LICK OBSERVATORY
LASER OPERATIONS

Principal Individual (PI): Kostas Chloros (408-238-9613)
Alternate Principal Investigator: Elinor Gates (408-238-9610) and Donnie Redel (408-238-4267)
Support Scientist (SS): Elinor Gates (408-238-9610)
Alternate Support Scientist: Paul Lynam (408-238-9617 or 408-238-0647)
Location: Lick Observatory, Mt. Hamilton, California

1.0 Reason for Issue

1.1 The UCSC Laser Safety Manual (under development 10/2003) requires a Safety Operating Procedure (SOP) for the operation of a Class 4 laser and operation of a laser delivered to an offsite location.

2.0 Responsibilities

2.1 Kostas Chloros (Ext. 8-9613) is responsible for the safety of this operation and for assuring that all work is performed in conformance with this SOP and applicable sections of the LLNL *ES&H Manual*. In the absence of the PI, 1) Elinor Gates (Ext. 8-9610), or Donnie Redel (Ext. 8-4267) shall assume these responsibilities.

2.2 UCO Lick Observatory is responsible for managing the covered work activities.

2.3 An Laser Use Authorization (LUA) to authorize this activity shall be prepared in accordance with the Laser Safety Manual (LUA) (underdevelopment 10/03). The LUA shall be updated when changes are made to this work scope or implementation of the controls of this SOP.

3.0 Scope of Work

3.1 This SOP covers the Laser Guide Star operations at the University of California's Lick Observatory located on Mount Hamilton, California.

3.2 Procedures within this SOP permit operation of the system during integration and maintenance periods when laser operations are confined within the telescope Dome, and approves operation with bypassed interlock open enclosures for alignment purposes. Operations for light delivery outside the Dome are also approved and covered in the Safety Procedures within the FAA request package for the Laser Guide Star Project (Appendix A).

3.3 The work to be done includes the operation of a 20-watt dye laser system, located in the 3-meter Shane telescope Dome at Lick Observatory. The laser will be operated in support of Laser Guide Star/Adaptive Optical System experiments.

3.4 The laser system at the Lick facility is a 20-Watt tunable dye laser. The system is comprised of 4 frequency doubled YAG lasers, a dye master oscillator, two dye amplifiers, a dye pumping system, optical delivery fibers, beam line telescopes, and laser diagnostic systems. A layout of the system is shown in the diagram in Appendix A.

3.4.1 The frequency-doubled YAG Pump lasers and the Dye Master Oscillator are located in the laser room of the Shane telescope. The laser light is transported through fiber optics from the laser room to the telescope dome. The dye laser pre-amp and power amplifiers, as well as the optical transport telescope and diagnostic packages are mounted on the 3-meter telescope support frame. The laser components are contained in interlocked metal cabinets and fixed beam tubes. The tubes enclose the beam between the two cabinets and exit shutter located on the side of the Shane telescope. Interlocked shutters are incorporated on the input of each fiber and on the output telescope to control light delivery through the system.

3.4.2 Three pumping systems with a capacity of less than 5 gallons each are located in a modified flammable liquid storage cabinet located in the laser room. The cabinet is exhausted to the outside by a ventilation system. Ethanol dye solution is pumped through flexible stainless sheathed Teflon dye lines from the pumping system to the laser table enclosure. The dye lines are contained in a conduit connected to the exhaust system to prevent build up of ethanol vapor in the event of a leak. Control of shutters and remote controlled mirrors is from a PC NT 4.0 computer based system located in the laser room. A comprehensive description of the system is listed in Appendix A.

3.4.3 This SOP approves the use of a radar unit to prevent the laser output from striking an aircraft.

4.0 Hazards Analyses and Controls

The hazards associated with this operation have been analyzed and are listed below. The controls specified for these hazards will reduce risk to employees and the environment to acceptable levels.

4.1 Material Hazards

Materials used in this operation are listed below. Further information regarding the hazards of these materials can be obtained by reviewing the Material Safety Data Sheets (MSDSs). MSDSs are available at the following Internet address: http://www.ehs.ucsc.edu/MSDS_and_Chemical_Info/ . If an MSDS cannot be found or if help is needed in using the database, contact the Environmental Health and Safety (EH&S) (831) 459-2553.

- Up to 15 gallons of ethanol is utilized as a dye solvent in the Lick laser. Ethanol is a flammable solvent with a flash point of 55°F. A leak or rupture of the pumping system could lead to a significant fire involving the alcohol. The permissible exposure criterion for ethanol in air is 1000 ppm.

- Rhodamine 2 (R2) laser dye is listed as a moderate control class dye and is dissolved in ethanol. R2 dye is a nonmutagenic dye. In solution it can cause eye irritation and is slightly toxic. Preparation of laser dye solutions, from powder to liquid, at the Lick Observatory is prohibited under this SOP. Only pre-prepared solutions of laser dyes will be used and stored at Lick Observatory.

- Small amounts of acetone, ethanol, and methanol are used to clean equipment and optical components on an incidental basis. These are all flammable liquids. High airborne acetone concentration may irritate the lining of the eyelids and mucous membranes of the nose and throat. Headache, drowsiness, and mild eye and nose irritation can occur from high ethanol and methanol concentrations. Prolonged exposure can produce headache, drowsiness, tremors, and fatigue. Extended dermal contact with the agents can produce dermatitis. Methanol can be absorbed by the intact skin. During normal usage, exposure by inhalation and skin contact should not be a significant concern.

- Four 50-gallon drums of dye solution are stored on the Lick Observatory site in a flammable storage area in the Optical Shop area of the Shane Dome. This solution is dye mixed with ethanol in a percentage suitable for filling the dye system at Lick. There is no provision for mixing additional dye solution presently under this SOP either at the Lick site.

The following controls will reduce the risk of material hazards:

4.1.1 Only authorized trained personnel familiar with the dye and dye handling equipment may work with the dye and dye solvent material.

4.1.2 Do not eat, drink, store food or beverages, or smoke in the dye work area.

4.1.3 Cap off dye lines that are not in use when portions of the dye flow system are removed.

4.1.4 Keep containers of solvents and dye solutions closed and stored in a flammable liquid storage cabinet.

4.1.5 Transport solutions in sealed, labeled containers. Containers should be made of impact-resistant and dye-solution-compatible materials.

4.1.6 When loading or draining ethanol dye mix into the dye pump cabinet reservoirs, the following procedures shall be implemented:

- Doors to the laser equipment room shall be opened and the exhaust fan for the dye pump skid cabinet activated to insure adequate ventilation.
- Dye concentrate and ethanol are transferred to and from the system by using a pressurized 5-gallon stainless steel container. A pressure regulator and pressure relief valve are used to insure that 20 psi is never exceeded during the dye loading.
- Only compressed nitrogen or argon shall be used as a purge gas.

4.1.7 If a dye spill occurs, only authorized personnel who are trained in the handling of dye should perform the cleanup. The spilled dye is considered hazardous waste that is to be collected and disposed according to Environmental Protection Department guidelines. Special cleanup rags, absorbent, and disposal containers are provided for this purpose. See section 4.6 *Environmental Hazards*.

4.1.8 Use safety glasses with side shields and face shield or chemical safety goggles. Use neoprene or nitrile gloves for handling dye dissolved in ethyl alcohol.

4.1.9 Due to the presence of flammable dye mixtures and the high average power laser, fire hazards must be addressed. There is one dye laser enclosure mounted on the Shane Telescope. The enclosure is equipped with a FM200 self actuated extinguishing system and a flame sensor (UV phototube). This fire sensor activates an audible alarm.

4.1.10 The CO_2 extinguisher and the flames sensor in the dye master enclosure on the Shane Telescope will be deactivated while personnel are working in the man-rated basket near the laser in order to prevent injury from the extinguisher accidentally being set off. There is a potential that the enclosure doors will blow open and hit a worker in the face or that large quantities of CO_2 could cause freezing or suffocation. The extinguisher will be pinned during these operations and a hand-held extinguisher will be carried in the man-rated basket as the precaution against fire. Workers will re-arm the extinguisher by pulling its pin when the dye laser is returned to normal operation.

4.1.11 A self-actuated FM200 fire extinguisher is installed in the dye reservoir/pump cabinet located in the laser room. This is activated by a heat sensor within the dye cabinet.

4.1.12 Use and storage of flammable liquids will be done in accordance with the California Fire Code (CFC) 2001.

4.1.13 A sink is located outside the laser room and is less than 100 ft. from the dye/solvent plumbing system and handling area. This sink will be used as an operable eyewash.

4.1.14 The dye pumping system located in a modified flammable liquid storage cabinet houses three separate pumping systems each having a capacity of 5-gallons of ethanol. The following design features have been incorporated to reduce the risk of fire:

- All electrical service for the pumps complies with the NEC for hazardous locations (Class I, Div. 2) inside the cabinet.
- The cabinet is vented via an exhaust duct to the outside to prevent the build up of ethanol vapors.
- The dome laser enclosure is ventilated by the dome negative air system.

