



OCTL



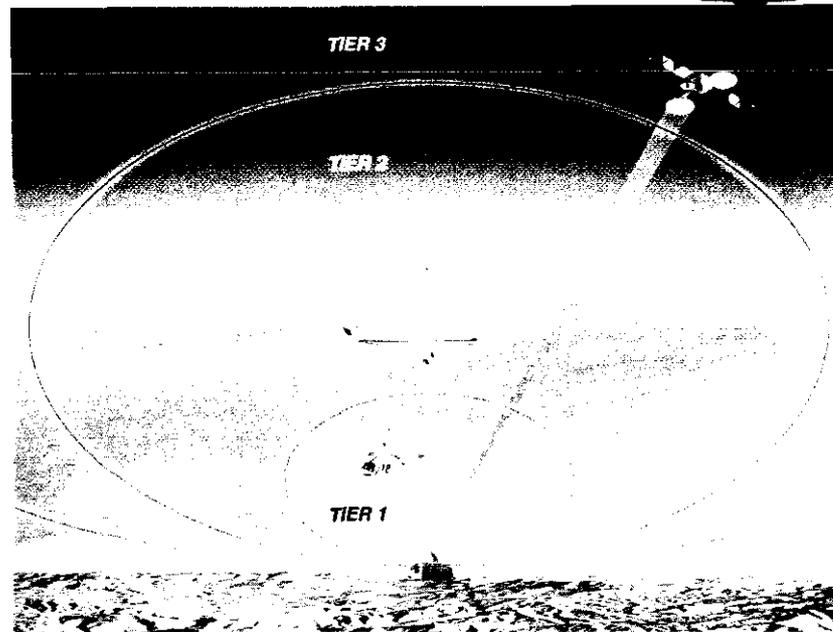
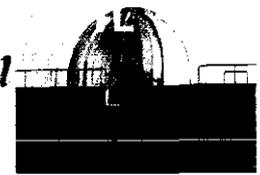
Development of a Safe Ground to Space Laser Propagation System for the OCTL

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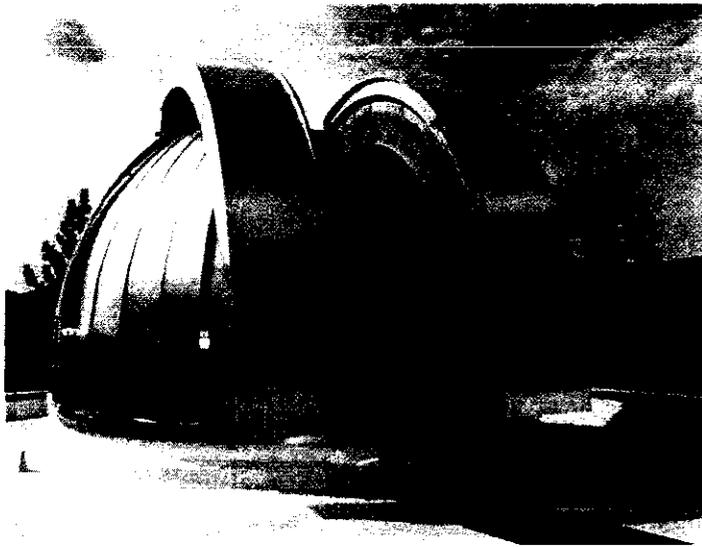
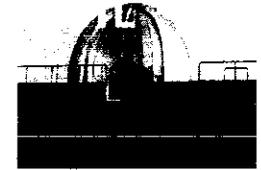


Multi-Tiered Safe Laser Beam Propagation



- Tier 0: Confined within OCTL building under OSHA guidelines
- Tier 1: FAA controlled region ranging from dome out to 3.4km
- Tier 2: FAA controlled ellipsoidal region ranging to 20km @ zenith and 58km @ 20° elevation
- Tier 3: Space Command region extends from near-Earth to the ranges of geo-stationary and high elliptical orbiting satellites

