S-AA-M-31

Cryogenic Target Handling System Operations Manual Volume IV–CTHS Description

Chapter 10: Upper Pylon (UP)

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Chapter 10
Upper Pylon (UP)

10.1 INTRODUCTION

Figure 10.1-1 shows the equipment installed in the OMEGA target area to allow cryogenic targets to be positioned and shot. The lower pylon is supported by the target chamber (TC) and extends downward from the center of the TC through the Target Bay floor. The upper pylon extends from above the center of the TC through a bellows joint at the top of the TC. The Upper Pylon (UP) is supported by a bridge structure that spans the Target Bay. A linear induction motor and shroud retractor are housed within the upper pylon and are used to remove the shroud just before the shot.

The target is housed in a moving cryostat (MC) that is placed at the center of the TC by the lower pylon equipment. The MC mates with a kinematic docking plate at the upper end of the lower pylon and is held in place by electric clamps. The position of the target is checked and adjusted using the Target Viewing System in conjunction with the Target Auto Positioning System (TAPS) and the fine motion stage in the MC. The linear induction motor in the upper pylon can then be operated to lower the gripper to engage the upper shroud and prepare it for removal.

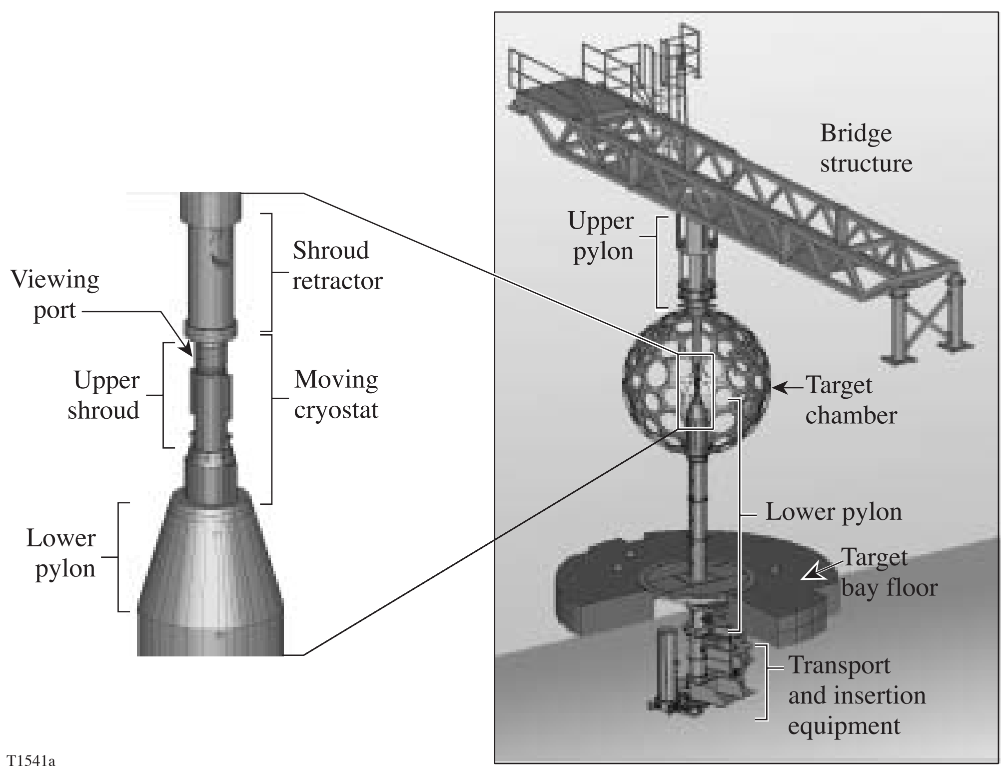

Figure 10.1-1
Upper and Lower Pylon Equipment Arrangement. The major equipment items in the OMEGA target area to facilitate cryogenic target shots include transport and insertion equipment beneath the target chamber, upper and lower pylons, and a structural bridge.

When the entire OMEGA system is ready, the power amplifiers are charged. This takes about 2.5 min. After charging is complete, the precision timing sequence starts at T–20 s. During this last 20 s, a “pre-pull” activity prepares the shroud for removal, and the signal that causes the linear induction motor (LIM) to remove the shroud is issued at the correct time relative to the laser shot. The LIM pulls the upper shroud rapidly upward exposing the cryogenic target to the laser beams. The sequencing equipment implements safeguards to ensure that the CTHS equipment has sequenced correctly and that the target is still in place after the shroud is clear of the beams. If the target is not in place the seed pulse from the laser drivers is interrupted to prevent energy from propagating.

10.2 EQUIPMENT OVERVIEW

The upper pylon mechanical equipment is described in more detail in the following subsections.

10.2.1 Upper Pylon Mechanical Design

Figure 10.2-1 depicts the upper pylon (UP) assembly, including the support plate, pylon housing, linear induction motor (LIM), pull tube, guide tube, and gripper assembly. The entire weight of the assembly is supported by a plate that is anchored to the Target Bay bridge. Adjusting screws on the bridge permit the UP to be aligned to the lower pylon (LP). A rigid guide tube extends into the TC to restrict lateral motion of the shroud assembly during removal. Significant reaction forces are generated

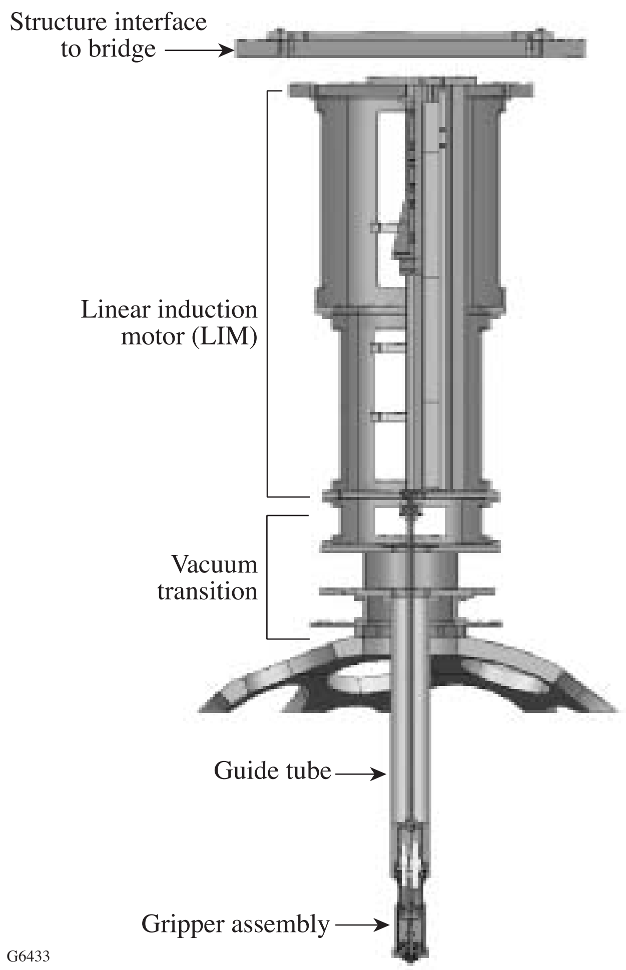

Figure 10.2-1
The mechanical components of the upper pylon are suspended from the bridge and extend into the target chamber via a vacuum transition that includes an isolation bellows.

within the UP as the LIM accelerates/decelerates during shroud removal. These forces are largely decoupled from the TC by use of a flexible stainless steel bellows at the vacuum transition.

10.2.2 Gripper Assembly

The gripper assembly is shown in more detail in Fig. 10.2-2. The LIM is used to move the gripper plunger into the upper shroud cup. The gripper socket is able to de-center and/or tilt within a narrow range to allow correct mating if a slight misalignment exists. Once the plunger is mated to the shroud, the gripper motor is activated; this raises the plunger and causes a set of steel balls to be driven radially outward. The steel balls engage a hardened steel groove built into the shroud. A linear potentiometer and limit switches track the plunger position.

A rigid assembly is formed between the gripper and upper shroud when the gripper balls engage the steel groove. A bearing sleeve on the outside diameter of the bearing housing restricts lateral displacement of the assembly within the guide tube as the LIM retracts for a shot.