4.1.15 Dyes shall be handled in accordance with the UCSC Laser Safety Manual (LSM) (under development 10/03)

4.1.16 When wipe cleaning use disposable nitrile gloves to prevent dermal contact with solvents.

4.2 Laser Hazards

Class 4 lasers can cause eye damage or severe skin burns with inadvertent exposure to the laser beams or diffuse reflections from nearby objects. Class 4 laser light is present in all the laser enclosures of the Lick laser and in fiber optics. Laser sources are listed in Appendix C.

YAG Pump Lasers

- 1.06 micron infrared lasers operating at 13 kHz.
- 532 nm frequency doubled YAG laser light is present inside the YAG Pump laser housings and fiber optic cable outputs in the Dye Master Oscillator (DMO) and Laser Table enclosures at 13 kHz.
- The light emitted from a fiber optic cable constitutes an eye hazard similar to that of the input laser beam within normal working distances from their output.

Dye Lasers

- 589 nm laser light produced from the DMO is present on the DMO table.
- 589 nm light is present at the exit of the single mode fibers.
- Up to 20-Watts dye laser light is generated from dye amplifiers on the laser table and is delivered through the system to the output shutter of the launch telescope enclosure.

The following controls will reduce the risk of laser hazards:

4.2.1 All laser operations shall be conducted by trained LLNL and/or UC Lick personnel adhering to the controls and procedures set forth in the UCSC Laser Safety Manual and this SOP.*"*

4.2.2 Access to the laser room and the Shane telescope dome room shall be by interlocked doors. Only authorized personnel and personnel trained in the hazards of lasers and the associated systems will have access to the cipher combination. All doors to these areas are interlocked to the laser safety system and will close shutters and/or disable power supplies when opened during unsafe (Class 4) conditions. Access panels to enclosures not interlocked shall require the use of tools, (i.e., bolted or screwed on access panels) and an appropriate warning sign warning that removal exposes personnel to Class 4 laser light. Interlocks shall be tested quarterly and the results shall be recorded in the Laboratory Safety Notebook.

4.2.3 During normal operations, all enclosures are closed reducing the laser hazard to Class 1 laser light in both the laser equipment room and telescope dome.

Interlocked metal enclosures contain the laser light throughout the system. Interlocked access panels are designed to close safety shutters, or disable YAG power supplies to eliminate laser light into the violated enclosure.

Safety control shutters operated from a central control console with keyed permissive/lockout control are incorporated into the system to permit the controlled operation of light delivery only when all requirements for safe operation are in place and have been verified.

4.2.4 When laser light delivery outside the telescope dome is to be initiated, the controls and procedures listed in Appendix A of this SOP shall be followed to prevent the inadvertent exposure of personnel outside the facility to Class 4 laser light.

4.2.5 Operation of the laser system in a bypassed interlock mode will be required for alignment and maintenance activities. The following administrative and equipment controls shall be in place when any bypassed interlock operations are being conducted:

- Only trained authorized workers (AW) who are authorized by the PI shall initiate bypassed interlock operations. A list of the AWs will be maintained in the Laboratory Safety Notebook.

- Before bypassing an enclosure, the AWs in conjunction with the PI or the alternate PI, shall insure that only AWs are present and that administrative controls for bypassed interlock operations of the SOP are completed.

- All bypassed interlocked alignment operations shall be conducted with lowest power alignment light to accomplish the task.
- Enclosures shall remain open and in bypass only as long as necessary to complete the task. When the work is complete, the bypass keys shall be returned to the normal position, which reactivates the interlocks.

4.2.6 When opening a laser enclosure, the worker shall guard against any unexpected or misaligned beam that could reach his/her or anyone else's eye.

4.2.7 Prior to active alignment, the AW should perform a visual inspection at the lowest practical beam power to confirm that all beams are contained within the appropriate optical apertures and confined to the controlled paths.

4.2.8 Only tools with dark, roughened surfaces may be used for laser beam alignment.

4.2.9 All personal items with specularly reflective surfaces (e.g., rings, watches, necklaces, badges, and keys) will be removed when performing laser beam alignment or working in close proximity to laser beams.

4.2.10 Diffusely scattering surfaces may be used for visual examination of laser beam profiles or location. For powers under 100 mW at view distances greater than 50 cm., a white card may be used for a maximum cumulative exposure of 10 minutes in any 3-hour period. Viewing of higher power beams requires diffuse matte black beam blocks at viewing distances greater than 100 cm. Enclosures which are bypassed shall never be unattended when laser light is present.

4.2.11 All workers authorized to work directly with the laser system will be thoroughly familiar with and understand the safety system.

4.2.12 Special care should be taken when working with the optical fibers of the system. To prevent exposure to laser light the following steps shall be taken:

- All fibers shall be labeled indicating their light source.
- Before beginning work on a fiber that does not require laser light, steps shall be taken to insure that laser light cannot be present in the fiber (e.g., disconnect the fiber from the laser source).
- Never look directly into the output of a fiber that is connected to a laser source. Shutter all possible laser sources that may inject light into the fiber before looking into the fiber end.

- Fibers shall always be properly terminated, installed into a laser, amplifier, or pointed into a beam dump to prevent damage or inadvertent exposure of personnel to laser light.

- Handle fibers with care during installation and movement. Extreme bending or rough handling could damage a fiber and create a hazard at the break point when high power laser light is delivered. Fibers should be periodically tested for power throughput.

4.2.13 Before bypassed interlock alignments can be conducted in the telescope dome, the following steps must be taken:

- The gallery observation area shall be cleared and locked during operations in which any laser light is emitted from an enclosure in the telescope dome. A warning sign shall be posted.

- Intercom communication shall be established and maintained between the shutter control area and the individual performing the alignment operation.

- Manlift controls and procedures spelled out in Appendix D shall be followed when accessing the laser system components on the telescope.

4.2.14 The DMO table enclosure acts as barrier. This enclosure shall not be removed for laser alignment or beam delivery path alignment.

Steps shall be taken to insure that beam reflections, both specular and diffuse, are contained in controlled paths. Personnel entering the room shall ask permission from the AW conducting the alignment work before entering the area.

4.2.1.15 High power laser light is present inside the YAG laser enclosures. The following procedures will be necessary when alignment operations are conducted with the YAG laser enclosures removed.

- When the YAG 1-4 bypass key is turned, it will permit a YAG enclosure to be removed without shutting down the laser. The bypass key will also activate the red warning sign on the laser room door indicating that laser alignments are in progress and require a higher level of access code to enter. Only AWs are allowed in the laser room during high power alignment.

- Prior to beginning work, the AW will ensure that all nonessential workers are cleared from the area.

- Prior to working with exposed beams, the AW will perform a visual inspection of the optical layout to ensure that all beam paths are contained within the controlled area and that no flammable materials are in or near beam paths.

- The required safety goggles sufficient to reduce the laser power below the MPE will be worn at all times in the enclosed work area when exposed laser beams are present.

- Only blackened metal plates may be inserted into the laser beam.

4.3 Electrical Hazards

Contact with high voltage sources could result in severe electrical shock or death. The following lists the specific sources:

- High voltage/high current (208 volt, 50 amp) power sources are present in the commercial YAG power supplies. High voltages up to 30 kV low current lamp ignition sources are used to start the YAG flashlamps.

- Commercial RF amplifiers generating up to 50 W peak power of RF are utilized by the YAG Q-switches. The PRF of the RF amplifier is 13 kHz with a pulse duration of 1μs, for a duty factor of 0.026 and one watt average power. This is considered a non-radiation hazard per LLNL *ES&H Manual*, Volume II, Part 20.7, *"Non-Ionizing Radiation and Fields."*

- HV PZT driver power supplies generating 1 kV are used to drive scanning interferometers and PZT optic mounts located on the DMO diagnostic tables.

- 120-volt commercial electrical equipment will be operated in conjunction with the laser system. The possibility of an electrical shock can occur if protective housings are removed from the equipment exposing voltage sources.

The following controls will reduce the risk of electrical hazards:

4.3.1 All work with electrical equipment shall comply with the provisions of the California Electrical Coded (CEC) 2001 and the UCSC Lock-out Tag-out policy (http://www.ehs.ucsc.edu/Safety/ehs.asp?page=Lock-out_Tag-out).

4.3.2 The presence of exposed conductors at voltages greater than 50 volts within an enclosure shall be clearly indicated by labels.

4.3.3 Always work on equipment that has been totally de-energized.

4.3.4 High voltage systems utilized in the system are commercial designed. Any changes to electrical systems may not be conducted without approval of the PI and the Lick Laboratory Safety Officer.

4.3.5 An SOP is required before working on any energized electrical hazard Category 3 or 4 system.

4.4 Radar Hazards

The intrusion radar system is mounted on the barrel of the 3-meter telescope next to the projection lens of the laser launch telescope. The characteristics of the radar are described in Appendix A.

This radar poses a minimal hazard to personnel due to its remote location, the narrow angle of the beam, the distance between the beam and nearby reflectors, and beam divergence, which will preclude hazardous reflections from aircraft, etc. Radar and other emitters are not tolerated at an observatory due to electromagnetic interference with equipment, which typically occurs at levels well below the permissible exposure criteria for humans. The permissible exposure criterion at 9375 MHz is 10 mW/cm^2 according to IEEE/ANSI C95.1-1991.

