Eye Safe Laser Detection of Aircraft: Applications in Satellite Laser Ranging (SLR)

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Abstract

The wider use of lasers in the community is leading to increasingly tight restrictions on the penetration of air traffic space by laser beams. In some cases this is regardless of whether the laser beams are physiologically safe, because there are now concerns about pilot distraction by visible but harmless beams. The latest technique for allowing laser beams to operate in dense air traffic is laser radar. The limitations and advantages of this technique are described, as applied to the detection of aircraft for laser safety purposes in satellite laser ranging.

1. INTRODUCTION

It has always been understood that SLR systems must operate in a way that presents no threat to aircraft. In recent times, regulating agencies such as the FAA have become alarmed at the proliferation of laser radiation into airspace that carries civilian and other air traffic. In particular the use of lasers for entertainment has triggered a new wave of restrictive regulation that could seriously impair the operational efficiency of the SLR technique. New requirements will even limit the use of physiologically safe beams, if the laser is visible and a potential distraction to a pilot.

This increasing vigilance by the FAA and other agencies, as well as their international counterparts will inevitably lead to more restrictions on the laser penetration of airspace. Unless SLR lasers are both Class 1 AND non visible, SLR activity may be severely restricted, requiring aircraft detection and beam interruption systems.

SLR systems must therefore operate in a way that presents no threat to aircraft. In practise this means operating in one of two modes:

- **Intrinsically** eye safe operation by means of satisfying laser safety standards at aircraft altitudes. This can be by means of adopting a safe emission wavelength such as 1.5 micron, or by reducing laser energy to safe levels.
- **Protected** mode operation, where aircraft are detected before entering the potentially hazardous beam and the laser is shut down while the aircraft transits the beam. Aircraft detection has traditionally been performed by manual observers or microwave radar.

Protected mode operation can also be achieved by other means of detecting aircraft, and here we discuss the relative merits and operational performance achieved by aircraft detection systems based on laser radar.

2. RELATIVE MERITS OF MICROWAVE AND LASER RADAR

The availability of eye safe military laser tracking systems, with enough sensitivity to track small objects such as missiles at ranges out to 30 km, provide a strong technology platform for the development of eye safe aircraft detection systems.

Radar was originally developed for purposes of aircraft detection, and has proven effective in this role at SLR sites. However radar has some limitations or disadvantages when used for SLR:

- **Emissions**. Some sites do not allow radar emissions, as they can disrupt sensitive equipment, or cause interference with other radar or communications equipment.
- **Range**. Radars applied in this role, to be affordable, are typically restricted in range to 12-15km rather than the full operational range required of 30-40 km.
- **Field of View**. Radar's wide field of view (several degrees) may cause more and longer system ranging outages than strictly necessary for aircraft safety.
- **Separate installation**. There are safety issues related to the fact that the radar is a separate installation with separate pointing of the antenna, and boresighting of the two systems must be regularly checked.
- **Maintenance**. Because radar uses a different technology from laser ranging, its technical support and maintenance requirements will be added to those of the SLR operation, causing an increase in maintenance costs.

Laser radar operates by detecting aircraft in the same way that the satellites are detected, however the detection of aircraft requires more laser energy than satellites, because the aircraft do not carry retroreflectors. This implies that the aircraft detection laser will be even more hazardous than the satellite tracking laser.

The aircraft detection laser must operate at around 10 times the energy of the satellite laser, to reach aircraft at maximum range with strong probability of detection. However by moving the wavelength to an eye safe wavelength which is also invisible, this scaling up of energy is permitted within all current or projected ANSI standards, or FAA guidelines.

The advantages of laser radar in this role are:

- **Emissions**. No restrictions apply to the aircraft detection laser emissions.
- **Range**. Ranges of 20-30 km are easily achievable.
- **Field of View (FOV)**: <60 arcseconds, ensuring only aircraft which enter the beam are detected.
- **Boresight**. By using the same optics, laser radar is unequivocally boresighted to SLR laser.
- **Maintenance**. SLR support engineers can be used with no extra training.
- **Outages**. The FOV overlap allows SLR laser shots to be individually „edited", so in practise only one shot per aircraft is lost.
- **Versatility**. The aircraft detection can be used for other eye safe Lidar experiments.

The design of aircraft detection laser radar (lidar) essentially involves wavelength multiplexing the eye safe wavelength into the same optical system as the SLR laser. Because the Lidar has a field of view which is almost the same as the SLR, there is no advance warning of the approach of an aircraft, so the Lidar should fire at the same frequency as the SLR laser, shot-for-shot.

If each SLR laser shot is preceded by a Lidar shot, then provided the delay between the two firings is set to (say) 300 microseconds, the Lidar will detect any aircraft which is in the beam of the next SLR shot. The 300 microseconds is enough time to give over 40 km of range, and not enough time for even a supersonic aircraft to enter the beam if it is not already there when the Lidar probe is fired.

3. THE KEYSTONE (KSP) CLASS SLR AIRCRAFT DETECTION SYSTEM

KSP-class SLR systems are being deployed throughout the world, but their initial deployment (5 stations) was in the area around Tokyo, where aircraft safety is a major issue. Recognizing the advantages of laser radar in aircraft detection, the KSP-Class SLR systems use laser radar to provide aircraft safety. The systems fire a Lidar probe along the path of the SLR laser before each shot is fired, as a check to ensure that no aircraft or any other obstacle is in the beam.

A key advantage of the Lidar is that it will detect any object in the beam. This is a major advantage for the systems deployed in urban areas, as there are many apartment buildings and commercial offices within the field-of-view of the SLR system, and the Lidar will readily detect these and inhibit the SLR laser. If the Lidar inhibits more than 10 laser shots in series, the SLR system will suspend and query the system status. No normal aircraft will take more than 2 shots to transit the beam, even at 50 Hz operation. The principal features of the laser radar used are provided below.

KSP Class Aircraft Detection System

Specification

4.	TRANSMITTER**:**	**30 MJ, 100 HZ, 1.57 UM, 75 CM APERTURE**	
	Receiver	80 mm aperture, InGaAs detector	
	Range	>20 km to 1m target	
	Fail probability	<1%	1 shot
		<0.01%	2 shots
		<0.0001%	3 shots etc
	Pre-pulse timing	300 us	
	Interlock	Hardware only, fail safe	

The systems were deployed in 1997 and 1998 in Japan and Australia, and have undergone extensive testing. The receiver is shown in the photgraph below, attached to the telescope secondary ring.