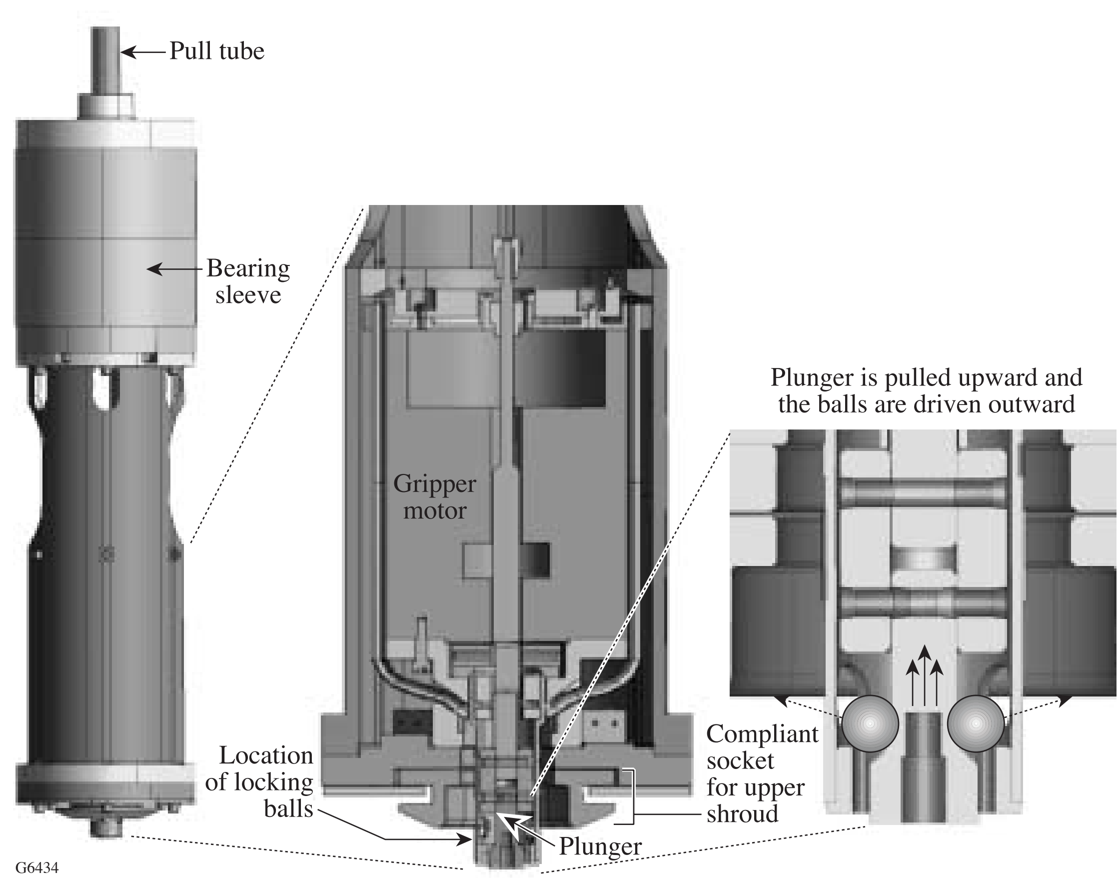

Figure 10.2-2
The gripper assembly includes a socket that engages a cup on the top of the MC upper shroud. The gripper motor moves the pintle upward, forcing a set of steel balls to move laterally and lock the gripper to the shroud.

The electrical services required by the gripper assembly are routed through the pull tube to a vacuum interface at the top of the tube and connected to the upper pylon controls.

10.2.3 Vacuum Transition

The pull tube is slender and hollow in order to minimize both its weight and friction drag at the two vacuum seals. As shown in Fig. 10.2-3, the space above the first seal is evacuated via a connection to the turbo backing manifold. The bore of the pull tube and intermediate space are connected to the target chamber and are at target chamber pressure.

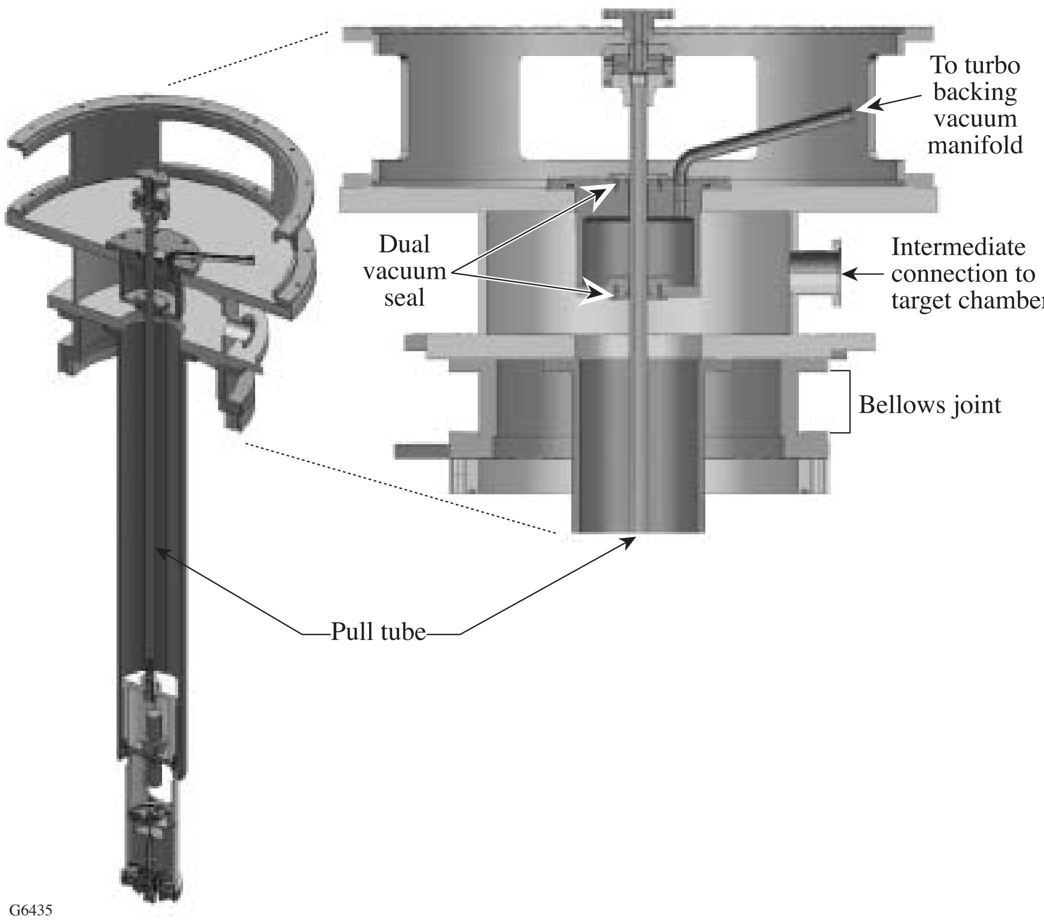

Figure 10.2-3
The vacuum transition section includes the dual sliding seals for the pull tube and an intermediate chamber in addition to the isolation bellows.

10.2.4 Linear Induction Motor (LIM) and Controller

Figure 10.2-4 shows the core components of the LIM. Two of the three-phase, laminated coil sections are used in the upper pylon to provide a 1.1-m-vertical-displacement capability. The motor can develop nearly 1000 lbs of thrust and can deliver good performance in rapid point-to-point positioning applications while virtually eliminating the effects of friction, inertia, backlash, and wear associated with rotary-to-linear drive mechanisms. An optical encoder having 200-line/mm resolution provides motor position feedback over the entire travel. The control system uses a retraction trajectory that minimizes impulsive loading to prevent unwanted target vibration. During a full-speed shroud removal, the shroud reaches a peak velocity of 5.5 m/s and acceleration up to 4.4 g.

The induction coils are driven by an Anorad Model EXP 40.0 kVA servo amplifier that produces a drive current proportional to an error voltage provided by a separate control board. The error signal is generated in response to the LIM optical encoder output and feedback parameters.

The control board is a PC-Serve SB214PC 4 manufactured by ACS Ltd. (Israel) for Anorad Corp. It is mounted in a PC located on the Target Bay bridge. PC-Serv employs digital signal processing (DSP) technology to achieve high-performance closed-loop operation and contains on-board memory capable of storing user-defined programs and data. While only one of the four axes provided by the card is used for this application, the on-board memory provided for the remaining axes is used to manage data required for a shot sequence. The controller communicates with the PC via its ISA bus, and with other hardware, using dedicated I/O lines, via an LLE-built interface panel. PC-Serve uses one of its analog inputs to digitize the servo current output. This signal is used by the controller to monitor the force produced by the LIM. Once the controller is initialized, it continues to operate as long as it receives power from the PC. Communication with the PC is not required during the on-the-shot shroud-removal operation.

Because of prior experience with PC's failing in the Target Bay on high-yield shots, it was decided that the PC-Serv controller should operate without relying on the host processor during the shot sequence. As a result, the key sequence commands and permissives are implemented using a hardware handshaking protocol for communication with the lower pylon PLC and other external inputs. The PC supplies power to the controller, but all control logic is performed in the PC-Serv DSP using programs written specifically for the CTHS application.

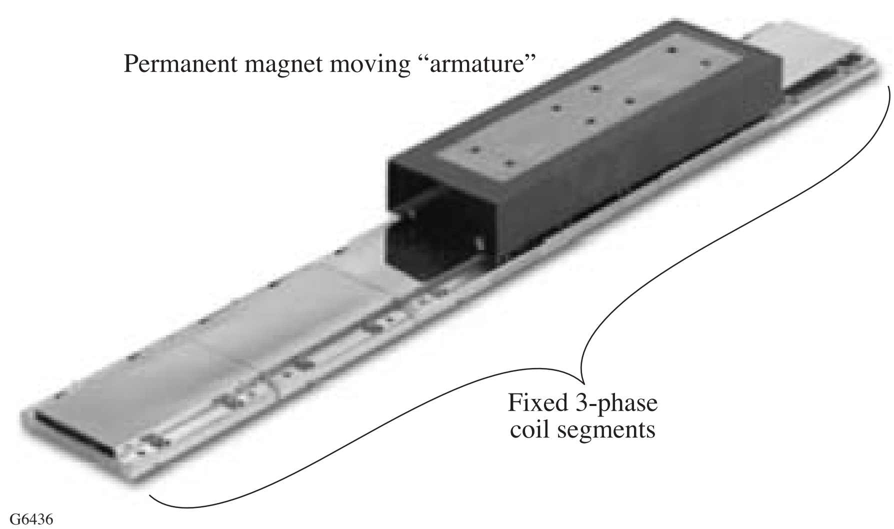

Figure 10.2-4
The linear induction motor (LIM) can be thought of as a standard rotary motor that has been "unwrapped." The basic parts are shown here.