The following controls will reduce the risk of radar hazards:

4.4.1 The radar shall be securely connected to a dummy load for maintenance, which reduces emissions to levels well below the permissible exposure criterion.

4.4.2 Exposures shall be assessed by the ES&H Team 2 Industrial Hygienist if there is reason to suspect that microwave exposures are occurring.

4.5 Elevated Work Hazards

Personnel may be required to access equipment located on the 3-meter telescope during laser alignment and maintenance activities. Man lifts and other special lifting equipment will be utilized. The potential for serious injury or death exists since falls from the equipment would exceed 6 feet. Two types of lifting devices are utilized: a man lift and crane-lifted man-rated bucket.

The following controls will reduce the risk of elevated work hazards:

4.5.1 Only Lick authorized personnel shall initiate the set-up of the man lift for operations.

- No more than four people may be on the man lift at a time.
- Never hang over the rail of the man lift to conduct work.
- Secure items on the lift to prevent objects from falling off the lift that could potentially harm someone standing below.

4.5.2 In order to work on the dye amplifier table or diagnostics table, a lifting device is required to elevate the worker to the location. The Shane telescope 5-ton bridge crane is used to elevate a man rated bucket. Only authorized workers shall set up and use the lifting devices. The following procedures shall be followed when working at the elevated heights:

- Only authorized, trained personnel shall conduct work with the man rated bucket.
- Only authorized, trained personnel may operate the crane with the man rated bucket attached.
- A safety harness shall be worn by personnel at all times when occupying the bucket.
- The procedures and controls for operations involving the man rated bucket, which is listed in Appendix D, shall be followed when operating the man rated bucket.
- The floor area underneath the man rated bucket shall be cordoned off to avoid exposing anyone on the dome floor to falling objects.

4.6 Environmental Hazards

Some of the activities planned and/or materials to be used in this operation have the potential of causing unacceptable or unallowable impacts on the environment.

The following controls will reduce the risk of environmental hazards:

4.6.1 Experimental personnel shall comply with the UCSC *Pollution Prevention Plan*.

4.6.1.1 Projects and programs shall evaluate their hazardous, nonhazardous, and construction/demolition (including clean-up and stabilization) waste streams for reuse or recycling opportunities, prior to disposal, to assist UCSC in meeting UC performance measure goals included in the contract for operation of UCSC regarding waste diversion.

4.6.1.2 Projects and programs shall evaluate their procurement practices to utilize products with recovered/recycled content (also know as affirmative procurement) where products are available, comparably priced, and within performance requirements to assist UCSC in meeting Secretary of Energy goals regarding affirmative procurement. The US Environmental Protection Agency (EPA) has audit authority regarding affirmative procurement at UCSC.

4.6.2 Any waste materials generated by work under this SOP will be handled appropriately as hazardous waste according to the policies and practices outlined by EH&S (http://www.ehs.ucsc.edu/Waste_Management/).

4.6.3 All generated waste shall be disposed of in accordance with the procedures established by the EPA hazardous waste permit for the Lick Observatory. For assistance in disposing of generated hazardous waste, contact the Facilities Supervisor, Joe Halay, (408) 238-9614.

4.6.4 Solvent substitutes, such as aqueous cleaners, shall be used to the extent practicable.

4.6.5 Wipes of acetone, isopropyl alcohol, and ethanol that are non-saturated are considered nonhazardous and may be disposed of in the municipal trash. Saturated wipes will exhibit the hazardous characteristic and need to be managed as hazardous waste. It is not permissible for wipes to be left out for the express purpose of drying.

5.0 Training and Required Reading

5.1 The Principal Investigator shall assure that:

- Individuals who use this equipment or perform this operation are trained to recognize the intrinsic hazards, are aware of basic safety information that relates to their job assignment, and know the safe operating requirements for this activity.

- The operating personnel have read and understood the contents of this SOP and all applicable references stated in this SOP.

-

6.0 Maintenance, Inspections, and Quality Assurance

6.1 The PI is responsible for ensuring that all required maintenance of safety systems and equipment is conducted at the recommended frequencies.

6.2 All safety interlocks are to be tested for proper operation at least every three months. A written record of this safety check and the proper functioning of the interlocks are to be maintained by the PI.

6.3 Maintenance of the electrical systems shall be performed by qualified personnel who have been properly trained and authorized. An example of the information required is in Appendix E, *Quarterly Interlock Checklist.* An interlock key diagram is listed in Appendix F.

6.4 All fall protection devices shall be inspected prior to use by the individuals using them.

6.5 All cranes, hoists, and slings shall be inspected daily by the operator prior to use. All cranes shall be formally inspected monthly by the operator. Cranes and lifting fixtures shall be load tested every three years. Records of these tests and inspections shall be maintained.

TRAINING MATRIX			
Class Number	Class Title	Personnel Required	Periodicity
EP0006 or	Hazardous Waste Generation and Certification	All personnel (LLNL and contract) who generate or handle hazardous waste shall attend this Environmental Protection Department course in order to ensure that waste generation, handling, and certification responsibilities are properly performed.	Within six months of being newly hired or reassigned and prior to the generation of hazardous waste.
EP0006R	Hazardous Waste Generation and Certification Review	Personnel responsible for characterizing hazardous waste and/or signing hazardous waste requisitions.	On an annual (365 days) basis following the completion of EP-0006.
HS4050-W ((web training)	Health Hazards Communication for SupervisorsPI	Once within 90 days of assuming the responsibilities of the PI.	
HS4240-CBT	Chemical Safety	Personnel who transport, handle, or work with chemicals.	Once prior to transporting, handling, or working with chemicals.
HS4242	Special training for toxic laser dye solution	Personnel who transport, handle, or work with toxic laser dye solutions	Once prior to transporting, handling, or working with toxic laser dye solutions
HS5200-CBT	Laser Safety	All personnel who work with or near exposed Class 2, 3, or 4 laser light or who service any system containing such light.	Prior to working in facility and every five years thereafter. (*A laser eye examination is also required prior to working in the facility*)
HS5220-W (web training)	Electrical Hazards Awareness	Personnel who work on or around electrical systems.	Prior to working in the facility and every five years thereafter.
HS5230-W ((web training)	High Voltage Safety	Personnel who work on or around high voltage systems.	Prior to working in the facility and every five years thereafter.
HS5620	Incidental Fork Truck Safety	Personnel who operate the fork truck (<9000 lbs capacity).	Once, prior to operating the fork truck.
HS5690	Incidental Crane Safety	Overhead crane operators who use cranes or hoists and rigging to lift 2000 lbs or less.	Prior to using cranes or hoists and every five years thereafter.
HS5700	Intermediate Crane Safety	Crane operators who lift 2000 lbs to 5 tons.	Prior to using cranes or hoists and every three years thereafter.
HS5960	Fall Protection	Employees who work or may work at elevated heights (e.g., roofs, scaffolds, towers, and man lifts).	Prior to work at elevated heights (e.g., roofs, scaffolds, towers, and man lifts).
	Lick Safety Orientation	All personnel who work at the Lick Observatory Site	Once prior to working at the Lick Observatory Site. Contact PI for briefing.

7.0 Emergency Response Plans and Procedures

7.1 Personnel operating at the Lick Observatory will fall under the auspices of the Lick Emergency Response Team, which includes fire fighting, paramedical, and ambulance services.

7.2 All electrical shock victims shall be transported to the appropriate medical facility due to the potential for delayed cardiac failure.

7.3 Injuries and medical illness that do not require an ambulance response, but do warrant medical attention, should be transported to Health Services by an uninjured party. If in doubt of the seriousness of the injury, treat it as an emergency.

7.4 Notify the Principal Individual (PI): Kostas Chloros (408-238-9613) of any safety-related occurrence resulting from Lick Guide Star activities as soon as time permits. Kostas Chlroros, UCSC EH&S, and the UCSC Risk Manager are responsible for follow-on reporting of any occurrence resulting from Guide Star activities at Lick Observatory.

8.0 References

8.1 UCSC Injury Illness Prevention Program (IIPP).

8.2 UCSC Chemical Hygiene Plan (CHP).

8.3 UCSC Laser Safety Manual (LSM) (under development 10/03).

9.0 Review and Approval

The following reviewers have distributed this plan to appropriate personnel within their organizations for review of technical accuracy. The controls listed in this plan are adequate for the subject work to be done. This operation is consistent with technical safety requirements or operational safety requirements.

Reviewed by:

Kostas Chloros Date
Principal Investigator

Concurred by:

Date Date

UCO Lick Director – Claire Max

Concurred by: *Approved by:*

Date Date

UCSC Laser Safety Officer – Ken Smith

<u>Controlled Distribution:</u>
Chloros, K.
Gates, E.
Gavel, D.
Smith,G
Max, C
Lynam, P
Smith, K.
Other LLNL folks?

