platforms inside the TC.

Although the TC is back-filled with dry air, it is still considered a confined space. As such, the manned access to the TC interior is performed under a modified set of confined-space rules.

Access to the TC interior is restricted to qualified personnel. A strict access protocol defined in Part III, Sec. 3008 of LLEINST 6610 (S-AA-M-16) OMEGA LLE Radiological Controls Manual is enforced. Dedicated, disposable clothing is used within the TC to prevent cross contamination. Other safety equipment is also used, such as respirators, safety goggles, etc. Surveys for tritium contamination precede any TC entry. Upon TC entry, the first task is to collect and dispose of target debris.

7.6 TARGET POSITIONER SYSTEM

A six-axis target positioner system (TPS), capable of positioning a non-cryogenic target to within ±5 μm of the designated TC center, is used for most target shots. Figure 7.6-1 illustrates the elements of this subsystem. The TPS is a single-load, vacuum-load-lock–equipped, computer-controlled device that support's operations with a broad spectrum of target types, some of which are depicted in Fig. 7.6-2. It is deployed with a full-authority, direct-control operator interface.

Each TPS axis motor is fitted with a magnetic, relative encoder and end-of-travel limit switches, which are tracked by the control system. Final target position is determined by position information derived from the target-viewing system (TVS).

Range of Motion

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. 7.6-3(a). To reduce the requirement for compound axial control to perform simple axial movement, stages are arranged as shown in Fig. 7.6-3(b).

TPS Axes Specifications

The specifications for motion along the seven axes are:

T AXIS

Full travel: 80.22 in. (2,037,588 μm)
Estimated travel time over range: ~5 min
Encoder resolution: 1.3 μm/count, 1.6×10^6 counts full travel
Positioning accuracy required:

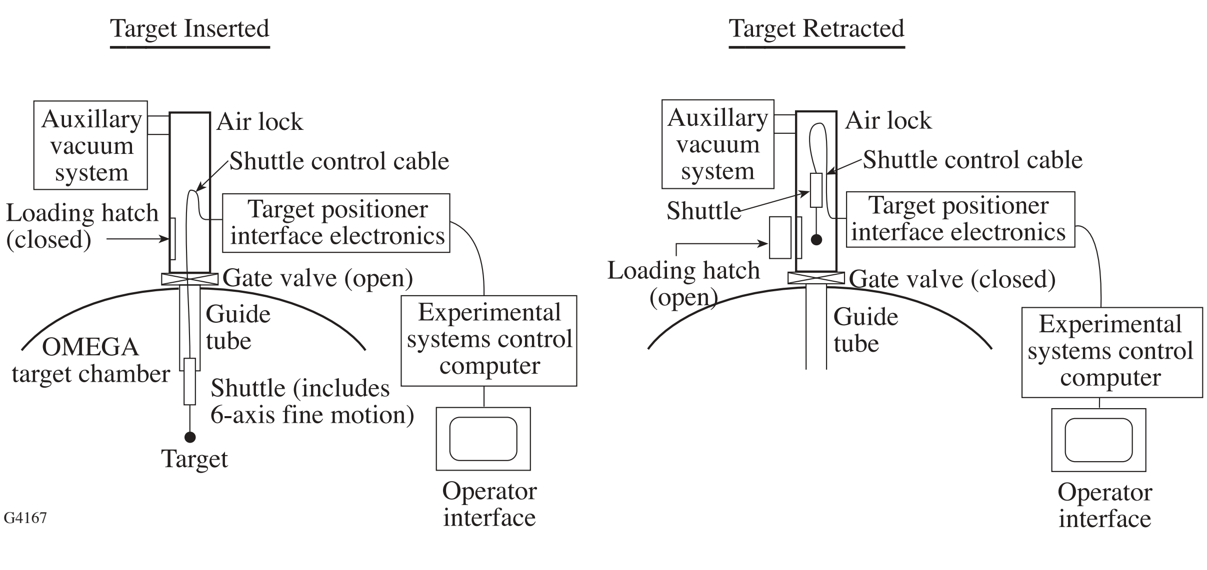
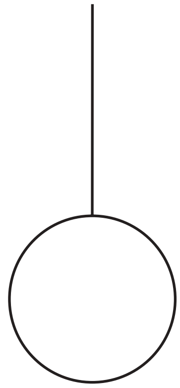
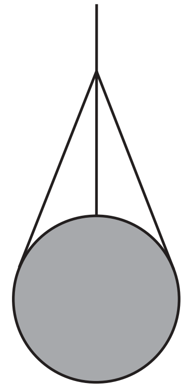


Fig. 7.6-1
Target positioner conceptual mechanical layout.



(a) Spherical
d = 700 to 2500 μm
Clear, transparent, or opaque

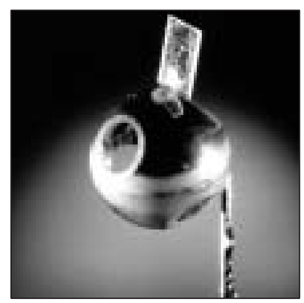


(b) Spherical (multipoint mount)
d = 700 to 2500 μm
Clear, transparent, or opaque

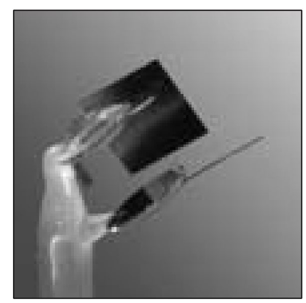
G4505

(c) Direct-drive cylinder

(d) Cylindrical hohlraum



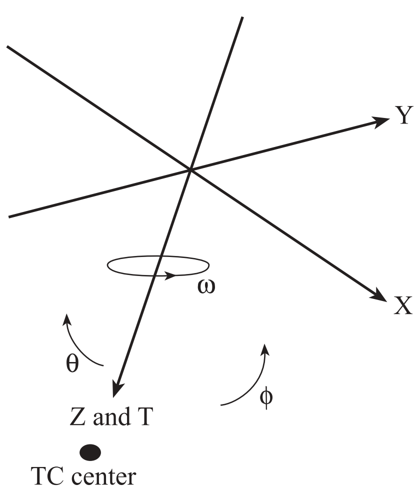
(e) Tetrahedral hohlraum



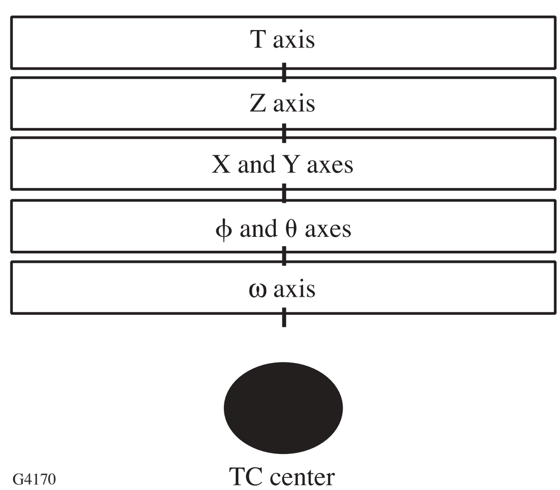
(f) Planar

G4770

Fig. 7.6-2
Typical target types handled by the target positioner.



G4506



G4170

Fig. 7.6-3
(a) Target chamber axes; (b) relative positions of target positioner axial stages.

Insertion — within capture range of 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 μm/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 μm/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 μm/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
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° due to gear head

Loading Operations

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.