Setup and post-shot data recovery are achieved by interactions between the host PC and PC-Serv that occur before and after a shot. A Windows-based application called "OmegaLIM" runs on the PC and provides capabilities that include the ability to

- Initialize hardware and software control settings;
- Upload and download programs, operating parameters, and data;
- Provide the ESO with real-time diagnostic information;
- Provide an operator interface for manual intervention in the event of hardware malfunction;
- Interact with the shot executive via OIP messages;
- Record extensive diagnostic information during every shot sequence;
- Load arbitrary trajectory profiles; and
- Restore the controller to a known state following catastrophic failure of the PC or PC-Serv or both.

Servo setup parameters and error diagnostics can also be entered and displayed using an LCD keypad and a serial communication link that connects directly to the PC-Serv board.

The LIM is equipped with a ratchet-like electromechanical latch that serves as a safety mechanism in the event of power failure. The latch consists of solenoid actuated cog mounted on the armature that can engage with a linear gear rack fixed to the stationary structure. Each of these are made of hardened steel. During normal LIM operation, the PC-Serv controller energizes the solenoid and issues a command to the servo to move upward. This permits the cog to be pulled free from the rack—the LIM may then move freely up and down under servo control. A "SOFTPARK" operation is used when the LIM is to be stopped and de-energized. In this process, cog solenoid is de-energized while the LIM is stationary, and the LIM is lowered onto the latch until the load-sensing logic determines that the latch is bearing the full weight of the LIM. The LIM servo is then de-energized.

In the event of power loss or a servo fault, power to the solenoid is cut, causing the cog to be released. In this condition, the LIM may move upward, but as soon as it begins to move downward, the cog engages with the rack. Uncontrolled free fall is restricted to the pitch of the rack, which is approximately 1 cm.

A manually installed mechanical "key" that positively locks the armature to the rack is provided to ensure safety when servicing requires removal of the safety shields that normally surround the moving mechanism.

10.3 CTHS INTEGRATION AND SOFTWARE ARCHITECTURE

The capability to carry out cryogenic target shots has been provided by integrating the operation of key CTHS elements with the existing OMEGA control system and operating procedures. The issues addressed include control of the use of the lower pylon to connect an MCTC to the target chamber and place the MC at TCC, viewing and positioning the cryogenic target, controlling the upper pylon to grip the shroud, and sequencing the shroud-removal process to the OMEGA shot cycle. In addition, it is necessary to ensure that the target is in place after the shroud is removed.

The integration effort resulted in an operating doctrine that includes the qualification, operating procedures, and posting an Experimental Cryogenic Technician (ECT) to operate the lower pylon and the MCTC for shots. The roles of the Experimental System Operator (ESO) and the Experimental System Technician (EST) were extended to include the operation of the upper pylon equipment. The operational procedures for these positions and the Shot Director now include detailed instructions for each of the variations of cryogenic shots. The operators are supported by features of the OMEGA Control System, which are discussed in the remainder of this section.

10.3.1 OMEGA Control Room Software

The OMEGA Control System, which is described in more detail in Chap. 11 of "OMEGA System Operations Manual, Volume I – System Description" (S-AA-M-12), makes use of two separate timing services to coordinate shots: (1) A nonprecision system of network messages that are passed between key computer programs called the OMEGA Intercommunication Protocol (OIP); and (2) The Hardware Timing System (HTS) that distributes periodic rates and T–10 and T–0 shot triggers to users that require precise electronic triggers.

The OIP and the software executives function to ensure that the task-specific applications required for the shot are included and are ready at specific milestones. In particular, the Power Conditioning System cannot be commanded to charge until all required elements report that they are ready. Figure 10.3-1 illustrates the key parts of these services.

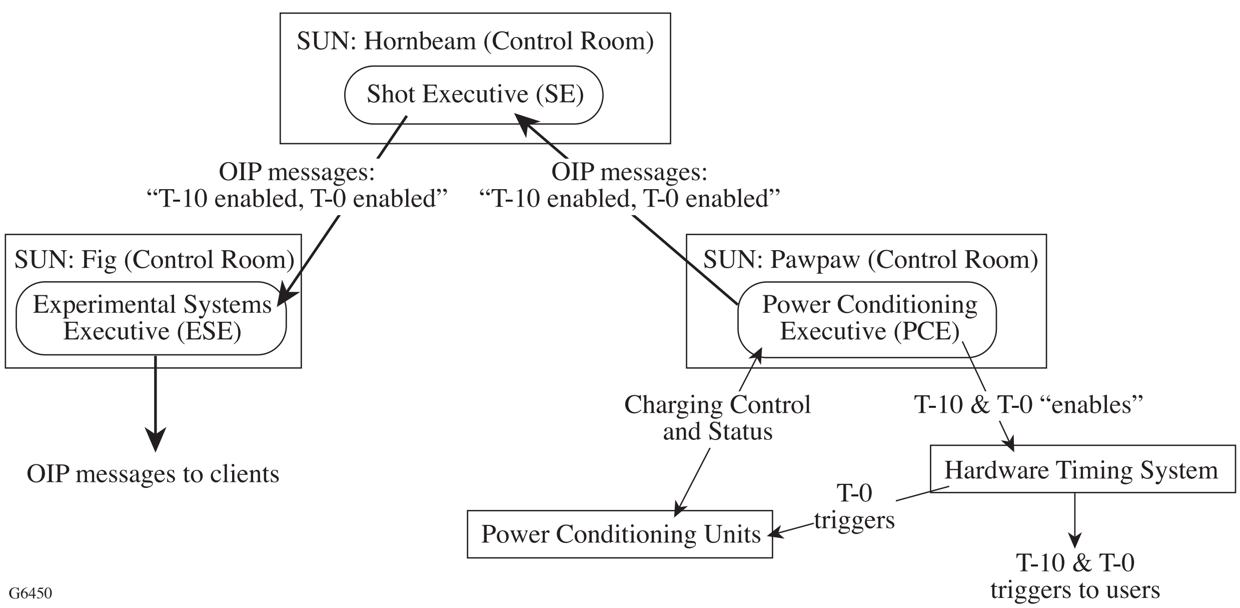

Figure 10.3-1
OMEGA shots are coordinated by the OMEGA Intercommunication Protocol (OIP) messages on the ethernet and electronic Hardware Timing System signals. The key elements for cyrogenic shots are shown here.

When all the Power Conditioning Units have charged to the specified voltage, the Power Conditioning Executive software (PCE) enables the HTS to output triggers 10 sec before the shot (T–10) and at the time of the shot (T–0). These triggers occur in precise synchronization with the HTS periodic rates that generate the laser seed pulse. The "enable" signals precede the triggers by just less than 10 sec and the PCE sends corresponding OIP network messages to the Shot Executive (SE) at the same time. ("T–10 Enable" is transmitted 20 sec before the shot, "T–0 Enable" is transmitted 10 sec before the shot.) The SE passes these OIP messages to its clients, including the Experimental System Executive (ESE). The ESE, in turn, passes them to its clients.

Figure 10.3-2 introduces the control computers and software applications that are directly invovled in preparing for and executing cryogenic shots. (Target detection is discussed separately in the next subsection and some additional details are introduced in subsequent sections.)

10.3.1.1 Experimental System Executive (ESE)

The ESE software runs on a SUN workstation (Fig. 10.3.2) in the Control Room and communicates with the database and other executive processes via the OMEGA Ethernet. The primary function of the ESE is to integrate the operation of the target chamber diagnostics and vacuum system into the operations of the overall OMEGA system. It includes the graphical user interface that displays the status of each of the primary software elements of the experimental system. This software is operated by the ESO.

10.3.1.2 CRYOSHOT

CRYOSHOT is a GUI application that was developed to provide the ESO with an interface to the CTHS elements used on the shot via the lower pylon PLC (see Fig. 10.3-3). The lower pylon PLC implements a state machine that defines the sequence of lower pylon configurations and processes that are involved in mating the MCTC to the lower pylon, connecting to the TC, inserting the MC, docking