APPENDIX A: SAFETY PROCEDURES LASER GUIDE STAR

Purpose

The purpose of these safety procedures is to assure that non-eye safe lasers can be operated at the 3 meter Shane telescope, Lick Observatory, Mt. Hamilton, California without exposing any person, either at the telescope or in an aircraft nearby, to hazardous levels of radiation.

Summary

The laser guide star technique involves the propagation of a laser beam towards stars and other astronomical objects to provide a beacon or guide star, for use with adaptive optics as a means of compensation for atmospheric turbulence. This laser system is not powerful enough to damage materials but it is hazardous to human eyes if the beam is viewed directly. Viewing diffuse reflections of the beam is not hazardous to human eyes. These conclusions are based upon the Maximum Permissible Exposure (MPE) levels set by ANSI standard Z136.1-1993. It is therefore required that adequate safety procedures be implemented to prevent direct exposure of the beam to persons on the ground or in aircraft.

The safety procedures for the Lick installation are based on the experience gained at LLNL in over two years and greater than 25 propagation events, and on the techniques developed at the Starfire Optical Range at Kirtland Air Force Base, Albuquerque, New Mexico. The aircraft safety system for the Lick Observatory consists of two Visual Observers (VO) located on the ground on opposite sides of the dome at a distance of about 20 feet which provides each visual observer with a greater than 180 degree visual observation and an "intrusion" radar which is boresighted to the laser beam. The VO's are trained to look for aircraft and are in constant communication via an intercom link with the Laser Operator (LO) and the test team. The VO's keep them informed of air traffic so that the LO can shut down the laser system in an orderly fashion well in advance of approaching aircraft. This is the normal mode of operation. The VO's also have cut off switches that enables them to immediately activate the laser beam block if a low flying aircraft suddenly appears or if the LO fails to respond.

The intrusion radar protects highflying aircraft from being illuminated by the laser beam. These aircraft may not be visible to the VO. The intrusion radar is modified weather radar which has a narrow cone of radiation approximately 7.5° wide centered about the laser. An aircraft entering the radar cone at an altitude of 10,000 feet (or 5600 feet above Mt. Hamilton) at a speed of 250 knots would require over a second to intersect the laser beam, which is in the center of the radar cone. The time to block the laser beam is under 0.1 second giving an acceptable safety margin for this operation. It is the experience at LLNL and elsewhere that a VO can easily detect aircraft at altitudes well beyond 5000 feet so there is considerable overlap between these two aircraft detection methods. The intrusion radar is effective in detecting all aircraft to an altitude of 60,000 feet so that full coverage is provided.

Mt. Hamilton is the highest peak within a hundred mile radius and the closest local airport (Reid Hillview) is 10 miles away. The normal approach patterns for Reid Hillview Airport are not over Mt. Hamilton. To the West the entire San Jose area is visible. To the East lies the San Antonio

Valley and an unobstructed view to the first range of hills at a distance of about 10 miles. To the South there is an unobstructed view across the Santa Clara Valley to Loma Prieta and Mt. Umunhums at a distance of about 20 miles. To the North, Mt. Diablo is visible. Under these conditions the two VO's have an excellent viewing capability and search radar is unnecessary.

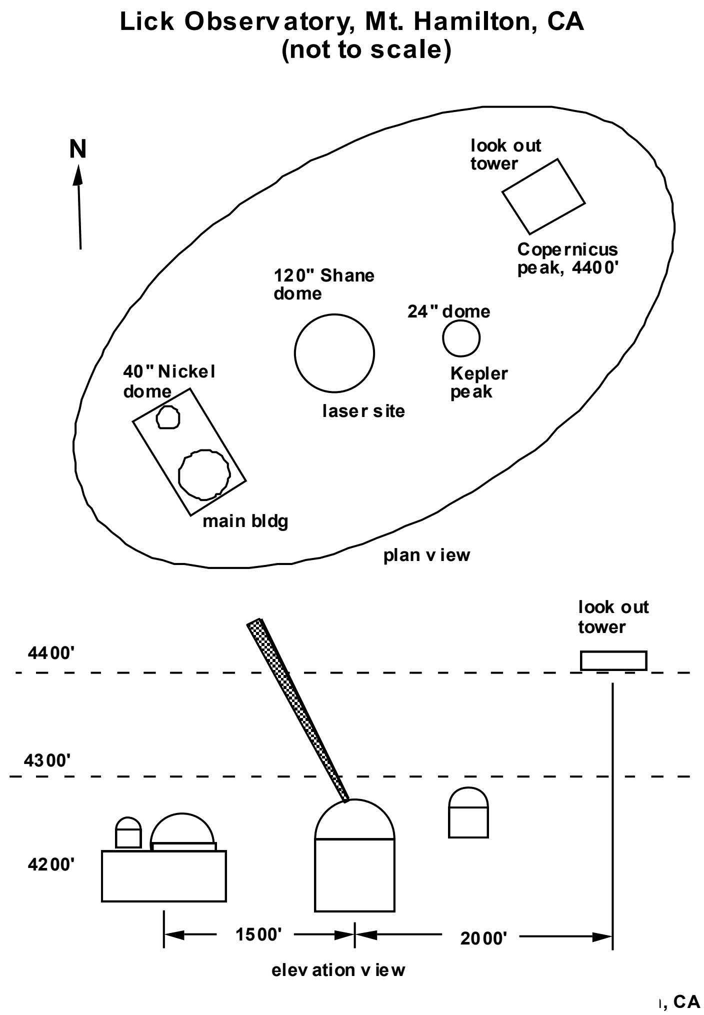


Fig. 1

LASER INSTALLATION

The laser beam is broadcast out of the viewing slit of the Shane telescope dome. The beam is parallel to the optic axis of the telescope and separated from the axis by a distance of 2.5 meters. The layout of the laser system is shown schematically below. The dye laser, pre-amp, amplifier, and diagnostics are mounted directly on the barrel of the telescope. The beam is expanded to a diameter of 20-cm using a refractive telescope and projected out of the dome slit. This dye laser is optically pumped by YAG lasers located in a room below the floor of the telescope along with support equipment. Optical fibers connect the pump lasers to the dye laser on the telescope enabling the laser beam to follow the telescope axis without complex pointing equipment. The output laser beam has an average power of ≤25 watts and is completely enclosed in tubes until the final large lens of the launch telescope. Both the laser and diagnostics tables have enclosures so that personnel are permitted within the dome during normal operation.

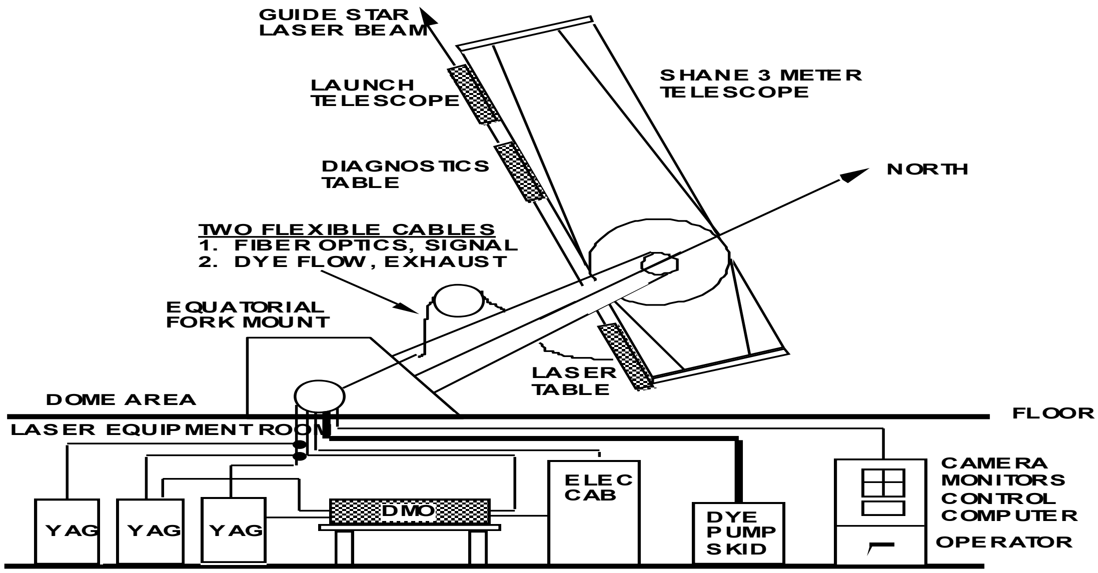


Fig. 2

The system is controlled by the laser operator (LO), in the main control room, who has multiplex communication with the two visual observers and the adaptive optics and telescope operators. The VO's have a cut off switch to activate a beam block as do the LO in the laser room and the operators in the telescope control room. Under normal procedures, the VO's will alert the team of an approaching aircraft and the LO will activate his switch to block the beam after informing the other members of the team. Under emergency conditions, any of the operators can block the beam without discussion. After the beam is blocked, the LO will reopen the beam block after confirming with the visual observer that no aircraft are approaching and conferring with the adaptive optics and telescope operators to make sure that there are no other objections. All laser operations will take place between the hours of 11 pm to 6 am unless air traffic is high enough to be deemed unsafe by the PI or his alternate.