7.7 Target-Viewing System

The primary means of determining target position is the target-viewing system (TVS). The TVS is a pair of back-lighted refractive telescopes situated with a nominal 90° relative angular separation. Each TVS arm includes a back-light source with imaging optics, a telescope assembly that includes (1) a 1:1 relay, (2) a hard reticle, (3) a beam splitter, (4) two magnifying relays, (5) two cameras (one for each magnification), and (6) one 3-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 telescope arm is also fitted with a significant amount of high-density polyethylene (HDPE) shielding to protect the electronic sensors from neutron radiation.

The general layout of the system is shown in Fig. 7.7-1. Specifications of the system are presented in Table 7.7-1.

The TVS controls provide remote control and position sense of the four shutters. Commands to the frame grabbers allow selection of the wide (30 mm)- or narrow (2.5 mm)-field-of-view cameras. The frame grabber software is also used to display computer-generated references on the video monitors and to acquire and store target images for future reference.

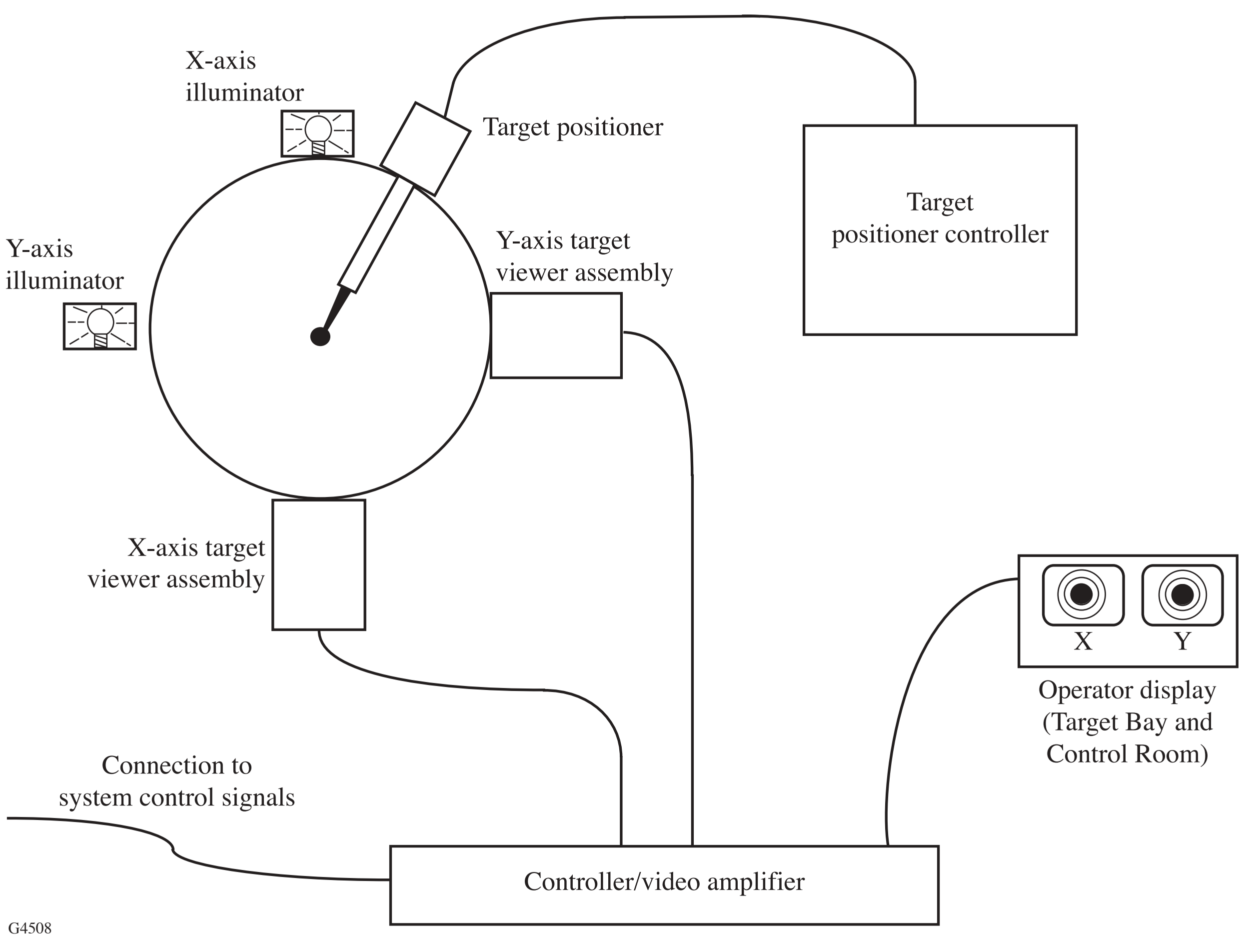


Fig. 7.7-1
Physical relationship of TVS and target positioner.

Table 7.7-1 TVS Specifications	
Optical speed	*f*/13.8
Number of axes	2
Detector locations	P5/P8; H6/H15
Available fields of view	2 mm and 30 mm
Maximum field of view	30 mm
Illuminator type	Incandescent quartz halogen, bandpass filtered
Illuminator wavelength	546.1±20 nm

The hard reticules in the TVS function as the Target Chamber Center (TCC) fiducials: During system activation, a reference fixture was surveyed to a location that was, within very tight tolerances, the intersection of the axes of all 92 precision machined ports on the TC. The 60 beam axes were then established to pass through that point, and the focus lens assemblies were installed on the beam axes. The TVS assemblies were then installed, and the reticules were aligned to the reference fixture and locked down, transferring the TCC standard to the TVS/reticle system. The fixture was then removed. The reticules, as viewed by the TVS optics, are now used to provide the position references for the alignment targets that are used for beam pointing and focusing and for the shot targets.

7.8 TARGET EXISTENCE DETECTOR

Because the beam ports on the OMEGA Target Chamber are arranged in opposing pairs, energy propagated forward in one beamline can pass through the chamber and propagate in the backward direction on the opposing beam train. This feature is routinely exploited for alignment using a low-energy alignment beam. High-value optics can be seriously damaged, however, if even a fraction of the high-energy shot pulse is allowed to pass the target and enter the opposing focus lens. The target existence detectors are among the provisions that have been put into place to prevent this from happening.

Automatic Imaging Target Existence Detector

The Automatic Imaging Target Existence Detector (AITED) is used on non-cryogenic target shots to protect against the situation where a properly aligned target moves or falls out of position late in the shot cycle.

The components of AITED are shown in Fig. 7.8-1. They consist of: a CCD camera and the associated light source and shutter equipment in the Target Bay; a frame grabber and computer in LaCave and a Rate Interrupt Module (RIM) and associated computer in the Driver Electronics Room; an operator interface provided at the Laser Drivers station in the Control Room. The frame grabber video signal is passed on to the OMEGA closed-circuit TV system Channel 46 so that the image can be displayed in the Control Room.

The camera shutter is controlled by the Hardware Timing System and a dedicated controller. It closes about 25 ms before every shot to prevent the flash from damaging the camera and opens after the software has been disarmed after the shot.

When the RIM relays are activated, the laser pulses from the OR are amplified normally in the Pulse Generation Room (PGR). When the RIM relays are deactivated, the triggers to regenerative amplifier power conditioning units are interrupted and the pulse from the OR is not amplified. The pulse that then propagates to the power amplifiers is too low in energy to be amplified to normal levels in the remainder of the system. As a result, opening the solid-state relays in the RIM prevents laser damage due to energy passing through the target chamber center.