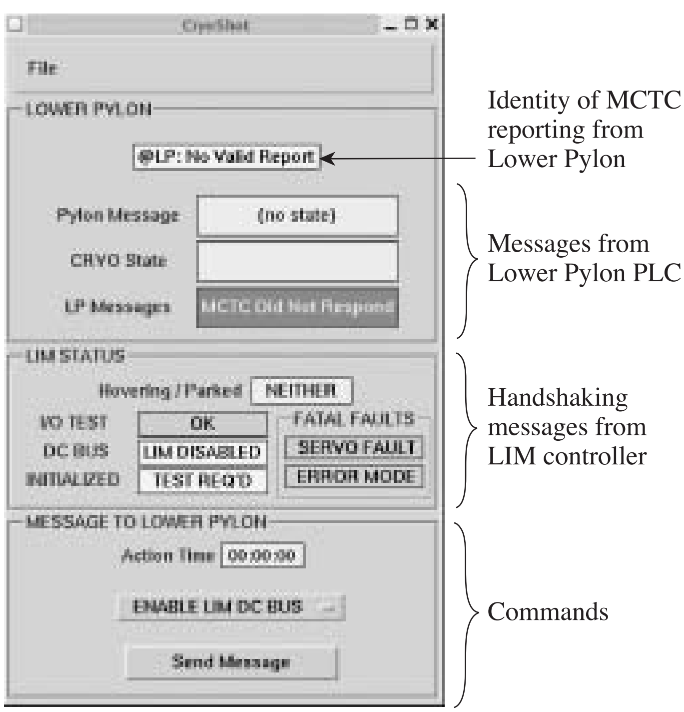

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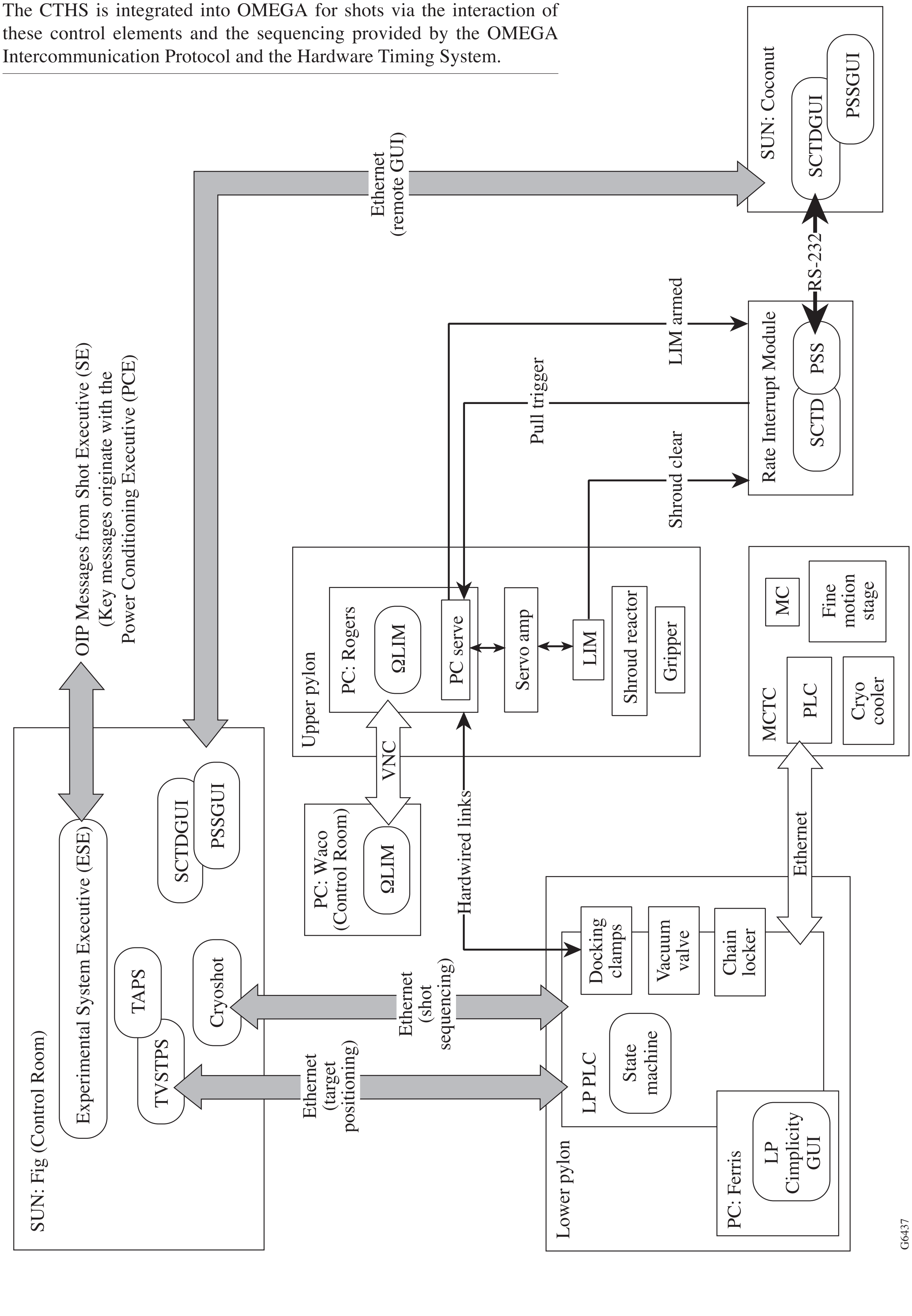
Figure 10.3-3
The CRYOSHOT application provides the ESO with an interface to the CTHS elements that are used on shots.

Figure 10.3-2
The CTHS is integrated into OMEGA for shots via the interaction of these control elements and the sequencing provided by the OMEGA Intercommunication Protocol and the Hardware Timing System.



it at TCC, enabling target positioning and shroud operations, and recovering after the shot. CRYOSHOT displays the state machine status to the ESO and allows many of the key steps to be commanded from the Control Room. CRYOSHOT also accesses the hardware handshaking communication between the lower pylon and the upper pylon and allows the ESO to prepare the LIM for operation and view its general status.

10.3.1.3 Target Viewing System/Target Positioning System (TVSTPS)

The OMEGA Target Viewing System/Target Positioning System (TVSTPS) application was originally designed to control positioning of targets by the ambient target positioner that is permanently installed on the TC (TPS-2). While this application actually runs on a Sun workstation in the Target Bay (not shown), its GUI windows appear on ***fig*** during shot operations. TVSTPS has been extended to include a "Cryo" mode that operates the viewing system illuminators intermittently to avoid disrupting the layering of cryogenic targets and communicates with the fine motion stage in the MC (rather than TPS-2) to adjust the position of the target. This software is operated by the ESO.

10.3.1.4 Target Auto Positioning System (TAPS)

The Target Auto Positioning System (TAPS) is an additional extension of TVSTPS that processes TVS images and generates positioner commands automatically. TAPS is used to precisely position both ambient and cryogenic spherical targets. This software is operated by the ESO.

10.3.1.5 Shroud Sequencing and Spherical Cryogenic Target Detection Program (S3CTD)

The Rate Interrupt Module (RIM) is controlled by the software applications AITED, which is not used on cryogenic shots, and the Shroud Sequencing and Spherical Cryogenic Target Detection Program (S3CTD). S3CTD has a Spherical Cryo Target Detector (SCTD) mode and Planar Shroud Sequencer (PSS) mode, which are mutually exclusive. The former implements the sequencing functions described here and the target detection functions required for spherical cryogenic targets. The latter implements only the sequencing functions and is used for planar cryo operations. (Target detection is not required for planar cryo shots.) Each mode provides the ESO with a GUI that is displayed in the Control Room on Sun workstation ***fig***. Each mode acts as an OIP client of the Experimental System Executive (ESE). Figure 10.3-4 illustrates the S3CTD GUI's.

10.3.2 Lower Pylon Software

The software applications at the lower pylon are summarized in the following subsections.

10.3.2.1 Cimplicity Operator Interface

The state machine is accessed via the Cimplicity operator interface. Each state has a GUI that manages the sequence of operations.

10.3.2.2 Lower Pylon PLC Program

The Lower Pylon PLC serves as the computer communication link between the CTHS elements used on a shot and interfaces them to the OMEGA Control System. A local Cimplicity GUI is also provided in LaCave for use by the ECT. The PLC controls the lower pylon vacuum, chain locker, and MC docking functions directly and communicates with the upper pylon via the hardwired handshaking protocol. This software is operated by the ECT.

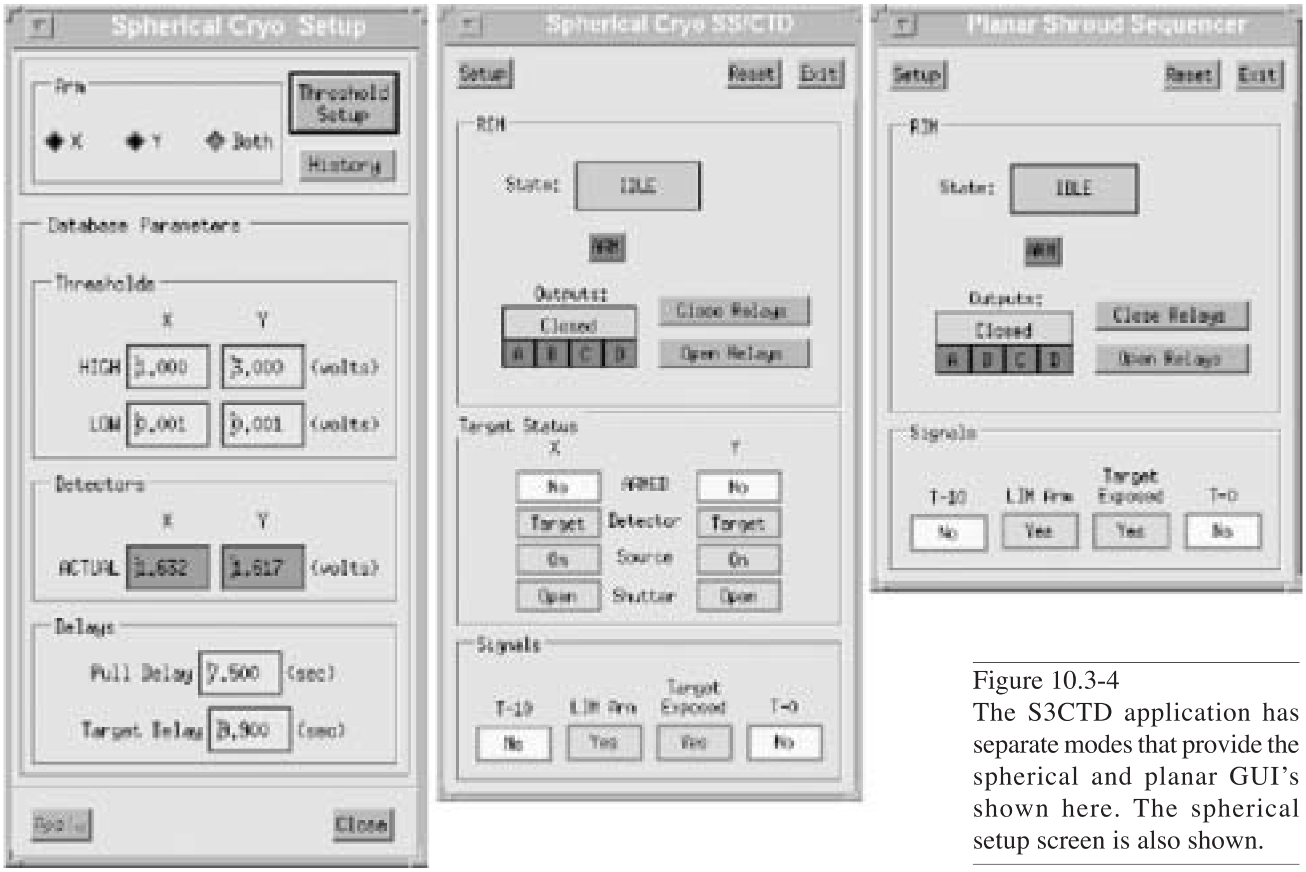


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Figure 10.3-4
The S3CTD application has separate modes that provide the spherical and planar GUI's shown here. The spherical setup screen is also shown.