Laser Description

The laser system for the Lick Observatory consists of a repetitively pulsed, liquid dye laser, which is, in turn, pumped by a set of three solid state lasers. The frequency of the dye laser is tuned to the sodium resonance line of 589 nm. The pulse repetition rate and pulse duration of the sodium light is 13 kHz and 150 nsec, respectively, and the (average) power level is < 25 watts. The peak power is considerably higher due to the short pulses and this fact is reflected in the eye safety analysis presented in a later section. The laser beam is expanded to a diameter of 20 cm before it exits the dome and the divergence is close to the diffraction limit for collimated beams at 7 microradians. This beam is not eye safe for all normal aircraft altitudes and special procedures must be in place to detect aircraft and close the beam if an aircraft approaches. The laser system is totally contained within the Shane dome. The operation of the laser system is under computer control by an operator in the laser room below the floor of the telescope. A full complement of safety systems is incorporated in the laser facility conforming to DOE, state, and local regulations.

Solid State Pump Lasers

Four solid state lasers pump the liquid dye laser. The lasers are frequency doubled, neodymium doped, YAG (yttrium aluminum garnet) rods pumped by a CW flashlamp. A stream of short pulses is obtained by an optical switching element (Q switch) located within the cavity of the laser. This laser normally emits in the near infrared spectral region at 1.06 microns but is frequency-shifted to half its wavelength by a KTP crystal also located within the optical cavity. The result is a 150 nsec pulse stream at 13 kHz with average power of 70 W.

The YAG light is delivered to the dye laser system through large core fibers. Each fiber has a separate shutter so many combinations of pump fibers can be operated independently as well as shut all in unison in an emergency. The laser power supplies are interlocked to guard against short circuits and loss of water-cooling. Each laser is in an enclosure that is interlocked against accidental exposure.

Dye Master Oscillator

The Dye Master Oscillator (DMO) consists of a small flowing dye cell pumped by two of the fibers from YAG 1. A suite of instruments sets the center frequency of the laser to the sodium wavelength and broadens the spectral profile of the laser to match that of the upper atmospheric sodium atoms. The DMO is mounted on an optics bench located in the laser room below the telescope. This room is temperature controlled and has a stable floor so that the DMO can be stabilized with a minimum of control equipment. A chiller maintains the dye temperature to within a few tenths of a degree Centigrade. The laser is also enclosed so that no light is visible under normal operation and the cover is interlocked against accidental opening. The output of the DMO light is split into two parts, one portion going to the suite of diagnostic instruments and the remainder focused into a single mode fiber for transport to the dye laser amplifiers on the telescope.

Dye Amplifier Table

The dye amplifier table is mounted on a 2' x 4' optical breadboard near the bottom of the Shane telescope barrel. The table contains a preamplifier, a power amplifier, and all necessary optics. Both amplifiers are excited by YAG pump light delivered via large diameter fibers from the laser room. The output power level from this unit is ≤25 watts with the same pulse format as delivered by the DMO. The table is enclosed and interlocked with all internal adjustments remotely controlled by the laser operator.

All external connections, including the optical fibers from the pump lasers, the dye flow lines and signal cables lie in cable trays from the laser equipment room to the telescope. The two sets of dye flow lines, one set for each amplifier, are encased within a flexible trunk, which terminates in the laser room. At the end of this trunk, an exhaust fan removes waste heat from the laser table as well as any alcohol fumes which might occur in case of a leak. Alcohol monitors are located at the end of the trunk, A1 enclosure, dye cabinet, DMO enclosure, and laser room and will sense any such leaks and shut the system down for inspection and repair. It has been our experience that catastrophic leaks such as burst fittings, broken windows, etc. are extremely rare and that if there is a leak, it is usually the result of seepage from an O-ring seal or connecting fitting. Such leaks are usually so small that they evaporate before forming puddles and do not present a major safety issue. The alcohol monitor will measure such leaks if they exist and provide a signal to the operator.

Alignment and Diagnostics Table

This subsystem controls the laser beam to maintain the sodium guide star spot size and pointing. The following three subsystems are required for these tasks:

- Closed loop pointing and centering which controls two optical elements using a set of cameras, which view portions of the outgoing laser beam. A computer algorithm relates the motions of the two elements to keep the laser beam pointed and centered to a predetermined, fixed reference.

- High speed tip-tilt mirror which removes laser beam wander caused by atmospheric turbulence on the uplink portion of the propagation path; the speed of this control loop is several tens of hertz in order to keep up with the changes in the atmosphere. The correction signal comes from the wavefront sensor which views the sodium spot through the Shane telescope.

Beam Launch Telescope

The beam launch telescope consists of three lenses.

- L1 is a positive lens close to the output of the dye amplifier on the laser table.

- L2 is a two-inch negative lens placed at the edge of the diagnostics table a few meters from the laser table. This lens enlarges the beam to 20 cm.

- L3 is a 12-inch diameter plano-convex lens. This lens has an aspherical surface facing the beam and a flat surface facing the sky. The aspherical surface collimates the beam from L2 and the flat surface reflects about 1%. The entire telescope is shrouded by a sheet metal tube so that no light is visible until the beam passes through L3. The lens, L3, is positioned near the end of the Shane telescope 3.5 meters from and about in the middle of the dome slit.

Description of the Safety Equipment

The following figure is a block diagram of the main components of the laser beam shutter, safety, and aircraft detection systems. The LO is stationed in the main control room. The LO is in contact with the telescope controller, adaptive optics operator in the ROR, and the visual observers. The Laser operator and the visual observers each have shutter control buttons which can independently block the laser beam, although the normal mode of operation is for the laser operator to close the shutter upon request from the VO's.

The VO will inform the laser operator of approaching aircraft and will instruct the operator to block the beam if an aircraft approaches within three miles of the laser beam in any direction. In case of an emergency or no response from the laser operator, the visual observer will close the shutter himself using his switch control.

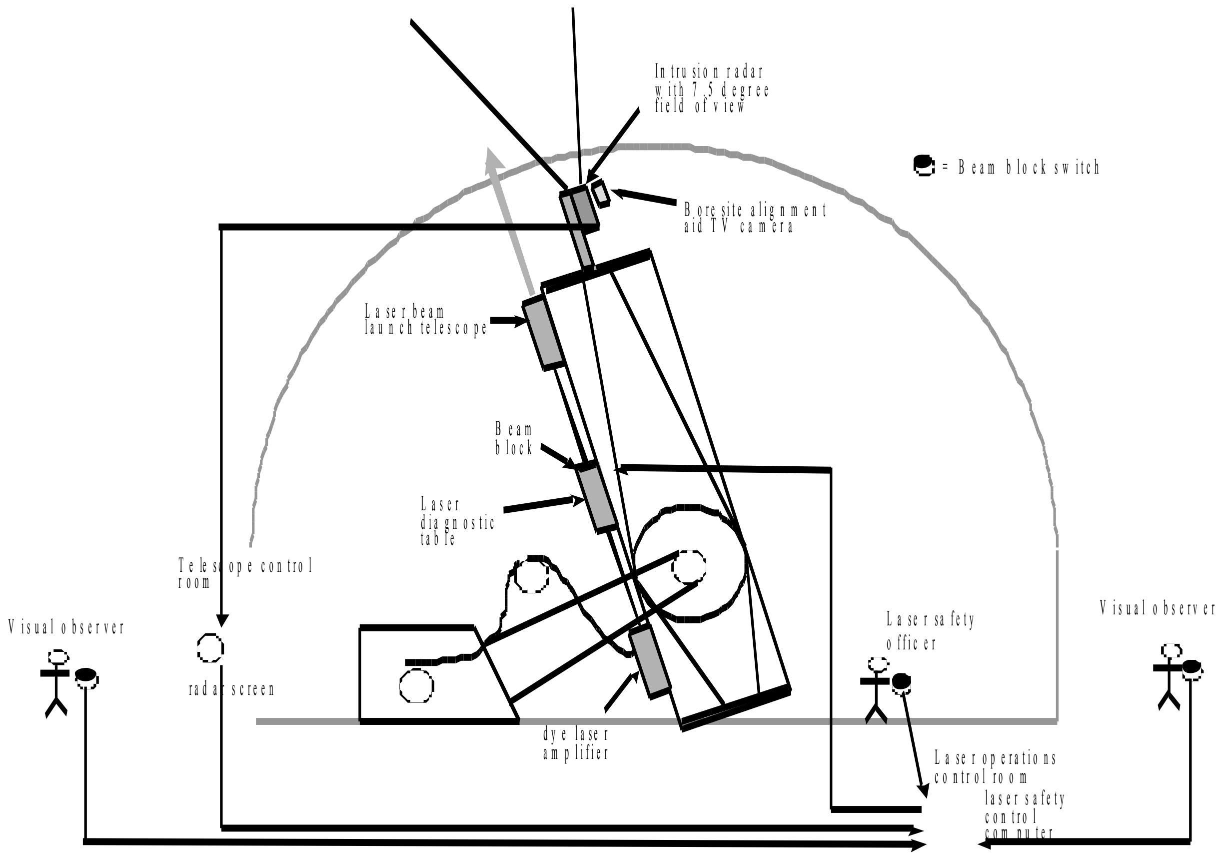


Fig. 3

The intrusion radar system is mounted on a rigid tube along the side of the telescope adjacent to the laser beam. The tube extends up far enough so that the 7.5° field radar cone clears the dome slit. The radar system consists of a transmitter/receiver electronics unit~~,~~ and a flat plate phased array antenna. If an aircraft enters the radar field of view, a signal will be generated automatically closing the laser shutter within 100 milliseconds. Due to the finite pulse width of the intrusion radar, the minimum detectable range is approximately 1500 feet, and for ranges closer than that, the visual observer provides aircraft detection. The maximum slant range for the radar is 12 miles.