During preparations for a target shot, the operator uses the software interface to specify the size and location of each of up to three image zones. This is facilitated by displaying the zone data as rectangular "RETICLES" on the video image. The operator also specifies a tolerance that is used as the target loss criterion. When the set up is acceptable, the image-analysis process is initiated. The software grabs frames of video data and sums the pixel values in each of the zones. The sums from the first frame are taken as the reference. The sums from subsequent frames are compared to the reference values. If any zone is brighter than the reference by more than the tolerance, the target is considered to have moved and the rate interrupt relays are deactivated.

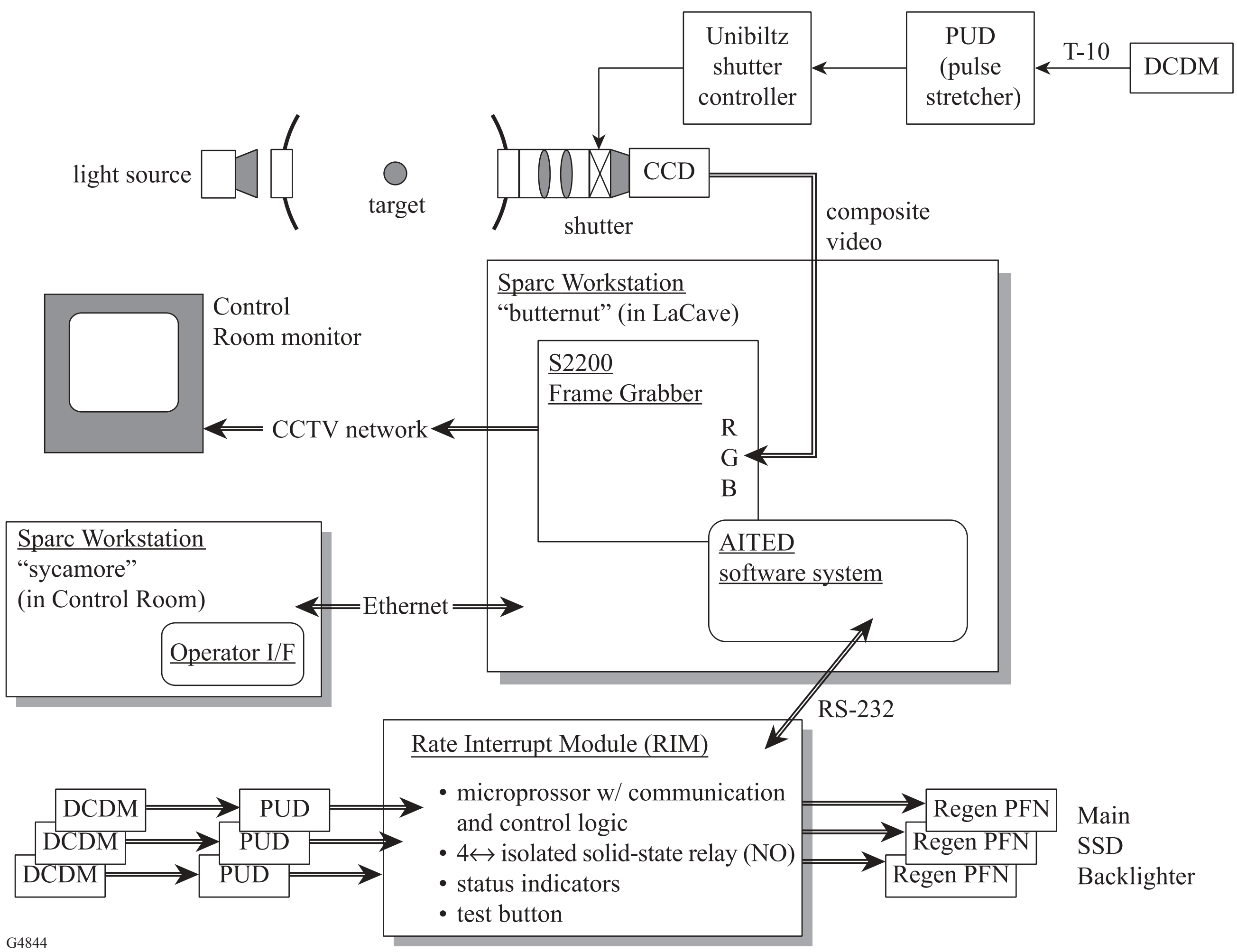


Fig. 7.8-1
Block diagram of the Automated Imaging Target Existence Detector.

Cryogenic Target Detector

Cryogenic target operations involve a separate set of subsystems that produce spherical implosion targets that consist of a normal shell with a layer of frozen D-D or D-T fuel on the inside. These targets are positioned at TCC by a moving cryostat (MC) that is inserted into the TC from the bottom using "Lower Pylon" equipment installed in LaCave. The MC includes a shroud assembly that surrounds the target—shielding it from the heat emitted by the (relatively) warm TC environment. Viewing ports in the shroud allow the position of the target to be checked by the TVS. At shot time, the shroud is pulled upward by a linear motor system that is part of the "Upper Pylon" equipment that is suspended from the bridge structure in the TB and extends through the top of the TC. The Cryogenic Target Detector (CTD) subsystem functions to coordinate the OMEGA shot cycle with the pulling of the shroud so that the shot occurs after the shroud has moved clear all of the laser beams and before the shroud/linear motor system has started to decelerate at the end of its travel. The CTD will prevent the propagation of high energy to TCC if the target is not in place when the shroud moves clear of it. The CTD can also inhibit the process under certain other circumstances.

The components of the CTD are shown in Fig. 7.8-2. Note that the shot intervention element of the AITED subsystem, the Rate Interrupt Module (RIM) is also used by the CTD. The major difference is that the CTD makes use of two orthogonal optical detectors that are similar to the TVS. These elements are co-located with the TVS equipment on the TC but view along slightly different axes and operate complete independently from the TVS.

Each CTD illuminator consists of a small diode laser with a collimating optical system and a fast acting shutter. The laser is turned on and off by the Orcgui control software system. This allows it to be operated manually as needed for check-out and also automatically—cued by the shot-cycle software messages. The separate fast shutter is controlled (like the AITED camera shutter) by the Hardware Timing System and a dedicated controller. It closes about 1 ms before every shot to prevent the flash from damaging the laser optics. It re-opens automatically after the shot.

The CTD optics focus the illumination laser beam through an aperture and onto a detector diode mounted within the TVS enclosure on the opposite side of the TC. This system is set up so that three distinct levels of illumination can be detected: (1) No light means that the illuminator is either not on or is shuttered or that the cryo shroud is blocking the CTD beam path. (2) A medium level means that the shroud is clear and that the target is in place. (3) A higher level means that the shroud is clear but the target is not present.

Cables connect the TB CTD equipment to the RIM in the DER. A small computer in the RIM is, in turn, connected to the Sun computer system and an operator interface is provided at the Laser Drivers station in the Control Room. The Laser Drivers Operator can set up the detection thresholds and arm either or both detection axes for a shot. The RIM can operate either in the AITED mode or in the CTD mode depending upon whether the AITED or the CTD gui is running on the Sun computer. The RIM also receives timing signals from the Master Timing Generator and a status signal from the cryo pylon system. The RIM outputs the trigger that initiates the shroud pulling sequence.