10.3.2.3 Lower Pylon MCTC PLC Program

A unique digital identification is embedded in the power plug at each location where an MCTC can connect to the Ethernet LAN. When the PLC in an MCTC recognizes that it is located at the lower pylon, it initiates Ethernet communications with the lower pylon PLC, reading a command table at the lower pylon and writing MCTC status information to another table at the lower pylon PLC. Two applications that run on Sun workstation ***fig*** use the LAN to read from and write to registers in the Lower Pylon PLC [both are OIP clients of the Experimental System Executive (ESE)]. This software is operated by the ECT.

10.3.3 Upper Pylon Controls

10.3.3.1 OmegaLIM Interface

OmegaLIM is used to enable user interaction with the embedded controller that operates the shroud retraction motor during cryogenic shot operations. The controller code is designed so that it will operate properly, independent of OmegaLIM. Information about the progress of each operation on the controller can be monitored and controlled through OmegaLIM. Once the controller is configured, OmegaLIM can be disabled or shut down without adverse effects. If it is disabled, however, critical diagnostic information will not be saved with each shot. Figure 10.3-5 is an image of the OmegaLIM GUI.

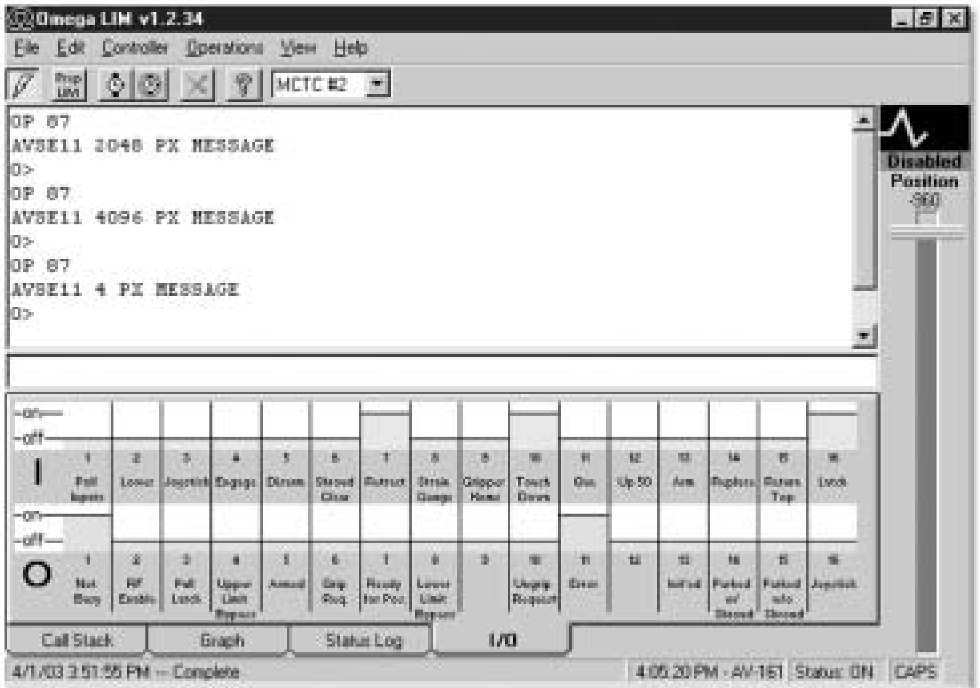

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Figure 10.3-5
The OmegaLIM GUI is available to the ESO via a VNC session with the LIM PC. It provides setup, status, and trouble-shooting capabilities.

10.3.3.2 Rate Interrupt Module (RIM)

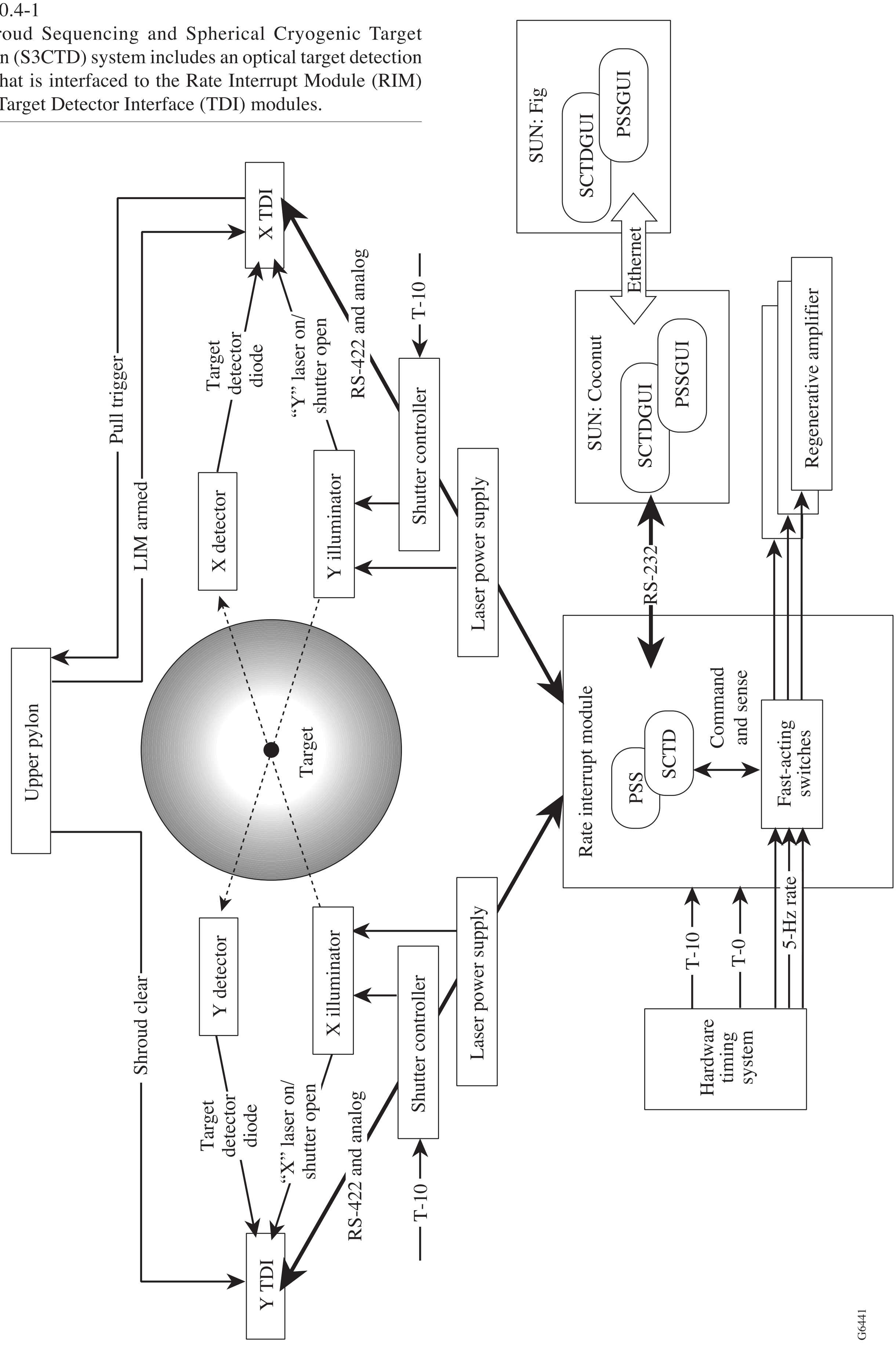
The Rate Interrupt Module (RIM) (Fig. 10.3-2) is a device that is installed in the Driver Electronics Room where it executes its primary function of interrupting the regenerative amplifier pump diode triggers. The RIM has an extensive set of status indicators on its face, but it is primarily controlled and monitored by software applications that run on Sun workstation *coconut* and communicate with the RIM via an RS-232 link.

10.4 SPHERICAL CRYOGENIC TARGET DETECTOR

Because the beam ports on OMEGA's target chamber are arranged in opposing pairs, energy propagated forward in one beamline can pass through the chamber and propagate backward down the opposing beam train. High-value optics can be seriously damaged if a fraction of the high-energy shot pulse is allowed to pass the target and enter the opposing focus lens. The target detection functions of the SCTD mode of the S3CTD system have been put into place to prevent this from happening on spherical cryogenic target shots. Figure 10.4-1 complements Fig. 10.3-2 and shows the details of the target detection system controls.