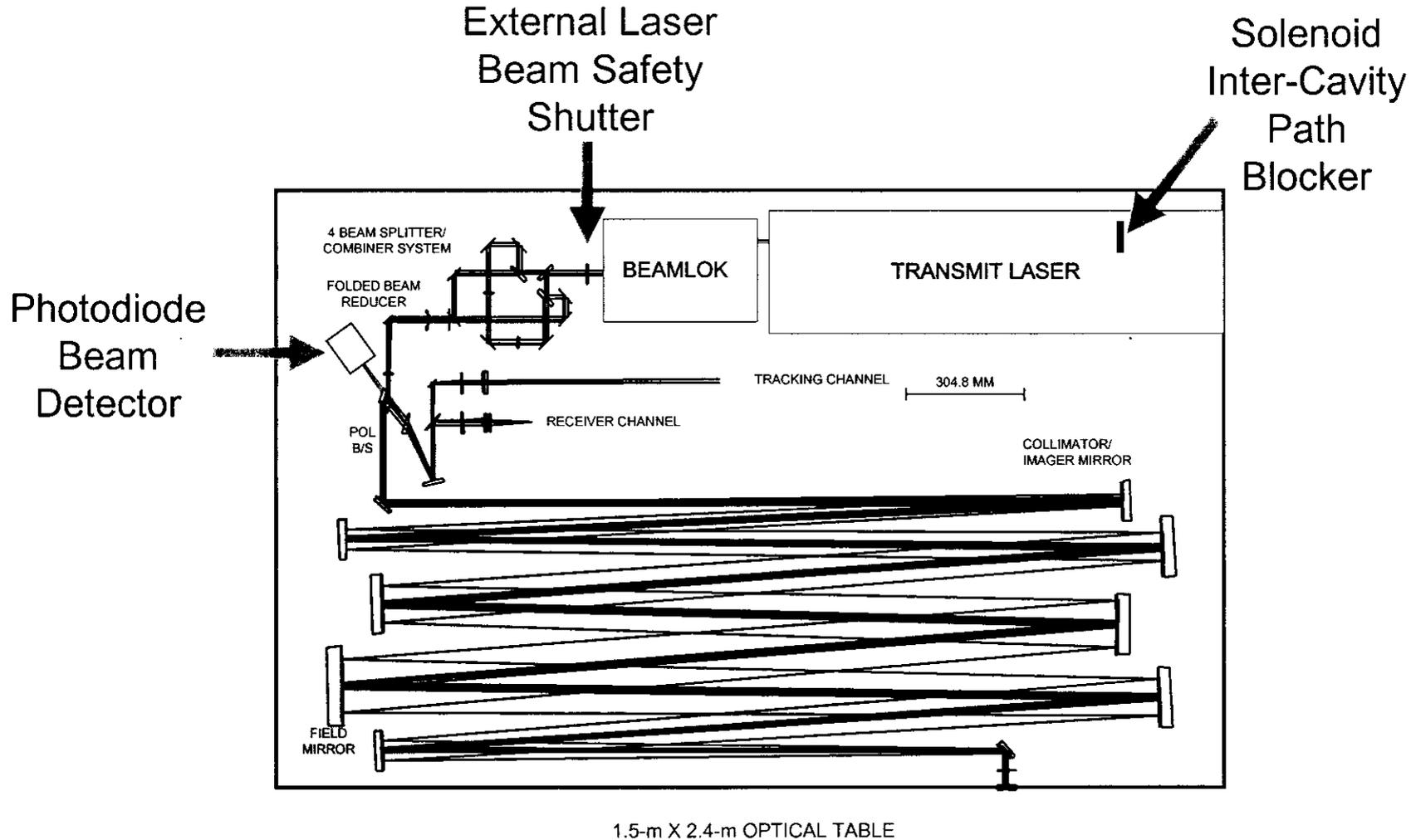
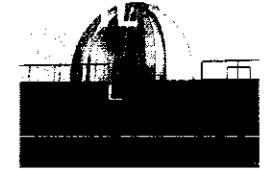
Optical Communications Telescope Laboratory