Figure 7.8-3 illustrates the cryogenic shot sequence. After the MC has been inserted and the target has been positioned and verified using the TVS, the CTD is set up and armed. The power amplifiers are then charged and the timing sequence starts at T-20 seconds. At about T-10 seconds, the cryo pylon controller initiates a "pre-pull" activity that prepares the shroud for removal. The RIM receives a "LIM

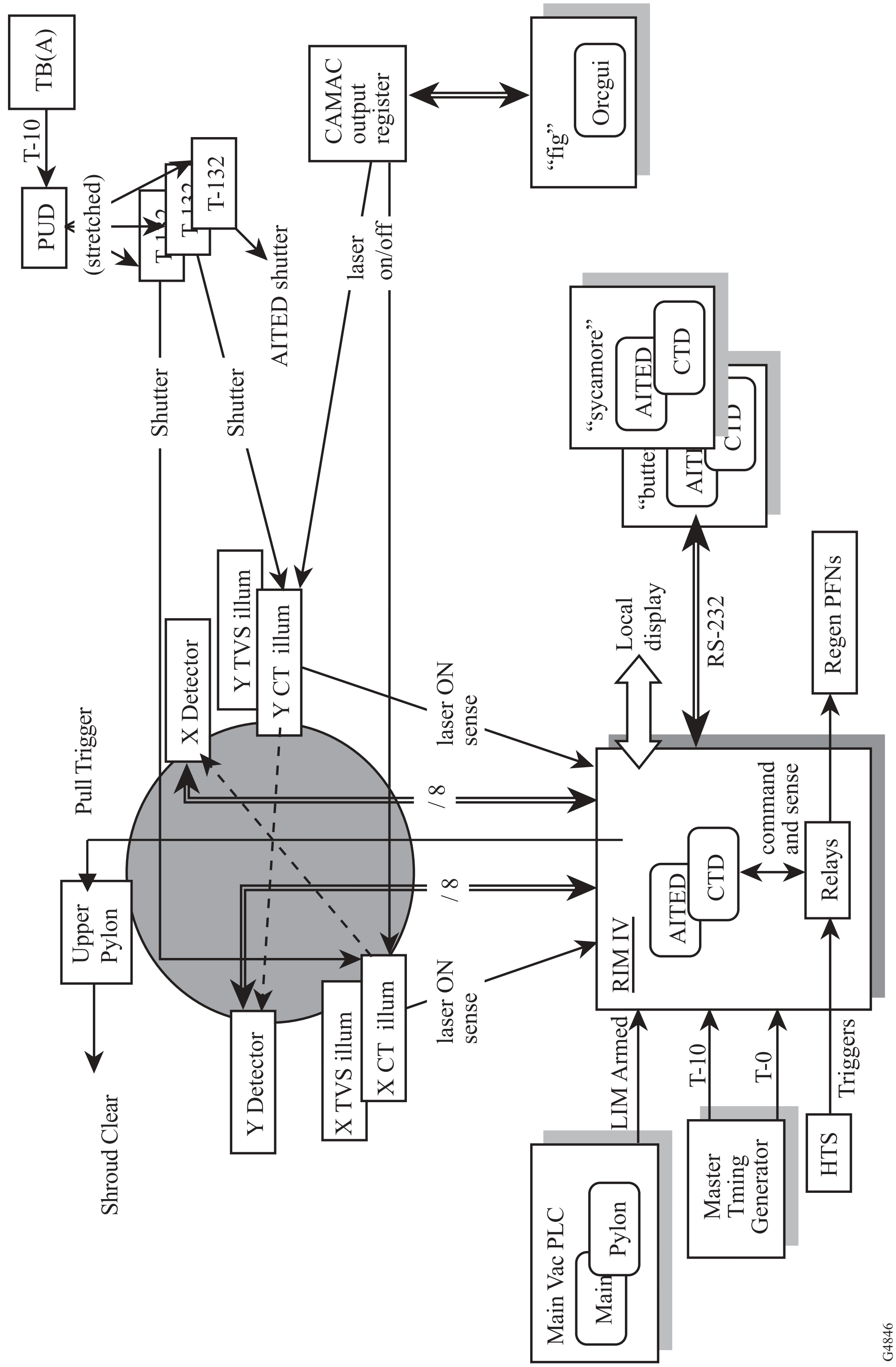


Fig. 7.8-2
Block diagram of the elements of the Cryogenic Target Detection subsystem.

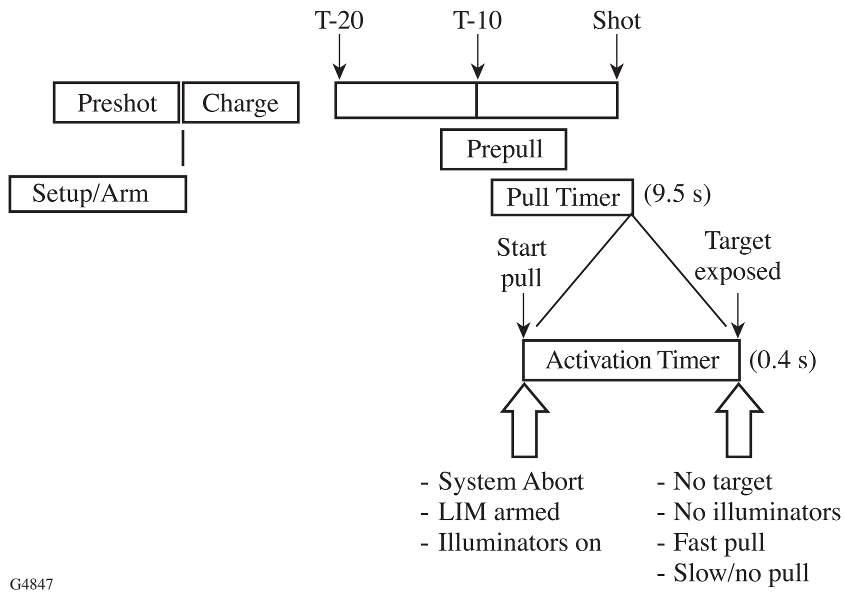


Fig. 7.8-3
Time line of the Cryogenic Target Detection shot-cycle events.

(Linear Induction Motor) Armed" signal when this is complete. Meanwhile, at exactly T-10 seconds, the RIM computer starts a timer (the Pull Timer) that counts down to the time that the Pull Trigger signal must be output. Since the shroud takes about 450 mS to clear the target after it is triggered, the Pull Timer will run for about 9.5 seconds. When the pull timer expires, the RIM logic checks to assure that it is prudent to initiate the pull. If so, the trigger is output and the RIM logic waits until the shroud should be clear. (This is timed by the Activation Timer.) The target detection logic is enforced when the shroud should be clear. The driver pulse is aborted if the detector signals indicate that the target is not present, if the illuminators have failed, or if the illumination is still blocked by the shroud. An abort will also occur if illumination is detected too early since the target could explode before the shot if it is exposed for more than about 50 ms. The detection logic will "standown" if the illumination is lost after having been present and the lasers are still on. (This means that the illuminator shutters are closing.) This will be set-up to happen a few milliseconds before the shot. (The solid state relays in the RIM can open within a millisecond.)

7.9 TARGET DIAGNOSTIC TRIGGERING, FIDUCIAL LASER, AND THE TIMING MONITOR SYSTEM

After manual set up, film loading, insertion, and pointing tasks have been accomplished, the shot sequence for a target diagnostic can include turning on high-voltage power supplies, acquisition of background images, arming, on-the-shot triggering, and data logging. The OMEGA Control System provides network messages that are used to initiate steps that do not require precise timing. (Network messages are not relied upon when timing precision better than about 1 s is necessary.) Section 7.12 provides some more detail on these processes. The OMEGA Hardware Timing System, described in Sec. 2.7, provides precise, dedicated, electrical signals needed for critical trigger functions. These signals have jitter well under 100 ps and can be adjusted in 100 ps increments.