The Spherical Cryogenic Target Detector (SCTD) uses a backlit imaging system that is very similar to the TVS. The target detector optical assemblies comprise two "axis sets;" each axis set consists of an illuminator and a detector. The axis sets are co-located with the corresponding elements of the TVS. Each illuminator is an optical breadboard that mounts a HeNe laser, a shutter, and the

Figure 10.4-1
The Shroud Sequencing and Spherical Cryogenic Target Detection (S3CTD) system includes an optical target detection system that is interfaced to the Rate Interrupt Module (RIM) via two Target Detector Interface (TDI) modules.



mirrors and lenses that focus the laser beam at TCC and direct it to the detector assembly on the opposite side of the TC. The shutter closes about 5 ms before the shot to prevent the flash from damaging the laser. Each detector is an optical breadboard that mounts to the TC adjacent to the corresponding TVS camera optics. The key functional elements of the detector are a manually adjustable iris and a photodiode. The optical assemblies are aligned so that the illuminator beam passes through TCC and impinges on the iris in the detector. The light that passes through the iris arrives at the photodiode. The diode signals are connected to the RIM, where they are interpreted as illustrated in Fig. 10.4-2.

When there is a target at TCC, some of the beam is blocked and the remainder arrives at the detector. The iris is adjusted to produce a halo of light around the shadow of the target. This results in an intermediate signal on the diode. As the target moves out of the aperture, the signal increases, leading to a “No Target” determination. While it is in place, surrounding the target, the moving cryostat upper shroud blocks the line of sight of the optical assemblies. As a result, the target detection features can function only after the bottom of the upper shroud has passed the target late in the pull sequence.

The HTS T–10 signal is used by the RIM to initiate the shroud retraction (see below) and to determine when the target detection logic should be indicating that the target is in the correct location (“Target” in Fig. 10.4-2). The signals from each of the axes are evaluated independently, and a setup

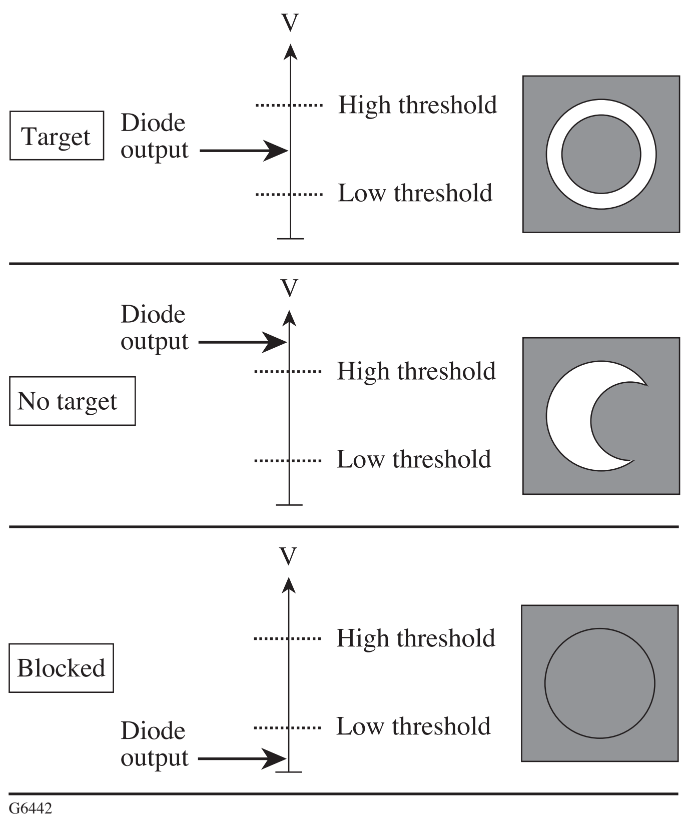


Figure 10.4-2
The target location is diagnosed by logic in the RIM. The signal level of the detector photodiode is compared to predetermined threshold values.

option determines whether either or both must detect the target in order for the shot to proceed. If the criteria are not satisfied, the switches that control the 5-Hz regenerative amplifier triggers are opened. This causes the seed pulse that propagates to the power-amplifier stages to be too low in energy to be amplified to normal levels in the remainder of the system. As a result, essentially no energy reaches TCC, and damage due to energy passing through TCC is prevented.

10.5 SHROUD SEQUENCING

The shroud must remain in place as long as possible before the shot in order to maintain the frozen target layer uniformity, but it must be removed and clear of the beams at the time of the shot. The LIM operates under closed-loop control to follow a trajectory that has been tailored to gently separate the upper shroud from the mating lower shroud, accelerate it rapidly to clear the beams, and then brake it to a safe stop. Figure 10.5-1 shows the basic trajectory. Here, the bottom of the upper shroud moves past the target approximately 1.5 s after the start of the pull and is out of the beams in another 40 ms. The shot can take place after that time but must occur before the LIM begins to slow down, nominally 54 ms after the bottom of the shroud passes the target. In practice, this trajectory is slowed by stretching the time axis to further minimize target vibration.

The shroud sequencing functions of the S3CTD system coordinate the OMEGA shot cycle with the pulling of the shroud so that the shot occurs after the shroud has moved clear of all of the laser beams. This is done by timing from the HTS T–10 signal and issuing the "Pull Trigger" to the LIM controller at the correct instant. The trigger is not issued unless the "LIM Armed" input is present; this

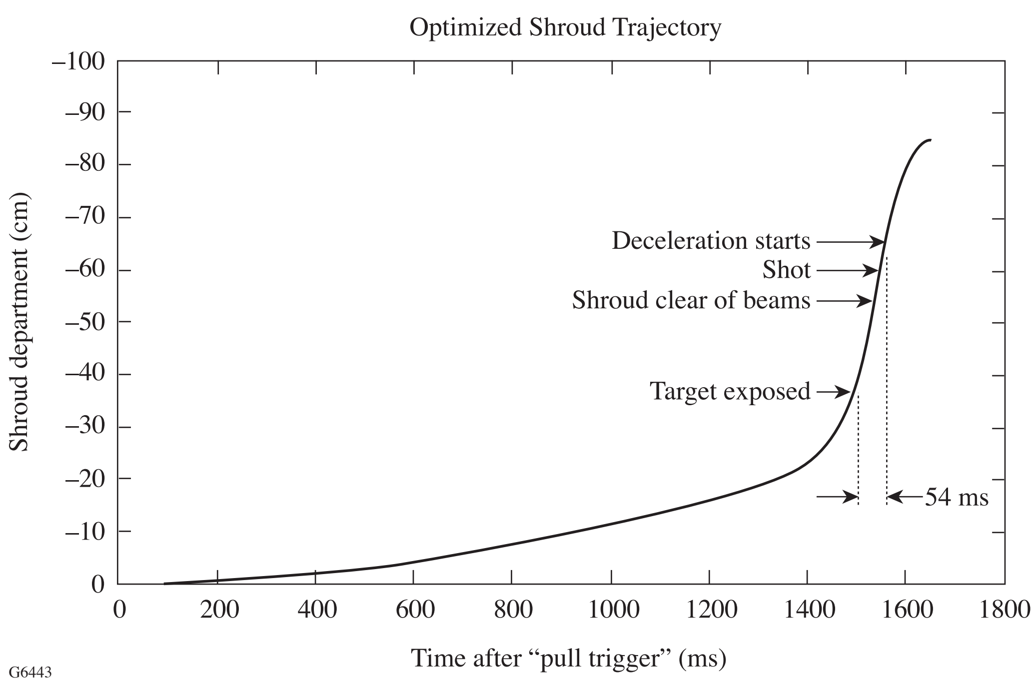


Figure 10.5-1
This basic shroud trajectory was developed to minimize the time that the target is exposed to the target chamber's thermal environment. Half-speed and slower versions of this trajectory are used to minimize target vibration.

indicates that the lower pylon has completed the "Pre-Pull" sequence. If this check fails, or if the shroud does not clear the target at the correct time, the RIM will prevent the propagation of high energy to TCC. If the shot is aborted for reasons outside of the control of the S3CTD system, the resulting OIP message will inhibit the pull trigger if it has not been issued and will prevent the propagation of high energy to TCC.

10.5.1 Shot Day Startup

At the beginning of a day that will include spherical cryogenic shot operations, preparations will include verifying operation of the cryogenic target detectors and powering and initializing the LIM. The CTD activities make use of the GUI's described above and involve a test with simulated shot triggers. They are not discussed in more detail here because they exercise capabilities that have already been introduced.

The LIM preparations can be carried out using the CRYOSHOT application. The CRYOSHOT command area (refer to Fig. 10.3-3) contains a command selection button and a "Send Message" button. These buttons allow the user to select a command from a list and send it to the lower pylon PLC. The selection button lists all possible commands, but only the commands that are safe and valid for the current state of the equipment are actually available to the operator. The complete list includes commands that do not involve the LP State Machine and support LIM preparation or securing actions:

- Enable LIM DC Bus – Powers the LIM servo and enables the motor to operate.
- IO Test – Exercises the LP/LIM controller hardwired handshaking confirm correct operation.
- LIM Motion Test – Causes the LIM controller to move the LIM through a complete travel cycle confirming operation of the motor, latches, and position switches.
- Disable LIM DC Bus – Removes power from the LIM servo, preventing motor operations.

After a locked power switch in the Target Bay has been manually engaged, the first three of these commands are used to perform the "I/O Handshake" test followed by the LIM motion test. The LIM is now ready for use. The final, "Disable ..." command can be used to temporarily secure the LIM until it is needed. It is also used as part of the shutdown sequence when the planned cryogenic operations have been completed.