The conical pattern of the radar beam provides a keep out zone for aircraft detection. At an altitude of 10,000 feet MSL, which is the approximate minimum altitude for commercial traffic in the air corridors above Mt. Hamilton, the keep out zone is approximately 750 feet in diameter, considering that the intrusion radar is at an altitude of 4400 feet. An aircraft traveling at 250 knots would require about one second to intersect the laser beam once entering the radar keep out zone. This time is more that 10 times the activation time for the laser beam block. At lower altitudes, there is still sufficient time to activate the laser beam block, but since the keep out zone is very small, we rely on the VO to provide warning long before an aircraft enters a keep out zone of three miles. It has been our experience that the VO has at least as much range as most small surveillance radars, of the order of 10 miles.

The laser and radar beams exit the dome through a slit, which is 20 feet wide. There are some orientations for which the laser and radar can be off center and it is important that control be exercised to keep these beams from intercepting the edge of the dome slit. One control accomplishes this; encoder readout. The encoder readout is in the telescope control room and indicates the position of the slit. The normal reason for this control is to prevent the dome from obscuring the telescope itself. In normal operations, the slit motor is programmed to follow the telescope tracking signal and will prevent the beams from hitting the slit edge.

A more detailed description of the components in the preceding figure is given below:

1. <u>Intrusion Radar</u>

    a. Bendix model RDR-1401B/IN2025A.

    b. 12 inch diameter antenna with 7.5° beam width, 27.6 dB gain.

    c. RF output power 7.9 kW peak power minimum, 11.8 kW max.

    d. Frequency (X Band) 9375 MHz ± 35 MHz.

    e. Pulse widths, 1.2 msec, 5,10,20,40 nmi ranges, 3.5 msec for 80 nmi.

    f. PRF 400 Hz for ranges, 40 nmi.

    g. I-F bandwidth 1.0 MHz.

    h. Noise figure - 9.0 dB.

2. <u>Communications</u>

    a. The laser operator, the Shane telescope operator, the adaptive optics operator, the laser safety officer, and the visual observers are in constant communication using headset communication.

3. <u>Laser System Control Computer</u>

a. Macintosh computer

b. LabView (commercial) software customized for laser system.

c. Generates and saves history records of laser propagations annotating date, on, and off times. Time record used to coordinate with Shane telescope computer to cross reference azimuth and elevation positions and objects viewed.

4. Fast Shutter

a. Located on Alignment and Diagnostics Table.

b. Manufacturer: NM Laser Corp., Sunnyvale, CA, Model LSY 125, electrically operated.

c. Closing time 50 milliseconds.

d. Normally closed position, held open by application of 15 volts, loss of power will close switch.

e. Fast shutter closes on signal from intrusion radar, cut off switch from visual observers and laser operator.

f. Beam block is an insertable mirror, which directs the beam into a dump and consists of a power meter for diagnostics.

5. Other Shutters

a. Output shutter located after the last element of the laser launch shutter. Shutter is normally closed and is held open by application of 50-psig air pressure on hydraulic cylinder. Shutter is closed on command of laser operator using computer control panel. Shutter will close in the event of a power failure. Closure time is 3 seconds.

b. YAG laser shutters located in the YAG laser head. Eight separate shutters, one each for each fiber, electrically operated and held open by application of a 24-volt signal. Automatically closes in the event of power failure.

6. Safety Log Book

a. Bound book kept at the LO's control station.

b. Log of safety equipment maintenance, modifications, and descriptive documentation.

c. Records of operation and validation of performance and calibration.

d. Records of trouble situations and repairs.

Safety Procedures

Positive control of laser emissions is the responsibility of the LO. The LO must determine that no aircraft or ground personnel are in the propagation lines of sight of the laser in order for laser propagation to begin or continue. The VO must keep the LO informed on the location and direction of travel of aircraft and initiate laser shut down when necessary. The LO and VO will use the following procedures to insure that the laser path is clear and to cut off laser propagation in the event that an aircraft approaches the beam.

Laser Operator Procedures

1. Qualification: Persons serving in the duty of Laser Operator will be trained by an authorized worker (AW) who is also a qualified LO. A list of qualified LO's will be maintained in the front of the current Safety Log Book (SLB). Training requirements include thorough reading and familiarization of these operating procedures, checkout and calibration procedures, and operation of the equipment including laser system, intrusion radar, TV camera, and communications system. It is further required that a LO be supervised for two sessions of actual laser propagation by a qualified LO.

2. Notification of FAA and Lick Observatory Personnel: The LO will notify local FAA personnel and the Lick Observatory Superintendent that laser propagation events are scheduled. This notification should occur at a minimum of 24 hours prior to the commencement of testing.

3. Safety System Preparation and Check-Out: On a periodic basis (determined by FAA requirement), the intrusion radar will be tested by a qualified technician and the results recorded in the SLB. Before each scheduled laser propagation time, the LO will perform functional tests using the performance monitor to verify operation of the beam blockage system. All test results will be recorded in the SLB annotated with the time and date and will be signed by the LO. Before beginning these tests, the LO will verify that the laser is blocked by closing the large shutter at the exit of the launch telescope and visually verifying its closure. The LO will verify that the fast shutter is closed and that the shutter switches are in the position giving control to the LO's control panel. The procedure for the intrusion radar checkout is as follows:

    a. Power up all systems and verify functional operation.

    b. Conduct intrusion radar operational check and threshold set using procedures outlined in a pre-run check list.

c. Verification that the fast shutter is actually operating.

d. Verification that communication between the VO and the LO is operational and that the VO's cut off switch is operational.

e. Verification of automatic shutter operation using the intrusion radar detection signal in combination with the performance monitor.

f. Verification of automatic shutter operation using the error signal pointed beyond the laser propagation limits.

g. Record all information in the SLB, date and sign.

h. This completes the safety system check-out.

4. Boresight Alignment of the Intrusion Radar and telescope: First, the intrusion radar and a TV camera will be aligned to each other. This alignment is accomplished using a convenient object, such as the radar tower on Loma Prieta or the communications tower on Mt. Umunhums, both of which are about 20 miles to the South. Since the Shane telescope cannot be pointed at the horizon, the intrusion radar assembly, including the TV camera, is removed from the telescope and pointed at these targets. Once the radar target is centered in the TV camera field, the radar and TV camera are locked down and secured. In this manner, the TV camera becomes a "transfer standard" for the intrusion radar for astronomical alignment since no radar return is possible from astronomical objects.

a. The intrusion radar/TV camera unit is mounted on a tube fixed to the side of the telescope adjacent to the laser beam.

b. The telescope operator points the telescope at a bright star, centering it in the telescope guider camera field of view.

c. If the bright star is not centered within the field of view of the radar transfer-standard TV camera, the LO will add fixed shims to the radar mounting unit until this condition is satisfied. Since the fields of view of the TV camera and intrusion radar are large when compared to the field of view of the telescope, which is tens of arc seconds, this adjustment is not critical and adjustment to one degree is sufficient.

5. Boresight Alignment of the Laser Beam: This procedure will be used to adjust the laser pointing so that the sodium spot in the atmosphere at 90 km is aligned with the astronomical object. Precise alignment is not automatically guaranteed since the laser is projected off axis by 2.5 meters from the telescope axis.

a. The LO will verify that the laser aperture is blocked by closing the large exit shutter.

b. The LO will request the telescope operator to point the telescope at a bright star and verify that the object is within the field of view of the TV camera located adjacent to the intrusion radar.

c. After following the Pre-propagation Warning and Laser Propagation procedures outlined below, the LO will initiate laser propagation and observe the positions of the laser beam and the bright star in the TV camera field.

d. The LO will point the laser beam using the Pointing and Centering controls of the laser system to position the laser beam directly upon the bright star. It is not critical that the bright star be in the exact center of the TV camera field of view for this rough alignment.

e. At this point, the laser beam should be visible in the telescope's guide camera field of view. The telescope operator will instruct the LO to make fine scale movement of the laser beam to position the sodium beacon directly on the bright star.

f. The laser, radar, and telescope are now aligned and astronomical observations may begin.

6. Pre-propagation Warning: At the adaptive optics system operator's request, the LO will initiate a warning for laser propagation.

a. The LO will request the VO to search the area for aircraft.

b. The LO will announce over the facility intercom that laser propagation will start.

c. The LO will verify with the VO that the beam path is clear and check the radar monitor for aircraft detection.

d. The LO will inform the adaptive optics system operator and telescope operator that the safety system is ready for propagation.