The timing fiducial laser, described in some detail in Sec. 2.5, provides an optical signal that is synchronized with the high-energy shot pulse. The equipment that amplifies, performs frequency conversion, and divides the fiducial laser signals for distribution is installed in the Target Bay on the top of the North End Mirror Structure. The seed pulse for the fiducial signal is generated in the Oscillator Room in conjunction with the other optical pulse shapes. This signal is a "picket fence" pulse train consisting of 10 pulses 500 ps apart that has a known, fixed relationship to the pulse shape that is delivered to the target on a shot. The signal is available to users at three wavelengths via fiber optic connections. IR and green pulse trains are generated at 10-s intervals. Conversion to UV requires operation of a LARA and can be done every 10 min. When the UV fiducial is in use, the LARA is operated on the shot.

The Experimental System includes a Timing Monitor subsystem that is used to set up the precision triggers for the target diagnostics and to record the timing relationships on target shots. At the heart of this subsystem are three TDS 684 oscilloscopes that are part of the Experimental System Control and Data Acquisition system. As is illustrated in Fig. 7.9-1, each oscilloscope is provided with a copy of the fiducial laser signal and can also acquire and record the "monitor" signal outputs from up to three target diagnostics such as streak cameras mounted in TIM's. Software routines are used to derive timing values from the oscilloscope records. The results from test shot cycles and actual target shots are used to adjust the timing of the diagnostic trigger so that the data is acquired correctly by the diagnostic.

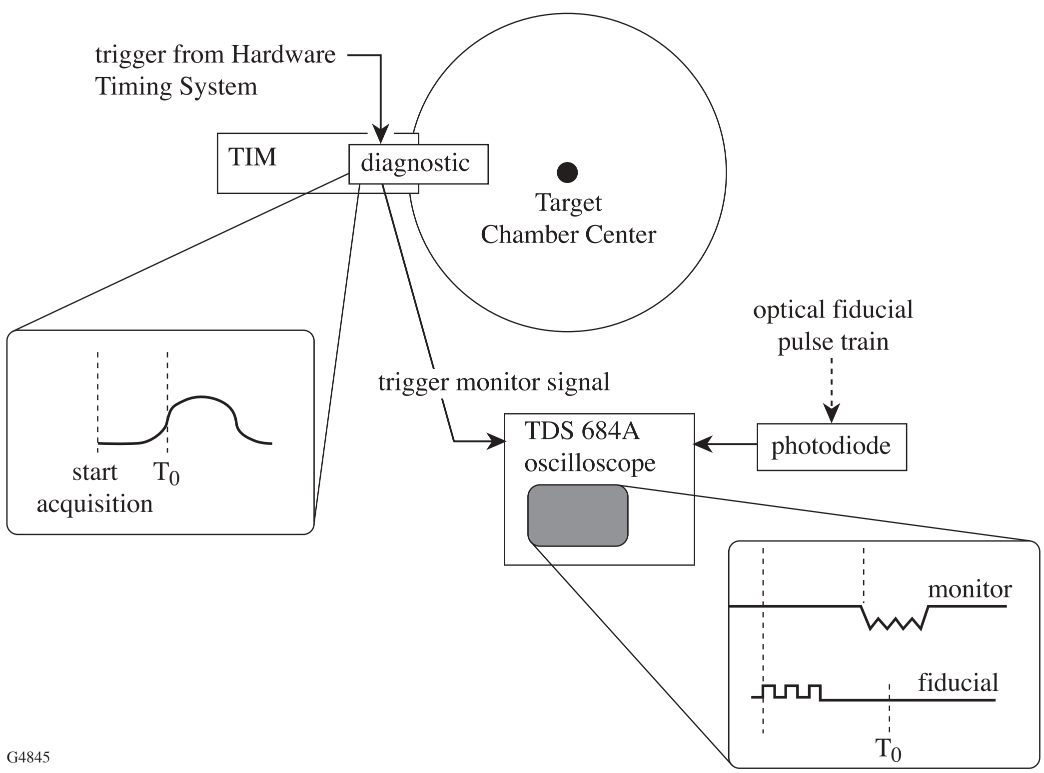


Fig. 7.9-1
Target Diagnostic Timing Monitor set up.

7.10 DIAGNOSTIC SUPPORT—TEN-INCH MANIPULATOR

The Experimental System provides an array of subsystems to support experimental diagnostic instrumentation on the OMEGA Target Chamber. Many of these systems are very generic and have been described in the preceding sections. Some are specific to a particular type of diagnostics and are covered it Chap. 8. The Ten-Inch Manipulator (TIM) is a diagnostic shuttle system that is used to position a variety of diagnostics near the TCC. Each TIM provides mechanical, vacuum, and electrical/control support and positioning for a single diagnostic payload.

Mechanically, the TIM (shown in Fig. 7.10-1) is an aluminum box mounted radially on a TC diagnostic port via a gimbaled flange. A flexible bellows provides an external vacuum seal, and a flapper valve with a 10-inch diameter opening isolates the inner end of the assembly. The box has an upper cover that can be opened to provide access to the interior. When closed, this cover completes the outer vacuum seals. A pedestal fitted with remotely controlled two-axis actuators supports the outer end of the assembly from the TMS and allows precision pointing adjustments around the gimbal axes.

The TIM's internal transport mechanism supports an instrument payload and can move it from the accessible space under the cover, through the open flapper valve, to a position with its forward end at or near the TCC. The TIM includes the vacuum components necessary to pump its internal volume to TC pressure so that the flapper 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 valve closed. Feedthroughs and a traveling umbilical provide the payload with power, signals, and communication, as needed, throughout the travel range.