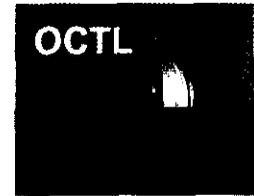
- Located at the JPL Table Mountain Facility in Wrightwood, CA
- 1-meter telescope dedicated to day+night operations for optical communications
- R&D optical antenna to develop communication strategies for future ground stations

| Laser | λ (nm) | Avg Pwr (Watts) | PRF (Hz) | Energy/pulse (Joules) | Peak Pwr (Watts) | Beam size at aperture (cm) | Pulse Width (ns) |
|----------------|----------------|-----------------|----------|-----------------------|-------------------|----------------------------|------------------|
| Doubled Nd:YAG | 532 | 12.5 | 1 – 50 | 0.25 | 0.4×10^8 | 30x21 | 6.6 |
| Yellow Laser | 589 | 20 | CW | N/A | 20 | 36 dia. | N/A |
| Diode Array | 810 | 2 | CW | N/A | 4 | 9 dia. | N/A |
| Nd:YAG | 1064 | 32 | 1 – 50 | 0.6 | 1.2×10^8 | 15x10 | 8 |
| EDFA | 1550 | 10 | CW | N/A | 20 | 11.8 dia. | N/A |

Safety Shutter Layout

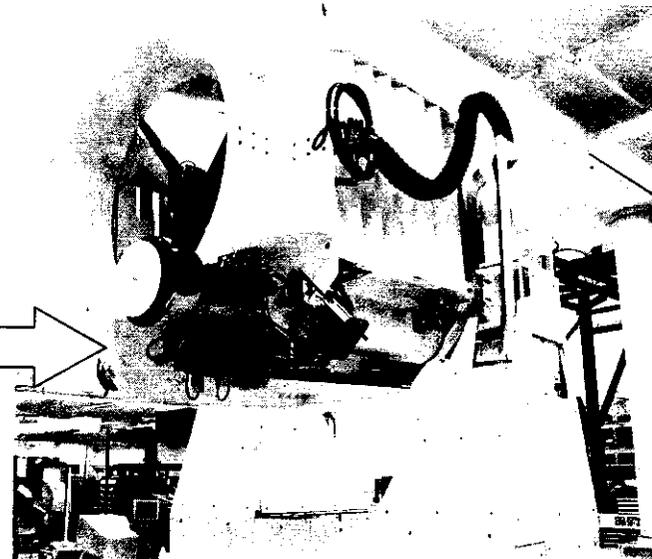
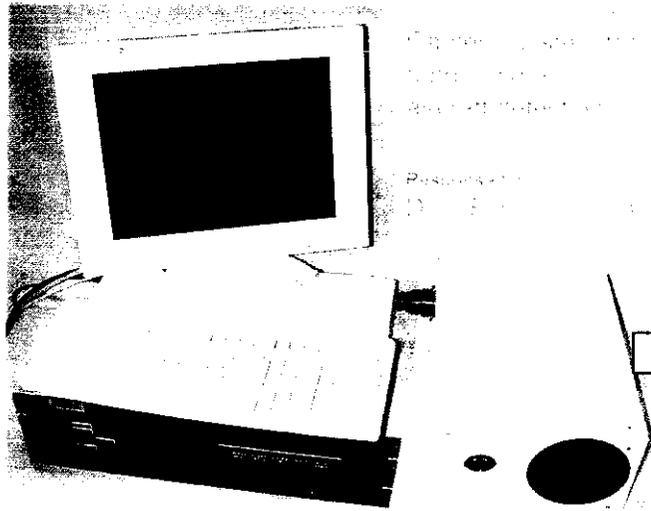


JPL *Multi-Tier Integration Requirements*



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- Assemble and coordinate tier outputs before commanding laser shutter
 - Each tier must:
 - Be capable of at-risk object identification
 - Provide output to signal object detection
 - Provide output to signal whether equipment is responsive