7. Laser Propagation and Shutdown Procedures:

a. LO announces over the facility intercom that laser propagation will commence.

b. The LO opens the exit shutter and finally the fast shutter and announces that fact on the facility intercom.

c. The LO immediately requests verification from the VO that the beam is going out of the dome slit and verifies with the telescope operator that the laser beam is centered in the field of view of the guider camera.

d. The LO and VO maintain dialog on air traffic.

e. When the VO determines shutdown will be required due to approaching aircraft, the LO informs the adaptive optics system and telescope operators and prepares for routine shutdown.

f. The LO manually closes the exit shutter and the fast shutter for redundancy when the VO determines that an aircraft is within a mile of the laser beam.

g. If an aircraft appears to pass within one half mile of the laser beam, the VO informs the TO of the time of closest approach so that the TO can determine whether or not the intrusion radar detects the aircraft. This test provides "target of opportunity" checks on the radar's performance even though the laser beam has been turned off. In this event, the VO will also inform the adaptive optics system and laser operators in case they may want to close the shutter to prevent aircraft landing lights from entering sensitive experimental equipment.

h. When the aircraft has passed the laser beam path as reported by the VO, the LO informs the other operators over the facility intercom that laser propagation is ready to resume.

i. When the adaptive optics system operator requests propagation, the LO checks with the VO for clear skies and reopens the exit shutter first and the fast shutter second.

j. If the intrusion radar detects an aircraft and automatically closes the fast shutter, the LO will close the exit shutter and proceed from step h until skies are determined to be clear.

k. The LO will not permit laser propagation unless the adaptive optics systems operator requires it. Propagation shall be held to the absolute minimum required for astronomical observations.

l. At the completion of a test series, the LO shall close the fast shutter, exit shutter, and pump laser shutters. The LO will turn off the intrusion radar.

Aircraft Observer Procedures

1. Qualification: Persons serving in the duty of Visual Observer will be trained in this function by the PI. A list of qualified VO's will be maintained in the front of the current SLB. Training requirements include thorough reading and familiarization of these procedures and an understanding of the criteria for normal and emergency shutdown of laser propagation.

2. Normal Aircraft Observer Procedures: These procedures apply to the Visual Observers who are stationed on either side of the Shane Dome.

a. Insure all security lights are off. No extraneous sources of noise (radios, unnecessary conversations, etc.) will be permitted in order to maximize the ability of the VO's to hear engine noises.

b. The VO's shall take their stations on opposite sides of the dome 15 minutes before laser propagation to permit eye dark adaptation.

c. Put on communications headset.

d. Test the cut off switch when requested to do so by the LO.

e. Know the intended astronomical object location before the beam is to be propagated (this information will be supplied by the LO).

f. At the announcement of the pre-propagation warning (made by the LO), scan the sky in the general vicinity of the astronomical object and search for aircraft. Report any aircraft that is in the vicinity of the expected laser beam path, or that can be heard but not seen, or that may be headed in the general direction of the laser path.

g. Transmit the all clear signal to the LO when requested if no aircraft are near or approaching the beam path.

h. Once propagation has started, the VO shall keep a constant vigil for approaching aircraft using hearing and the naked eye. Any aircraft spotted will be reported to the LO with a short description of azimuth bearing, approximate altitude, speed and direction of travel relative to the laser beam.

i. If an aircraft is approaching the beam, the VO will keep the LO informed of its location with respect to the beam and notify the LO when the aircraft is approximately 3 miles from the beam so that action to shut off the beam can be taken.

j. If the beam is not shut off in a timely manner and the VO estimates that the aircraft will come within a mile of the beam, the VO will inform the LO that he will use the cut off switch when the aircraft is within a mile of the beam.

k. The VO will activate his cut off switch to block the beam if the laser has not been shut down by the LO and the aircraft is within one mile of the beam. If possible, the VO will inform the LO of his actions prior to and during the act of activating the cut off switch.

l. In the event that the communications link between the VO and the LO is interrupted, both the VO and/or the LO will activate their cut off switches to block the beam.

m. The VO will inform the LO when the aircraft has passed beyond the beam and it is safe to propagate the beam again.

n. The laser beam will be blocked if a low flying aircraft (less than 3000 feet above the LOT) approaches within 45° of the beam. This procedure is to avoid startling or distracting pilots.

o. The VO will report any adverse sky conditions, such as cloud cover or fog, that develSOP during the night. If cloud cover or fog develSOP along the beam path, the VO will immediately notify the LO. Also, if the sky appears clear but bright spots or other abnormalities appear in the laser beam, the VO will immediately inform the LO.

3. Emergency Shut Down Procedures:

a. The VO's cut off switch will be used in response to any situation where the VO is surprised by an aircraft that could come close to the beam.

b. In the event of any technical or personal emergency, any of the operators, i.e., the VO, laser operator, adaptive optics system or telescope operator will activate their cut off switch.

APPENDIX B: SOP REVIEW

This SOP was reviewed by the PI, Kostas Chloros, and the operating personnel assigned to *Lick Laser Operations*. The listed hazards and their controls are clearly understood.

Initial Review		
Name	Signature	Date

Review After 6 Months		
Name	Signature	Date

Appendix C: Laser Table

LASER TABLE (ANSI Z136.1-2000) (SOP O-171) Don Gavel 05/21/01 Annual — Calculation by Lazan Plus 3.6, LIA 2000 + manual (FR) Form Rev. 02/13/01

Laser identification					Laser specifications								Direct eye exposure				Diffuse eye exposure			Skin exposure
ID #	Type	Make & Model	Comments	Class	Wavelength (nm)	Mode	Beam Size (mm)	Divergence (mrad)	Power CW (W)	Pulse Energy (mJ)	Pulse Length (ns)	Pulse Rate (kHz)	Time (s)	MPE (mW/cm²)	NOHD fiber (m)	Min. OD	Time (s)	NOHD (m)	Min. OD @ 0.5 m	MPE for 10 s (mW/cm²)
1	Dye	LLNL	-	3b	589	Pulse	1	> 0.39	(~0.13)	0.01	150	13	0.25	0.76	-	2.7	600	< 0.1	0	200
	Master osc.	Fiber out	Single mode				0.004	-							1.8					
		-	Alignment				1	> 0.39	(< 0.1)	0.003					-	2.2	30000	< 0.1	0	
2	Dye Preamp	LLNL	-	3b	589	Pulse	1	> 0.39	(~0.44)	0.038	150	13	0.25	0.76	-	3.2	600	< 0.1	0	200
3	Dye	LLNL	Laser out	4	589	Pulse	1	> 0.39	(~20)	1.54	150	13	0.25	0.76	-	4.9	600	1.5	0.9	200
	Amplifier		Telescope				250	0.002								1.8		-	0	
4	Nd:YAG	LLNL	1w	4	1064	Pulse	2	> 0.35	(~150)	11.5	150	13	10	3.0	-	5.2	600	1.3	0.4	1000
	Osc. preamp	4 @	2w		532			> 0.18	(~70)	5.38			0.25	0.76		5.4		2.8	1.1	200
	amp. pump	Fiber	NA=0.16				0.6	-	(~44)	3.4					15	5.2		2.2	1.6	
		-	Alignment	3b			1	> 0.35	(< 0.1)	0.003					-	2.2	30000	< 0.1	0	
x	HeNe, diode	Various	Several	2-3b	400-700	cw	~1	> 0.42	≤ 15	-	-	-	0.25	2.5	-	≤ 1.2	600	< 0.1	0	200

SPECIFIC COMMENTS: MPEs and ODs for Nd:YAG lasers are calculated on a per laser basis since multiple eye exposures from several lasers are not realistic. Nominal CW powers are listed for reference only.

WAVELENGTH: at which the laser is operated or capable of operating; **UV** <400 nm, **VIS** 400 to <700 nm, **IR** ≥700 nm, (**near-IR** ≥700 to <1400 nm, **far-IR** ≥1400 nm).

LASER SPECS: typically listed for the smallest accessible beam size, highest power or pulse energy, shortest pulse length, and highest rep-rate.

EXPOSURE TIME: MPEs depend on the length of exposure. Use the actual pulse duration for single pulses; use the following (or greater) for CW or rep-rated pulses:
direct eye exposure: **UV** - 10-30,000 s (i. e. 8-hr work day) (depends on expected exposure time and assumes 2 successive days exposure); **VIS** - 0.25 s (i. e. blink response time) or at least 1/Hz; **all IR** - 10 s
diffuse eye exposure: **UV** - 600-30,000 s (i. e. 8-hr work day) (depends on expected exposure time); **VIS or near-IR** - 600 s; **far-IR** - 10 s
skin exposure: **all wavelengths** - 10 s.

MPE: Maximum **P**ermissible **E**xposure for unintentional, intrabeam (direct) exposures for the listed duration – typically in mW/cm² for CW or rep-rated (≥ 1 Hz) beams and mJ/cm² for single pulses at < 1 Hz. Purposeful direct viewing is not permitted unless authorized specifically in an SOP.