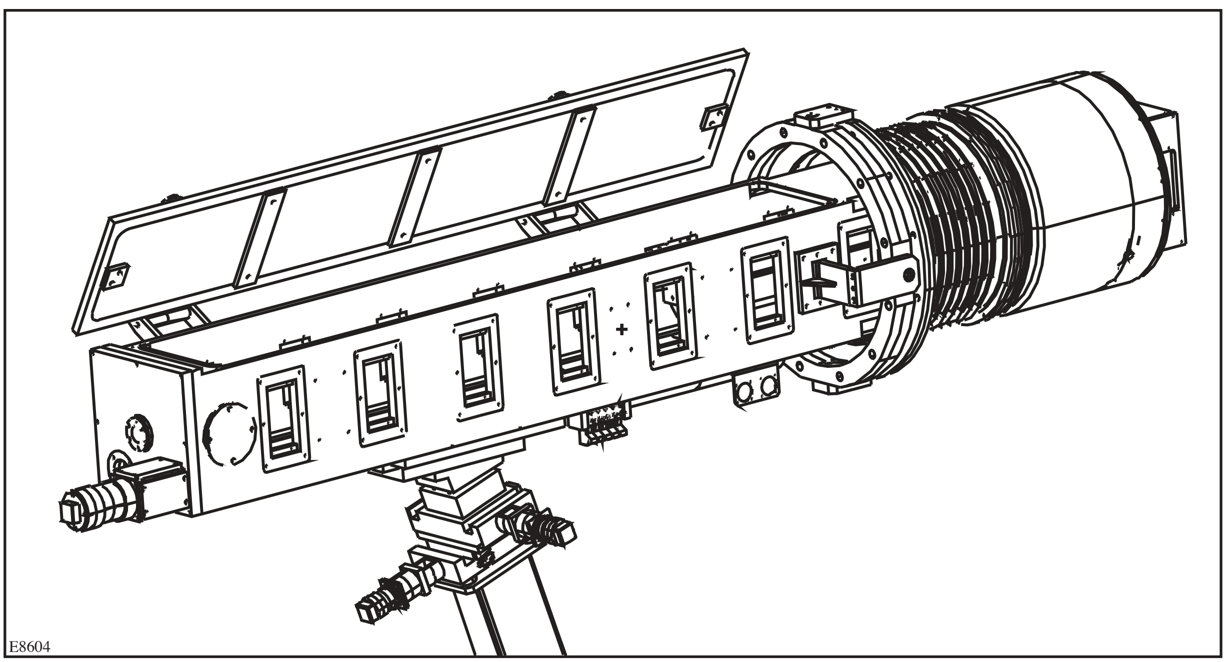
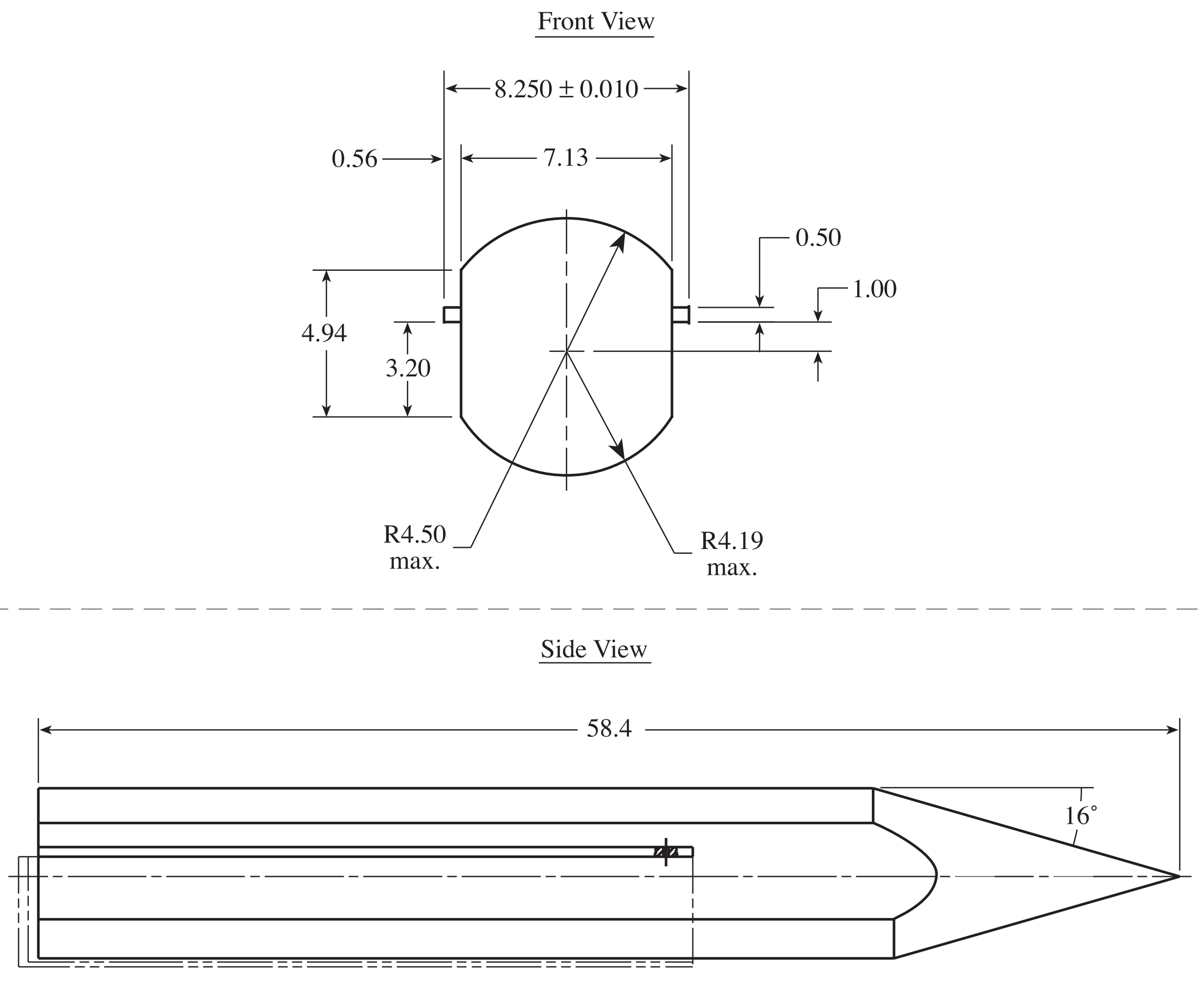


Figure 7.10-1
The LLE Ten-Inch Manipulator (TIM) is the standard interface for target diagnostics.

Table 7.10-1 lists some of the overall characteristics of the TIM. The payload envelope is illustrated in Fig. 7.10-2. Note that the payload is fastened to the carrier (called the "boat") using screws at a flange. The tapered shape at the inward end allows clearance for the laser beams when the envelope is at TCC.

Table 7.10-1 **Overall TIM Characteristics**
Steering resolution : < 10-μm resolution
Radial positioning: < 30-μm resolution
Insertion-to-insertion repeatability: < 50 μm
Cycle time (transport and vacuum): 23 min
Payload capability: 8.5-in. OD × 60-in. overall, 100 lb. max.



Linear dimensions in inches

Figure 7.10-2
TIM payloads must fit within this envelope and can weigh up to 100 lbs.

The boat is shown in Fig. 7.10-3, along with the adapter that allows an instrument designed for a LLNL SIM (six-inch manipulator) to be accommodated in the LLE TIM without modification. The TIM umbilical carrier has an 0.8 × 0.87-in. cross section. Up to four standard, 1.98-in. diameter feedthrough flanges are available. Table 7.10-2 gives a typical umbilical configuration.

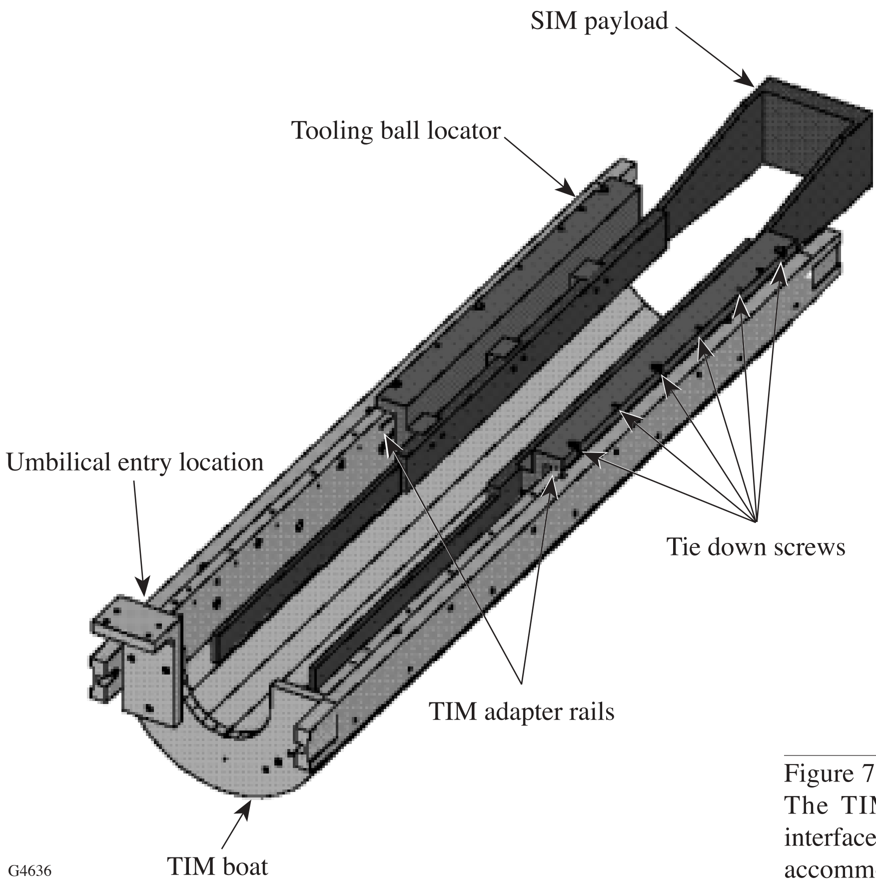


Figure 7.10-3
The TIM "boat" provides the mechanical interface for payloads. Simple, standard adapters accommodate LLNL SIM payloads.