Tier 1: ILL Imaging System

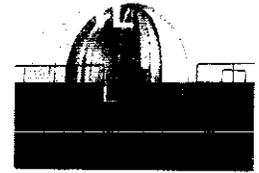


| Parameter | Value |
|------------------------------------|--|
| Required Maximum Operational Range | 3.4 km |
| Operating Wavelength | 7-14 μm |
| Field of View | 12° x 9° ("near") 46° x 35° ("far") |
| Resolution | 320 x 240 pixels |
| Power Requirements | 15 VDC |
| Weight | 5.1 kg |
| Image Acquisition Freq. | 30 Hz |

- Pair of LWIR detectors
- Packaged system includes object detection algorithms
- Requires access to telescope motion parameters

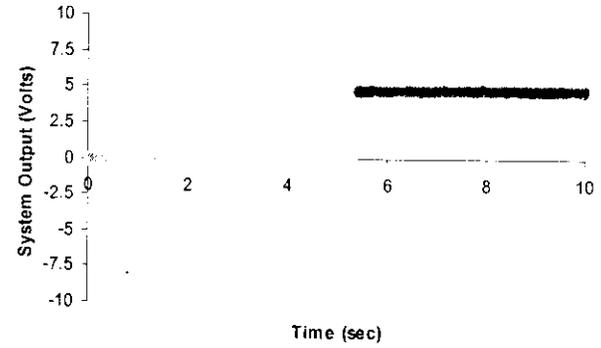


ILI System Response



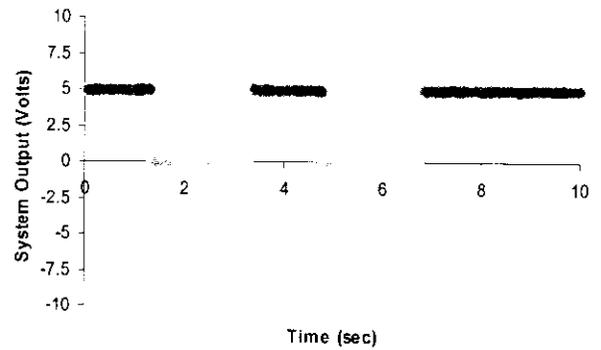
ILI System Status Response

• System Functional System Not Responding



ILI System Detection Response

• Standby Object Detection



Sky Sentry - Aircraft Detection and Warning System
Configure Help About

Narrow Field of View Camera:

Wide Field of View Camera:

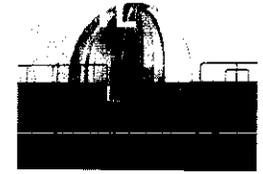
January 16, 2002
10:56:02 am MST
Automatic Shutdown Enabled
Logging Enabled
Serial Communications Active

Laser: 167.1 Azimuth, 42.9 Elevation
Satellite Velocity: 0.01 Degrees / Second

Ready NUM



Tier 2: Radar Detection System (Radar Display Interface)

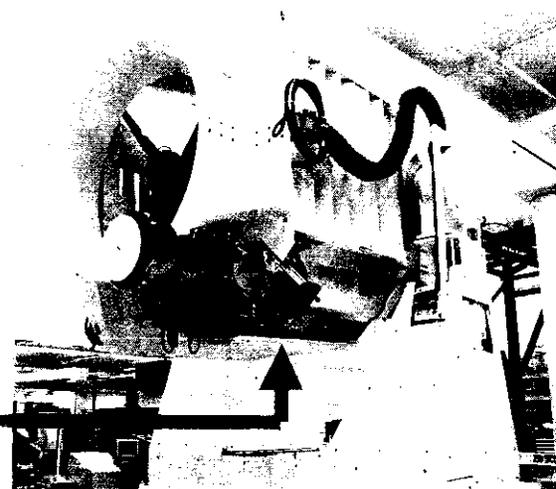
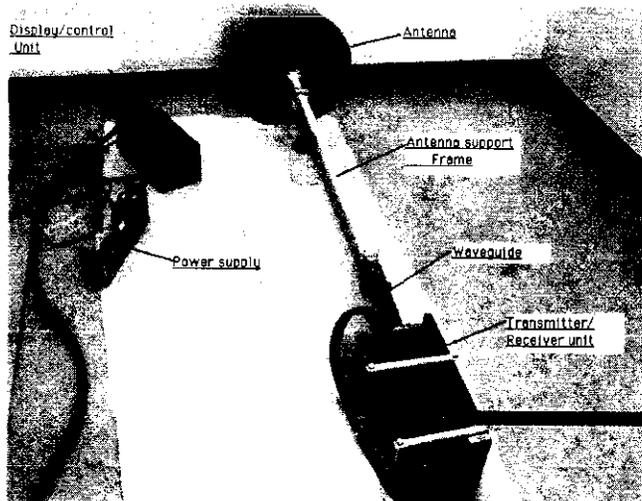