OD: minimum **O**ptical **D**ensity eyewear (at the designated wavelength) for full protection to MPE levels, typically at a distance of 0.5 m from a source. Optically aided viewing with telescopes, microscopes, cameras, etc. may require higher OD. **Note**: "alignment eyewear" for **visible beams 400-700 nm** may be used with an OD reduced by as much as 1.2 than specified in the "Min. OD" column (OD 1.2 is the equivalent to reduce a 15-mW HeNe to MPE level). Employ caution to avoid direct and stray beams. Since there is no aversion response to diffuse light, do not go below the OD level specified in the diffuse "Min. OD @ 0.5 m" column without LSO or SOP-documented approval.

DIFFUSE EXPOSURES: based on 100% Lambertian reflection at normal incidence from a non-specular surface at a nominal arm-length distance of 0.5 m.

NOHD: Nominal **O**cular **H**azard **D**istance beyond which laser viewing is safe without eyewear (listed for fiber output and occasionally for unaided viewing of diffuse beams if warranted).

APPENDIX D: MANLIFT BUCKET OPERATION

The PI shall review modifications of equipment or facilities that have the potential of impacting safety with the Lick Observatory Safety Officer. With respect to safety, the Lick Observatory Safety Officer has the responsibility and authority to approve the modification or to request a design review. When deciding to approve or require further review, the Lick Observatory Safety Officer shall, as appropriate:

1. Discuss the proposed modification with the requester.

2. Review the final design review documentation of the unmodified system and the proposed modifications.

3. Review the SOP and appropriate Safety Notes.

4. Consult with the operators of the equipment to be modified to determine possible safety concerns.

If the Lick Observatory Safety Officer has any concerns about the safety of the modification, he shall organize a peer review by personnel with the expertise to determine the safety of the modification.

The PI shall ensure that the modifications are recorded and that appropriate documents are updated.

<u>Work to Be Done</u>: Alignment and maintenance activities of the Lick Laser components mounted on the Shane Telescope at the Lick Laser Observatory at Mount Hamilton, Ca.

<u>Hazards Analysis</u> Personnel will be working at heights which introduce a potential falling hazard. The controls stated in this SOP are adequate to reduce the risk involved with this hazard to an acceptable level. The manbasket is manufactured by Lifting Technologies, Missoula, Montana, to satisfy the design criteria specified in 29CFR 1926.550(g).

<u>Controls</u>:

Refer to section 4.5.2 in the SOP.

1. The manbasket shall be used only for tasks outlined under "Work to be Done," and all other uses are prohibited.

2. Modifications shall not be made to the manbasket without written approval from the manufacturer and Hazards Control.

3. A list of authorized personnel shall be maintained by the PI.

4. The load in the manbasket shall not exceed 600 pounds at any time. This weight is to include the weight of the workers, their tools, and any materials that are present.

Lift Controls:

1. Workers shall wear full-body-harness fall protection with the lanyard attached to the lower block assembly of the crane.

2. Workers shall not sit, stand, or climb on the manbasket railing while the manbasket is in use. Use of ladders, boards, other devices, or extensions are prohibited.

3. The manbasket shall be used only for workers, their tools, and the materials necessary to do their work. Workers and materials shall be evenly distributed within the confines of the manbasket while the basket is suspended.

4. Workers shall keep all parts of the body inside of the manbasket during raising, lowering, and positioning.

5. Workers shall not exit or enter the manbasket once it is hoisted.

6. Dual-direction traveling is prohibited.

7. There shall be a second person in communication with the workers in the manbasket either on the intercom from the laser room or on the dome floor.

8. The floor area underneath the Man Rated bucket shall be cordoned off to avoid exposing anyone on the dome floor to falling objects.

Emergency Controls:

1. In case of an emergency, such as a fire or earthquake, the manbasket shall be lowered to the floor level in a controlled manner.

2. In the case of a crane failure, whereby the manbasket cannot be lowered, workers shall remain in the basket until a safe method is approved by the summoned emergency response team and Lick Laboratory Hazards group to remove them.

3. The crane shall be controlled using the remote radio control pendant by one of the workers in the manbasket. If the worker or workers become incapacitated while hoisted in the manbasket, the safety watch shall immediately call the Lick emergency number and summon assistance. It will be necessary to access the wired pendant at the main crane operator station and switch the transfer switch from radio to wired pendant.

LIFT INSPECTION CHECKLIST	
	Master Link
	Slings (4)
	Swaged lower end fittings (4)
	Sling eyes (4)
	Cotter Pins (4)
	Manbasket skid frame
	Manbasket skid base
	Sling eyes swaged fittings (upper) (4)
	Sling attachment pins (4)
	Test weight
	Eye bolts (4)
	Floor grating
	Top guard rails
	Corner Posts (4)
	Mid guard rails
	Sling fairleads (4)
	Kickplate base angle
	Mesh Panel
	Handrail
	Test Weight attachment pin handles (2)
	Test Weight attachment pin tabs (2)
	Test Weight attachment points (2)
	Test Weight base
	Proper balance when hoisted several inches without occupants

Inspection performed by: ____________________________ Date: _____________________

Appendix E

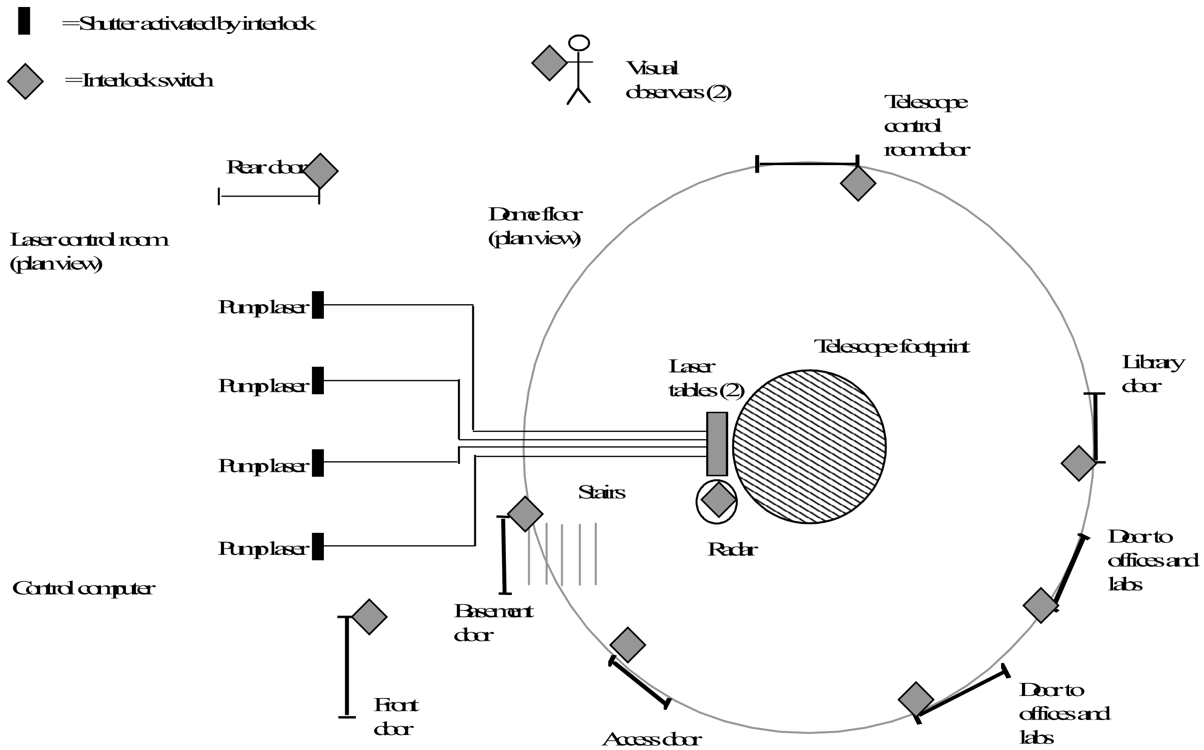
QUARTERLY INTERLOCK CHECKLIST

BUILDING ______________________________ SYSTEM ____________

ROOM ________________________________ DIVISION RESPONSIBLE ____________________________

DATE	DOOR INTERLOCKS	RUN/SAFE BOXES	KEY SWITCH	ALARMS (AUDIBLE & VISIBLE)	REMARKS	SIGNATURE

Appendix F: Interlock Key Plan



Controlled Distribution:

Bailey, B.	*	Goldstein, W.	L-051
Beach, R.	L-005	Gavel, D. (2)	L-258
Brown, C.	L-484	Jones, B.	***
Bauman, B.	L-258	Max, C.	L-413
Danforth, P (3)	L-570	Pennington, D.	L-477
Gates, E.	**	Rainer, F.	L-487
		Stone, R.	**

* K. Smith, UCSC EH&S Department, Santa Cruz, CA, 95064
** E. Gates, R. Stone, UC Lick Observatory, Mt. Hamilton, CA, 95140
***B. Jones, UCO Lick Observatory, UCSC, Santa Cruz, CA, 95064

O-171:dl