Table 7.10-2 **Typical TIM Umbilical Configuration**
One 15-conductor (22 AWG) payload power cable
Two coax (RG-188) signal cables
One optical fiber (400 mm, 4w, monomode with SS jacket)
One 28-conductor (22 AWG) CCD control cable
Two 1/4-in.-diam (Teflon with SS braid) coolant hoses

7.11 DIAGNOSTIC SUPPORT—TARGET CHAMBER PORTS

As was indicated in Table 7.1-1, the OMEGA Target Chamber provides 32 large ports for diagnostic purposes, in addition to the 60 beam ports. Some of these ports are dominated by the installation of a single piece of equipment, but many provide for the installation of smaller ports and support multiple instruments. While the detailed configuration of the TC ports changes frequently to accommodate the needs of specific experimental campaigns and the availability of instruments, many of the ports are essentially permanently allocated. Table 7.11-1 lists the diagnostic ports and indicates these "permanent" allocations. Figure 7.11-1 shows their locations on the TC.

Table 7.11-1
Permanently Allocated OMEGA Target Chamber Diagnostic Ports

Port	Permanent Item	Port	Permanent Item
P1	Cryogenic system shroud retraction	H1	
P2		H2	Target positioner #2
P3	TIM #1	H3	Imaging x-ray streak camera
P4		H4	
P5	X-axis TVS viewer	H5	Neutron temporal diagnostic
P6	TIM #4	H6	Y-axis TVS viewer
P7	TIM #6	H7	TIM #2
P8	X-axis TVS illuminator	H8	X-ray microscope #1
P9	Neutron path to MEDUSA/NTOF	H9	GMXI
P10		H10	Charged-particle spectrometer
P11		H11	
P12	Cryogenic target positioner	H12	
		H13	KB x-ray microscope #3
		H14	TIM #5
		H15	Y-axis TVS illuminator
		H16	DANTE
		H17	
		H18	TIM #3
		H19	Cryopump #1, #2, and #3 Main Vacuum manifold
		H20	Personnel access hatch

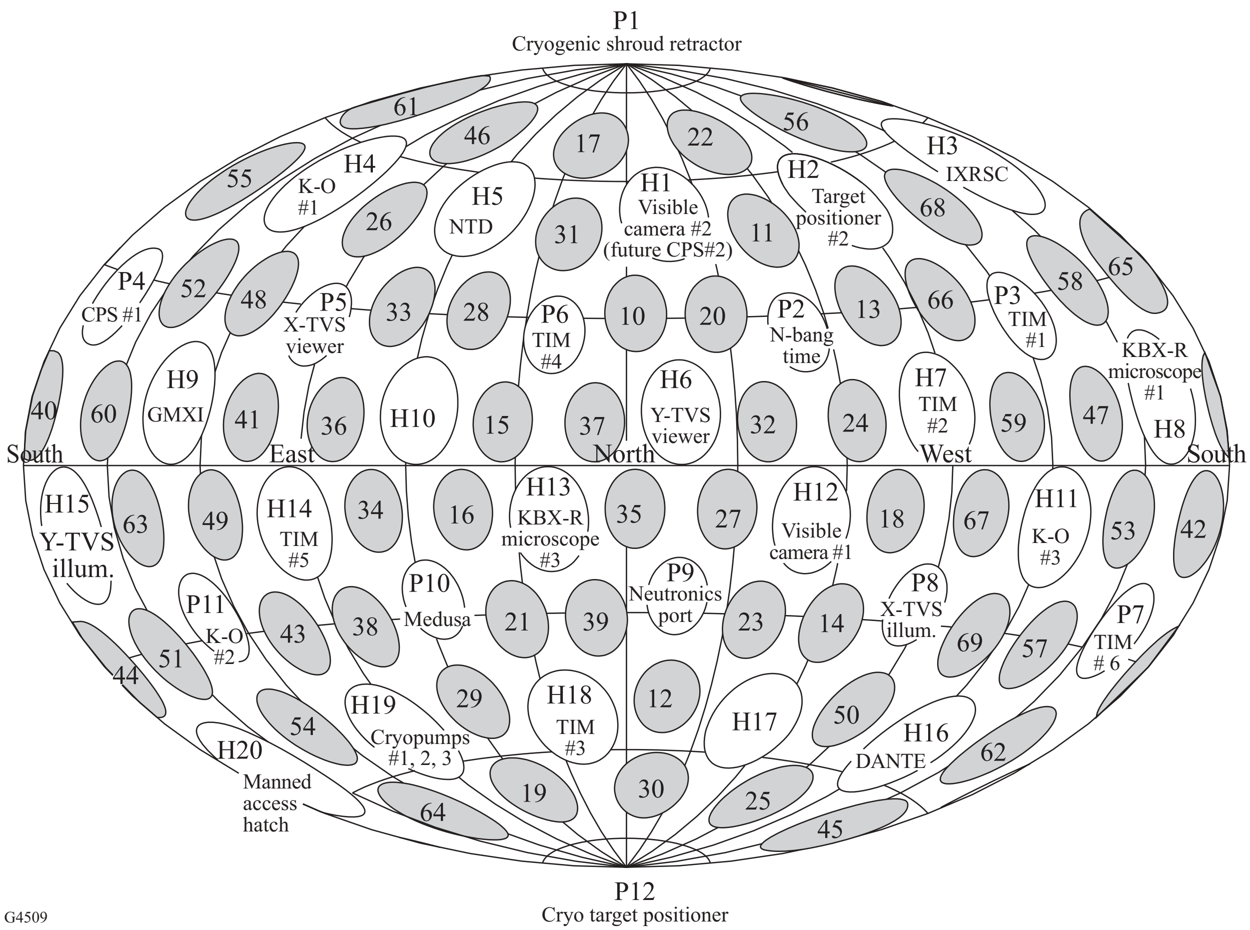


Figure 7.11-1
OMEGA Target Chamber with "permanent" diagnostic port allocations (see also Table 7.11-1).

7.12 EXPERIMENTAL SYSTEM CONTROL AND DATA ACQUISITION

The Experimental System controls utilize approximately 13 software applications running on five major platforms that are linked by the OMEGA Ethernet LAN. A PLC network consisting of more than a dozen programmable logic controllers (PLC's) complements this system and implements the basic vacuum control and interlock functions. Figure 7.12-1 is a schematic of this setup.

The primary operator interface consists of three screens on a Sun Workstation ***fig*** in the Control Room: Sun Workstation ***hazelnut***, which is installed on the upper platform in the Target Bay, provides a secondary operator interface and hardware interfaces for many of the subsystem controls. Sun Workstation ***catalpa*** in LaCave provides the interface to the Main Vacuum PLC. PC ***sanjuan*** on the middle platform in the Target Bay provides an operator interface to the Main Vacuum PLC. PC ***aledo*** in the Control Room provides duplicate of the ***sanjuan*** functionality. Two television monitors in the Control Room and two at the upper platform complete the control displays.