10.5.2 Shot Preparations – The LP State Machine

The state machine software runs in the lower pylon PLC and functions to manage lower pylon, MCTC and LIM operations through nine numbered states by a combination of automated sequences and operator prompts. The state structure ensures that the operations are executed in the proper sequence. Figure 10.5-2 illustrates the engage shroud sequence and the transition Permissives. The states are also shown for the Cryoshot GUI (displayed in the GUI in Fig. 10.3-3) and the lower pylon state machine GUI.

The Cryoshot GUI provides the following commands to the Control Room operator :

- Engage Shroud – Causes the LIM to move from its home position to contact the upper shroud, (activating a "touchdown" switch in the gripper assembly), operates the gripper motor to lock the gripper and shroud together, and moves the LIM slightly upward to ensure that the upper shroud is supported by the retractor, relieving the MC of its weight.

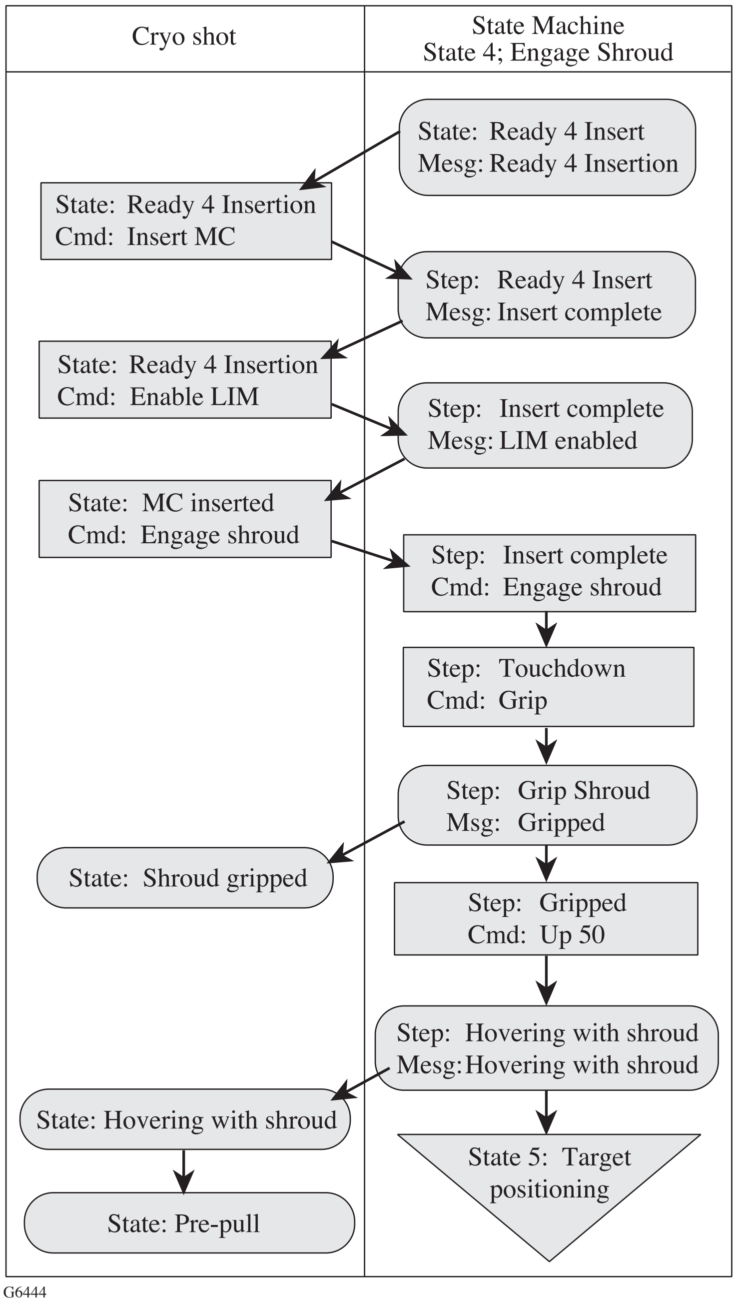


Figure 10.5-2
Lower Pylon Engage sequence.

- Pre-pull – This message is sent automatically by CRYOSHOT during the shot sequence (see below).
- Lower Shroud – Causes the LIM to move from its home position to a position just above the point where contact between the upper shroud and the lower shroud should occur.
- Replace Shroud – Causes the LIM to attempt to move downward from the preceding position to the touchdown position. During this operation, the LIM current is monitored. A drop in the current indicates that mechanical interference is unloading the LIM. When this occurs, motion is stopped and the LIM is retracted slightly and parked. The operator has the option of repeating this command, if it seems appropriate, until the operation is successful.

- Return to Top – Causes the LIM to move to its home position at the top of its travel and to park there.

- Enable LIM – Enables the LIM operation.

- Disable LIM – Disables the LIM operation.

- Motion Test – Performs the LIM motion test between the lower pylon and the LIM. This test is used to calibrate the position sensors and ensure correct operation of the LIM.

- IO Test – Performs the I/O handshake test between the lower pylon (LP) and the upper pylon (UP). This test is used to verify that the control connections are operational between the LP and the UP.

Preparations for a specific cryogenic shot begin when the MCTC containing the target is positioned at the lower pylon. When the MCTC PLC is connected to the Ethernet, it reads the code in the power connector and reports its location to the database via one of the CTHS PC's. It also begins to exchange data with the lower pylon PLC as has been described. Both CRYOSHOT and TVSTPS query the database periodically to identify the MCTC at the lower pylon. The result is displayed to the ESO in the "@LP:" field near the top of the CRYOSHOT GUI (Fig. 10.3-3). TVSTPS uses the MCTC identification to retrieve the current values of the reticle offsets that are used to correct for the effect of the shroud windows on the apparent location of the target.

When the MCTC has been connected to the chain locker and to the lower pylon and the volume between the MCTC isolation valve and the lower pylon isolation valve has been evacuated, the CTHS elements are ready for the MC to be inserted to TCC. The ESO is responsible for the other target area preparations and for ensuring that equipment items do not collide at TCC. The ESO will request that the MC be inserted when all is ready. The drive motor in the chain locker is then operated to drive the MC upward to engage kinematic location points at the top of the lower pylon. Electrically operated mechanical clamps are then activated to secure the MC to the lower pylon. This condition is State 4 in the State Machine.

The cryo mode of TVSTPS turns the TVS illuminators off and switches the target positioning interface from TPS-2 to the fine motion stage in the MC. This mode provides a "Cryosnap" sequence which turns the illuminators on for approximately 2 s and acquires and stores images (narrow x view, narrow y view, wide x view, wide y view) of the target. The images are displayed on monitors and are available for analysis and archiving. When the MC arrives at TCC, Cryosnap is used to verify that the MC is docked correctly and that the target is intact.

The system logic allows the position of the target to be adjusted in this state and in the next state. Current practice is to start the TAPS feature of TVSTPS and allow it to run while the next sequence is accomplished. Whenever a manual or an automatic target positioning command is complete, Cryosnap is automatically activated to acquire a new set of images. TAPS processes each image set to determine the location of the target relative to the computer-generated reticle circles that represent the desired location of the edge of the target considering the effects of the shroud windows. The resulting location error values are used to generate new positioning commands, and the process is repeated until the error is within the acceptable limit. This takes several minutes.

The Engage Shroud sequence takes several minutes and ends with the LIM and the Gripper ready to remove the shroud for the shot. This is State 5 in the State Machine.

The written procedures include provisions to ensure that SCTD and OmegaLIM are both configured for the same shroud pull trajectory. The state logic in the OMEGA control system executives functions to ensure that that SCTD is armed and ready. CRYOSHOT and TVSTPS must also be ready for the shot before the executive system will allow the laser amplifiers to begin to charge. For CRYOSHOT this means that the lower pylon is reporting State 5 and that periodic communication checks remain successful.

10.5.3 The Shot Sequence

Approximately 2.5 min. are required to charge the laser amplifiers. During this time the configuration of the CTHS elements remains static. When charging is complete, the OMEGA Power Conditioning System enables the Hardware Timing System to output the T–10 and T–0 shot triggers. Each enable is sent as soon as the preceding 0.1-Hz synchronization signal is received. A corresponding software message is also transmitted on the LAN: "T–10 Enable" is sent approximately 20 s before the shot, and "T–0 Enable" is sent approximately 10 s before the shot. The events that take place in the CTHS elements from "T–10 Enable" onward are illustrated in Fig. 10.5-3.

When CRYOSHOT receives "T–10 Enable," it waits 2 s and then sends the "Pre-Pull" command to the lower pylon, causing the State Machine to transition to State 6. In the process, two timers are started in the lower pylon PLC and the MCTC is given a "State 6" message.

The "State 6" message causes the MCTC PLC to execute the Pre-Pull sequence that prepares the MC for the shot and to start a timer that will run past the time of the shot and begin the recovery from the Pre-Pull actions. Another timer is set to stop the helium compressor that is used to cool the MC at approximately T–7 s. This eliminates a source of vibrations that can disturb the target. Figure 10.5-4 shows the other MCTC items that are involved.

From the time the shroud is placed over the target in the FTS until just prior to the shot, helium exchange gas is delivered to the Fine Control Box through valve PV-5122 and an umbilical tube. The parting joint bellows are pressurized via valve PV-5152, and a second umbilical tube at this source also holds the box vent valve closed. This forces the exchange gas into the layering sphere and tends to hold it there.