Picture courtesy Capt. J. Snodgrass
Maui Space Surveillance Center, USAF.

- Similar to AMOS RDI system
- Radar feed supplied by local TRACON
- Development awaits completion of joint NASA/FAA Memorandum Of Agreement



Tier 2: Radar Detection System (Interim Approach)

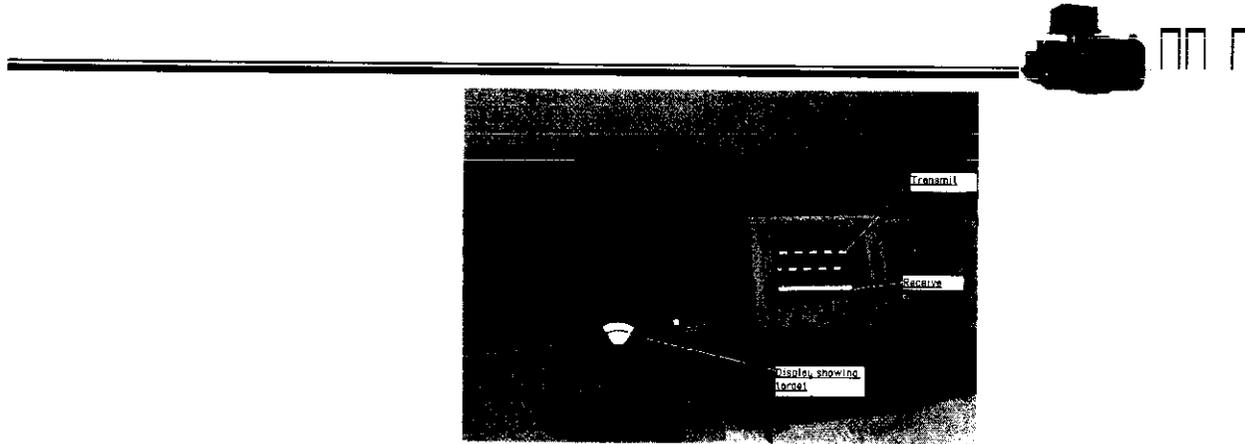
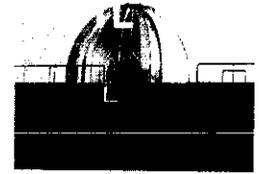


| Parameter | Value |
|------------------------|----------|
| Maximum Range | 300 nm |
| Operating Frequency | 9340 MHz |
| Total Field of View | 11° |
| System Noise Figure | 7 dB |
| RT Power Output | 8 kW |
| Power Requirements | 28 VDC |
| Weight | 16 kg |
| Pulse Repetition Freq. | 121 Hz |

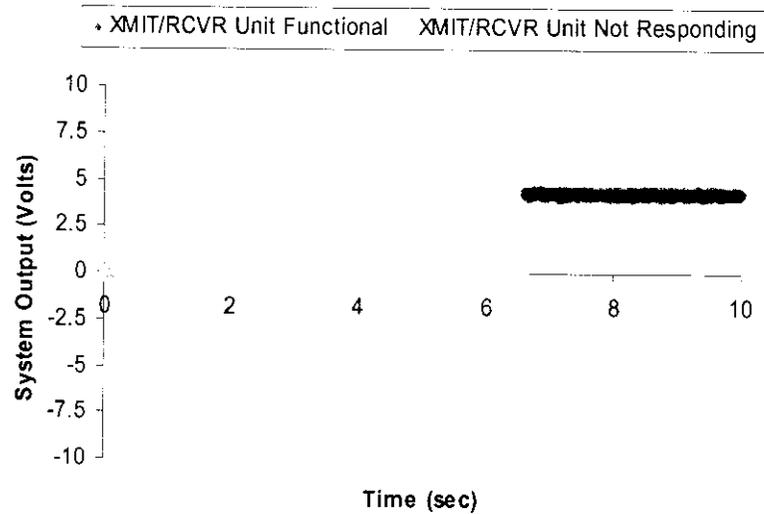
- Honeywell Weather Radar
- Requires access to site terrain map to avoid false detection caused by returns from local environment