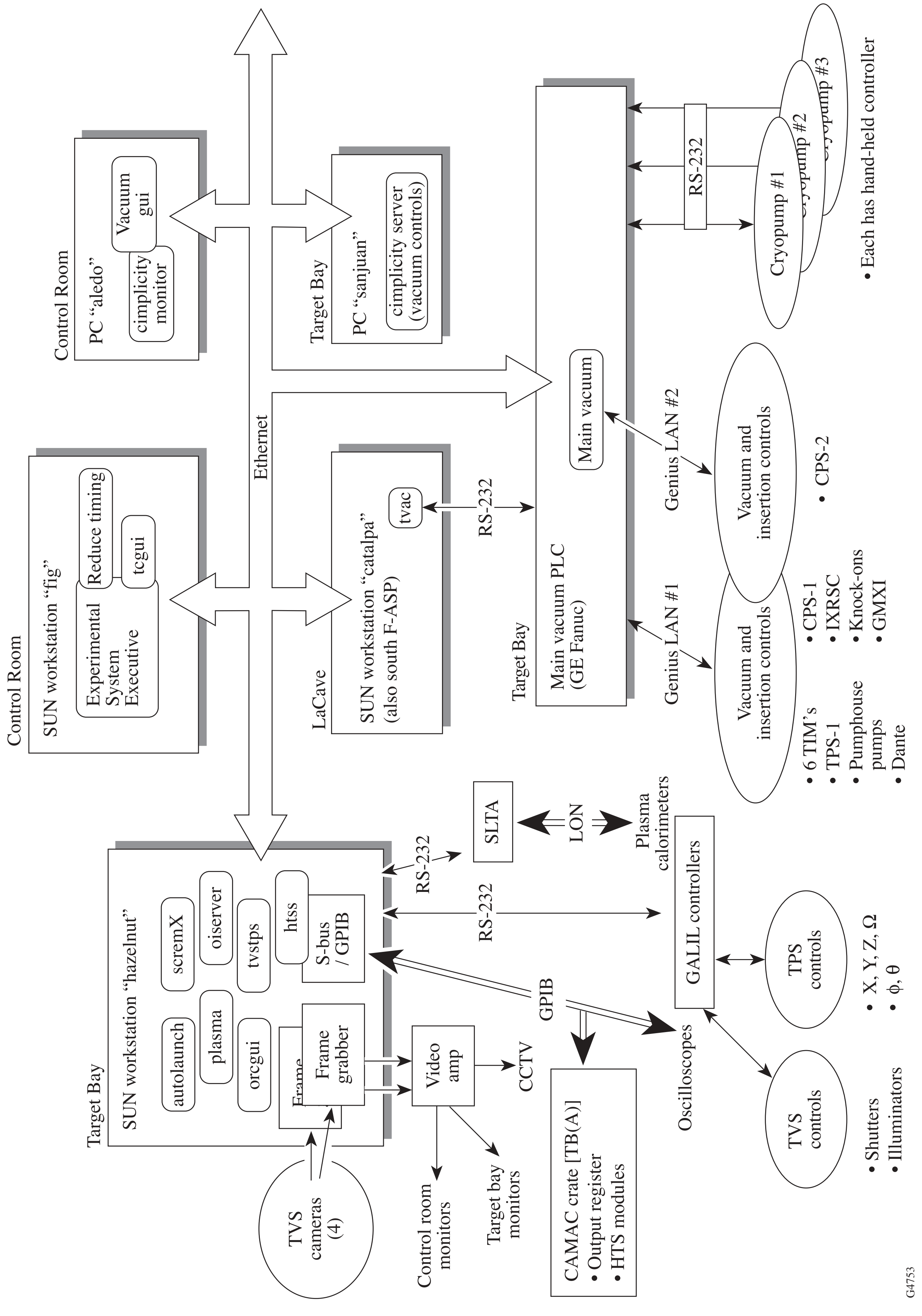


Figure 7.12-1
The Experimental System controls utilize a variety of software applications running on five major platforms linked by the OMEGA Ethernet LAN.

7.12.1 EXPERIMENTAL SYSTEM EXECUTIVE

The OMEGA Control System uses subsystem executive programs to coordinate and monitor the shot-cycle actions of the diverse parts of the facility. The Experimental System Executive (ESE) provides these functions for the Experimental System Operator. It includes a graphical user interface (GUI) that displays the status of the overall OMEGA system and each of the primary software elements of the experimental system. The ESE functions as the messaging hub that distributes shot-cycle messages to these elements. The ESE also communicates the status of the Experimental System to the Shot Director.

7.12.2 SOFTWARE ELEMENTS

Each of the elements of the Experimental System's control and data acquisition system are discussed briefly here.

Target Vacuum Controls—Remote control of the valves and positioning motors that are interfaced to the PLC network is provided by Unix command-line interface program ***tvac*** that runs on Sun workstation ***catalpa***. This facility allows the control room operator to initiate and monitor sequences that are implemented by the PLC's. The same functions are available to the technicians at the various equipment locations in the Target Bay via touchscreens that are part of the PLC network.

Autolaunch/Acquire/Screm—System and target diagnostic data acquired by oscilloscopes are handled by a series of Unix programs that run on Sun workstation ***hazelnut*** 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 ESE and arm the scopes so that they acquire data when triggered by a precision external trigger. The precision triggers are provided by the OMEGA Hardware Timing System (see Chap. 2). 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

- ***autoLaunch*** for Timing Monitor scope acquisition, and
- ***scremX*** for IXRSC acquisition.

Switch Event Control—Another application that runs on ***hazelnut*** operates a CAMAC output register located on the upper TMS platform in response to the shot sequence messages. The program, ***orcgui***, creates a GUI on one of the Control Room screens. This allows the operator to configure each of the channels of the output register to turn on or off in response to the messages. The CAMAC switches are used to operate devices such as shutters and power supplies automatically near shot time.

Plasma Calorimeters—The plasma calorimeters make use of the same Neuron/LON technology that is used by the other calorimeters in the OMEGA system. In this situation, an application called ***Plasma*** runs on ***hazelnut*** and includes both the LON and messaging elements that allow the calorimeters to automatically prepare for a shot, acquire data, and transfer it to the Unix file system.

Target Diagnostic Configuration—An application called ***tcgui*** is run on ***fig*** to provide the operator with a means to set up a list of the active diagnostics to be logged to the database as part of the shot record.

Target Positioning and Viewing—The TVS and the TPS are physically and functionally distinct, but are controlled by the same control hardware and are operated together via a common software interface named ***tvstps***. The ***tvstps*** program runs on ***hazelnut*** with its graphical user interface generally displayed on ***fig*** in the Control Room. The GUI provides the operator with the means to select which TPS to control, to operate each of the fine positioning axes, to control the TVS field of view and shutters, and to operate motor-disconnect features. The TPS vacuum and target insertion functions are controlled via the separate ***tvac*** program.

In addition to the TPS and the TVS mechanisms, ***tvstps*** controls the TVS frame grabbers and acquires digital images from them. It is also used to generate and store frame grabber reticle files that are used for positioning non-spherical targets and those that are not located at TCC. Composite video outputs from the frame grabbers are connected to the OMEGA closed circuit television (CCTV) system. RGB outputs from the frame grabbers are connected to pairs of video monitors in the Control Room and the Target Bay. Frame grabber control and image acquisition functions are provided by program ***oiserver*** on ***hazelnut***.