Early in the Pre-Pull sequence (see Fig. 10.5-3), valve PV-5122 is closed and valve PV-5190 is opened to exhaust the exchange gas to the turbo backing system. Approximately 10 s later, valve PV-5152 is closed and valve PV-5124 is opened to evacuate the helium. This allows the exchange gas to vent past the bellows into the TC. The layering laser, which is mounted on the outside of the MCTC, is then shuttered.

When the valve, shutter, and the compressor shutdown commands have been issued, the MCTC PLC signals the lower pylon PLC that the LIM can be armed. When the lower pylon's LIM arm timer expires, the LIM arm signal is passed to the LIM controller, where it enables the LIM to respond to the pull trigger that comes from the RIM. The "LIM Armed" condition is then signaled to the RIM.

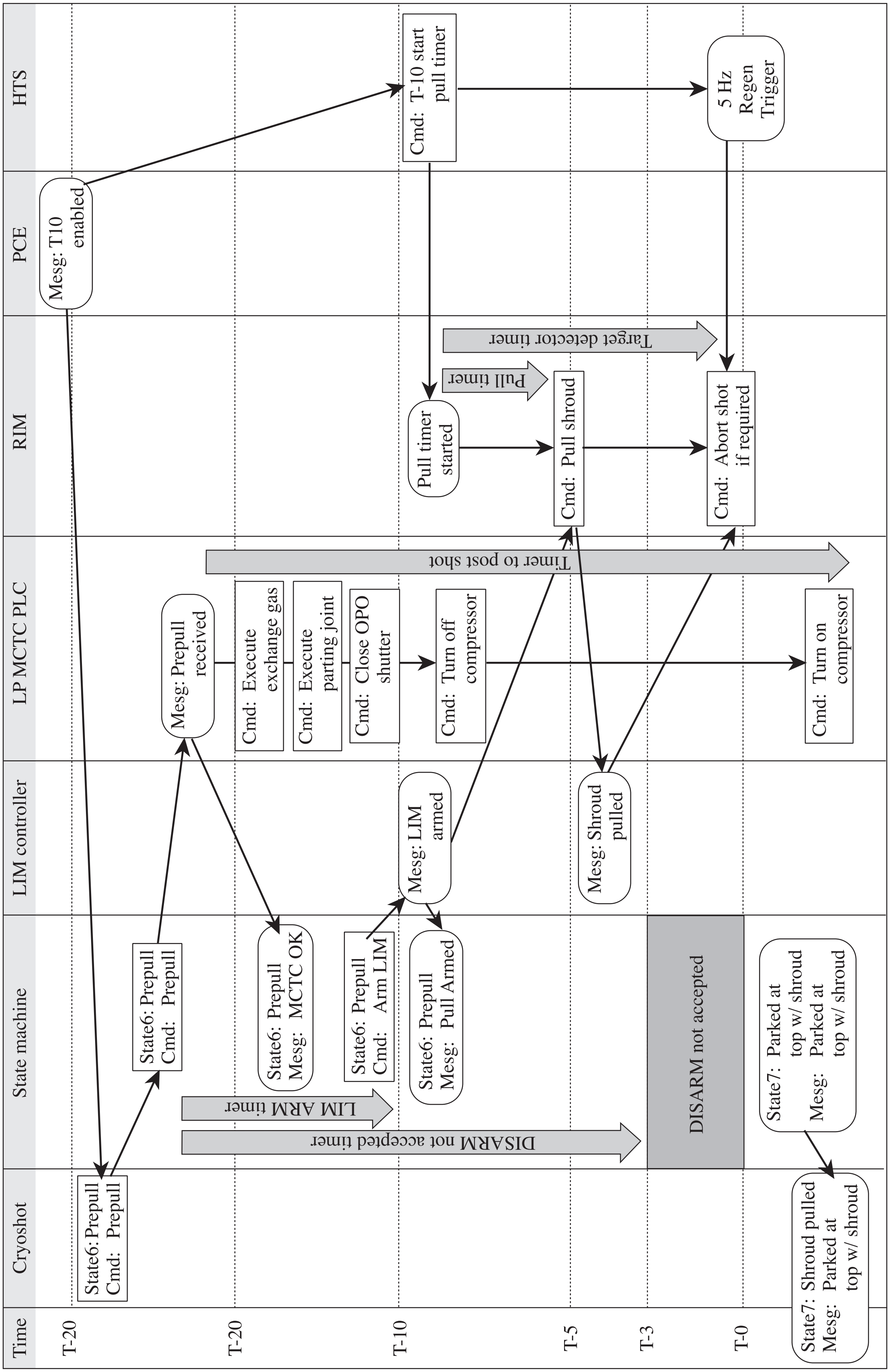


Figure 10.5-3
The event sequence for spherical cryogenic shots (timing is approximate and for reference only).

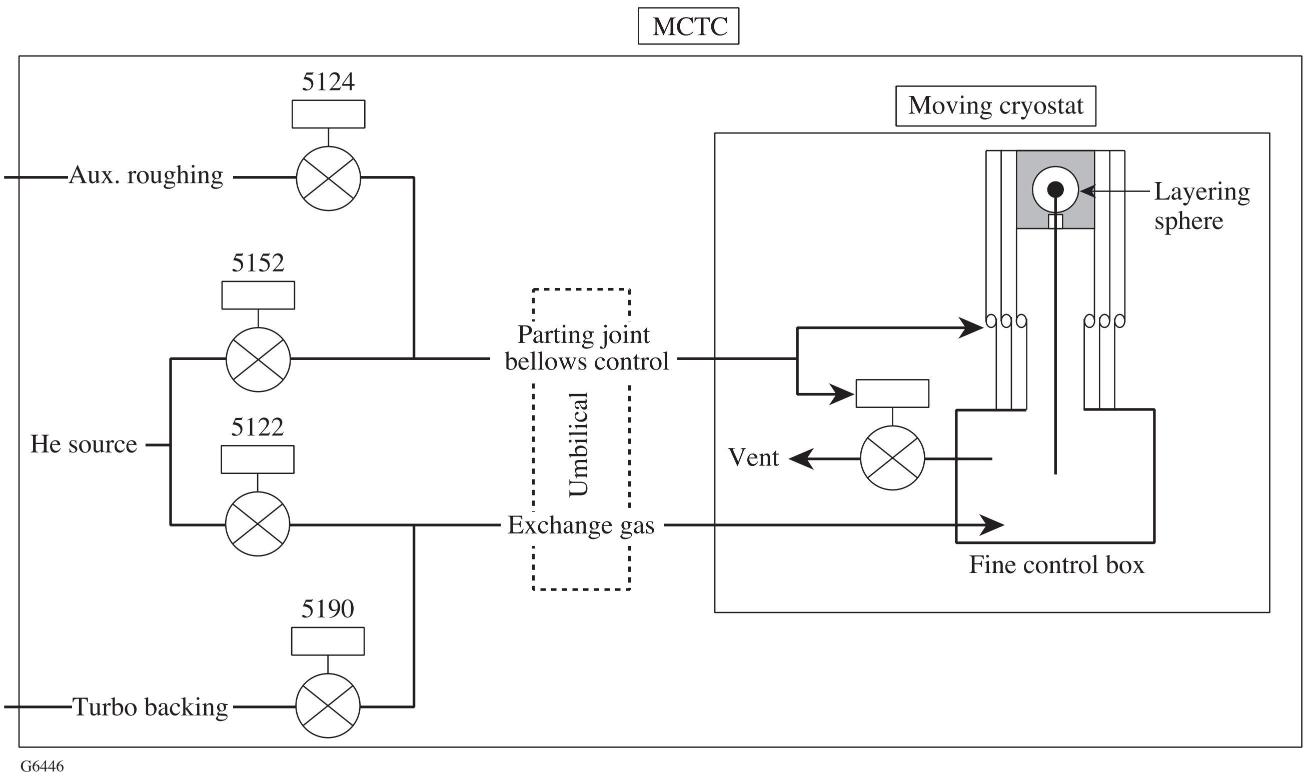


Figure 10.5-4
The MCTC delivers helium "exchange gas" to the layering sphere and maintains an inflation pressure on the parting joint bellows. During the Pre-Pull sequence, the valves shown here are operated to remove the gas and release the bellows.

As Fig. 10.5-3 shows, the sequencing functions of the RIM are initiated when the T–10 trigger is received. This causes two independent timers to be started. The pull timer counts to the precise millisecond when the LIM must be triggered. The target detect timer counts to the time when the shroud should be clear and the target detectors should be indicating that the target is in place.

If the "LIM Armed" signal has not been received, the pull trigger signal is not issued and the regen triggers are interrupted to prevent the shot.

When the target detect timer expires, the armed target detector axes must be reporting "target" and the "shroud clear" signal from the LIM controller must be present for the shot to take place. If these tests fail, the regen triggers are interrupted to prevent the shot.

10.5.4 Aborts and Disarm

A shot can be aborted as the result of problems anywhere in the system. The fact that an abort is underway is conveyed by the OIP ABORTING message. CRYOSHOT and SCTD act on this message to make the system safe and preserve the target if possible.

When SCTD receives the ABORTING message, it commands the RIM to open the fast-acting switches to prevent propagation of the high-energy pulse to TCC. If the pull trigger has not been issued, it is inhibited.

CRYOSHOT can support an abort up to T–3 s by sending the “Disarm” command to the lower pylon PLC. This causes the hardwired “Arm LIM” signal to the LIM Controller to be rescinded so that the shroud will not be pulled even if the trigger arrives from the RIM. The lower pylon reverts to State 5 and also signals the MCTC to “Disarm.” The MCTC responds by skipping to its post-shot activities, which sequence the cryo cooler back on and reinstate the exchange gas.