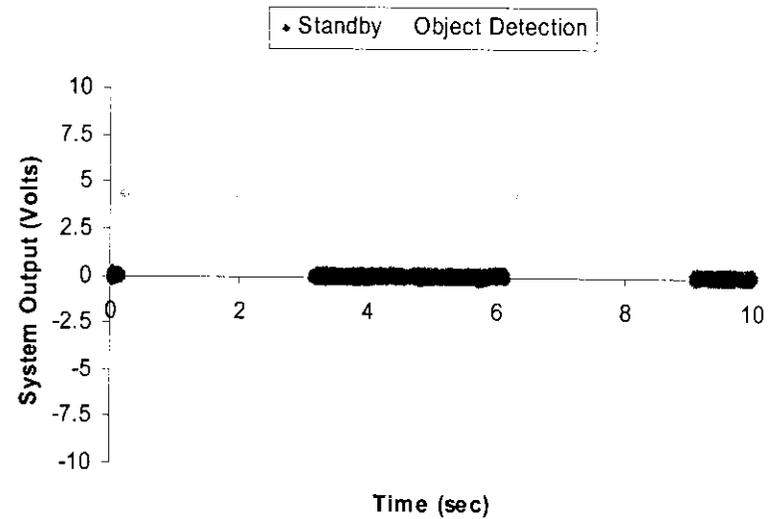
Radar System Response



Radar System Status Response

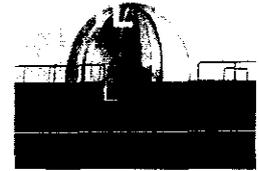


Radar System Detection Response





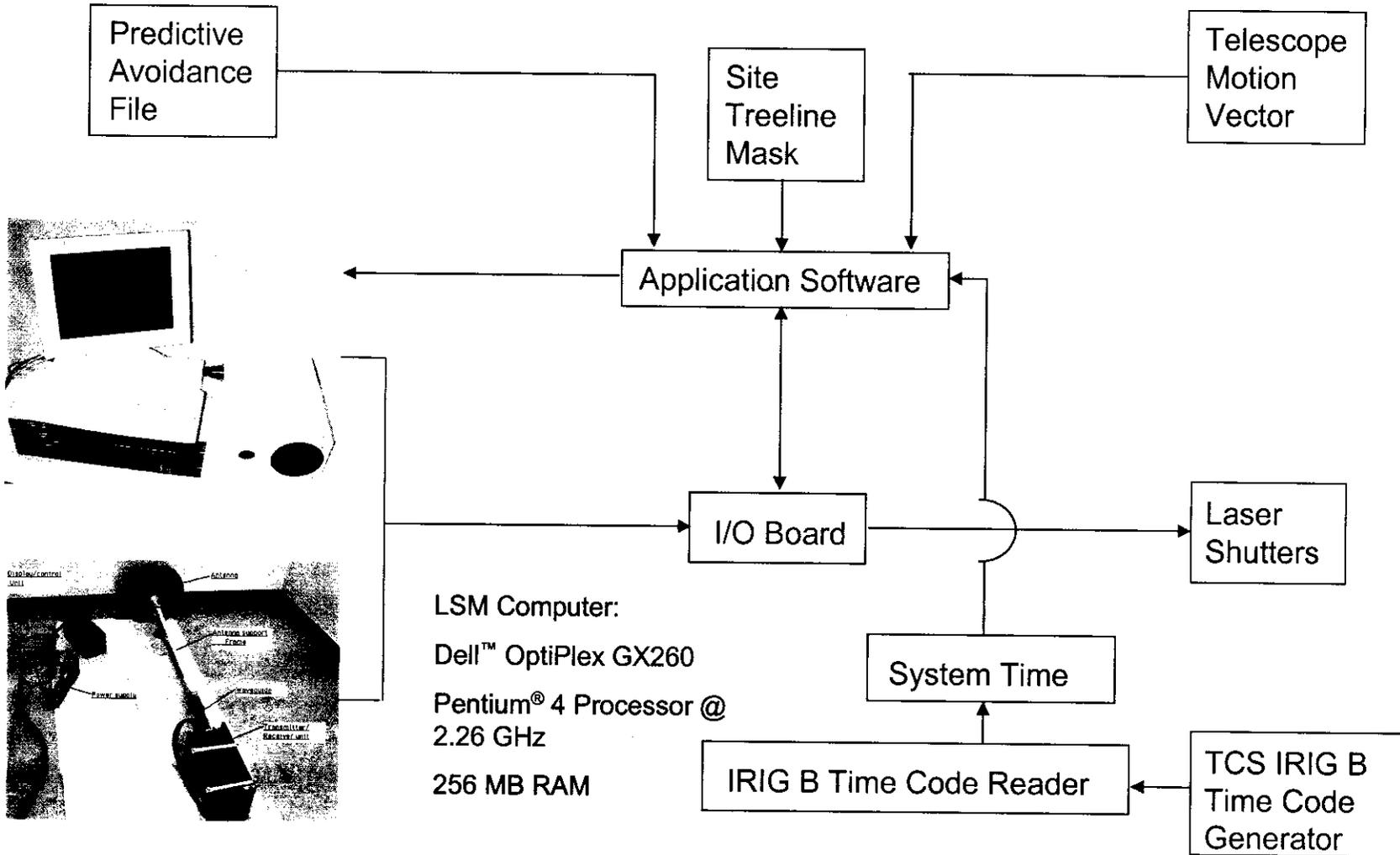
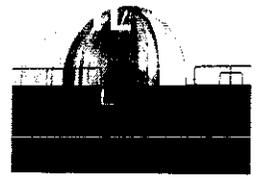
Tier 3: Satellite Predictive Avoidance



- Laser registration (Cheyenne Mtn.)
 - Site information
 - Site coordinates and point of contact
 - Laser parameters
 - wavelength, divergence angle, energy, jitter angle, etc.
 - Written permission from target owner
- Predictive avoidance
 - OCTL operation times (when pulsed lasers will be used) must be submitted no later than 48 hours prior to operations
 - U.S. Space Command will issue times non-waived lasers cannot propagate 24 hours prior to operation
- Integrated system must maintain accurate time

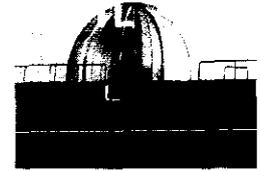


Laser Safety Monitoring System





LSM User Display



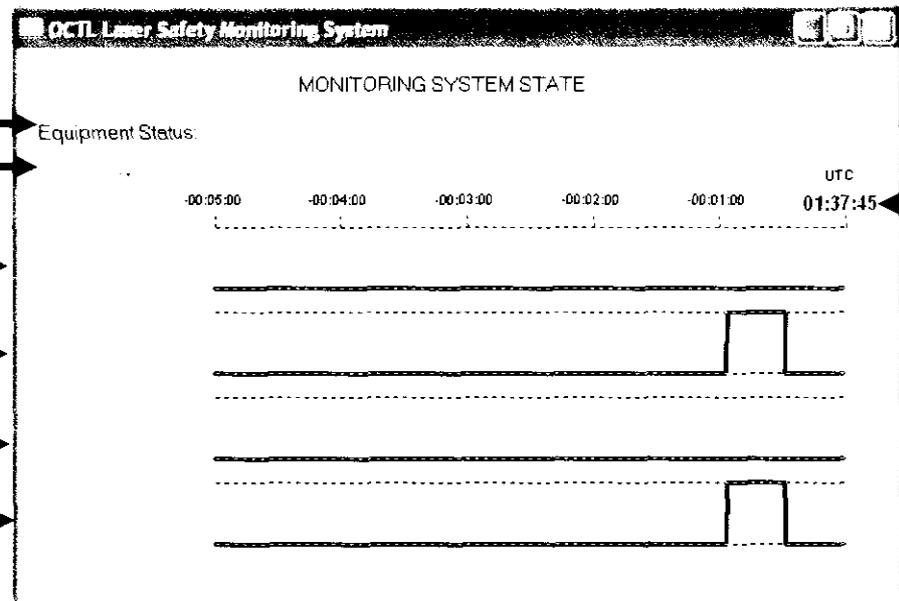
- “Equipment Status” row displays operational status of each tier and the I/O board
 - Green = Equipment functional
 - = Equipment not responding

- “Treeline” warning
 - Green = Pointing above site terrain
 - = Pointing below site terrain

- 5 minute time history plot of detection status for each tier
 - Tier labels are highlighted according to corresponding detection status
 - Green = Safe for laser propagation
 - = Object Detection

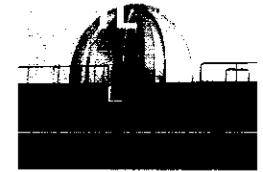
- 5 minute time history plot of shutter response (external and inter-cavity)
 - “Laser Beam” label is highlighted according to shutter response
 - Green = Verified that shutter commanded to open
 - = Verified shutter commanded to close

- Running clock of current time
 - reference for time history plots
 - evidence that software is executing



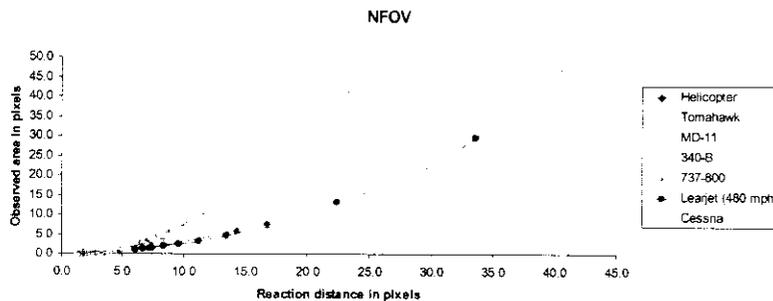
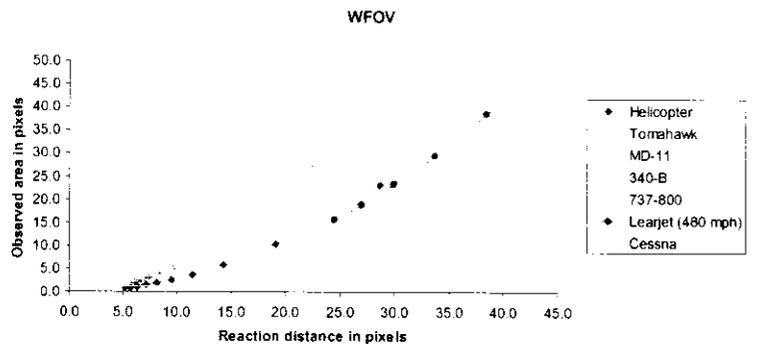


Aircraft Detection Response Time



Tier 1

- ILI Scenario Study



- Minimum allotted time for shutter response = 200 msec

Tier 2

- Total response time < 0.166 sec
- Radar FOV = 11°
- Commercial aircraft (600 mph) @ 3.4 km
 - Half FOV travel time = 1.2 sec
- Enough time to prevent aircraft illumination?

YES!



-
- Developed a three-tier system for safe laser beam propagation through the atmosphere
 - Baseline for system development to support autonomous ground stations

 - Integrated system uses
 - 1) Pair of LWIR cameras for ranges below 3.4 km (~2 miles)
 - 2) Radar detection system within FAA airspace
 - 3) Scheduled transmission windows approved by Laser Clearinghouse

 - Scheduled for OCTL deployment in FY '04