IN-SKY SAFETY FOR SATELLITE LASER RANGING

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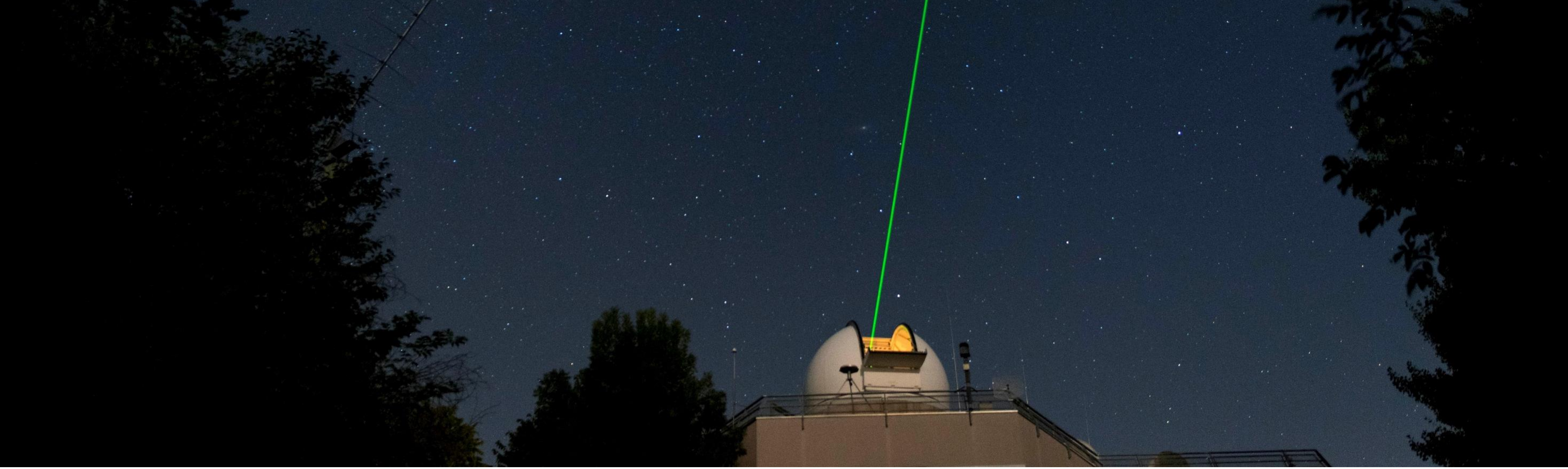
SGF, HERSTMONCEUX



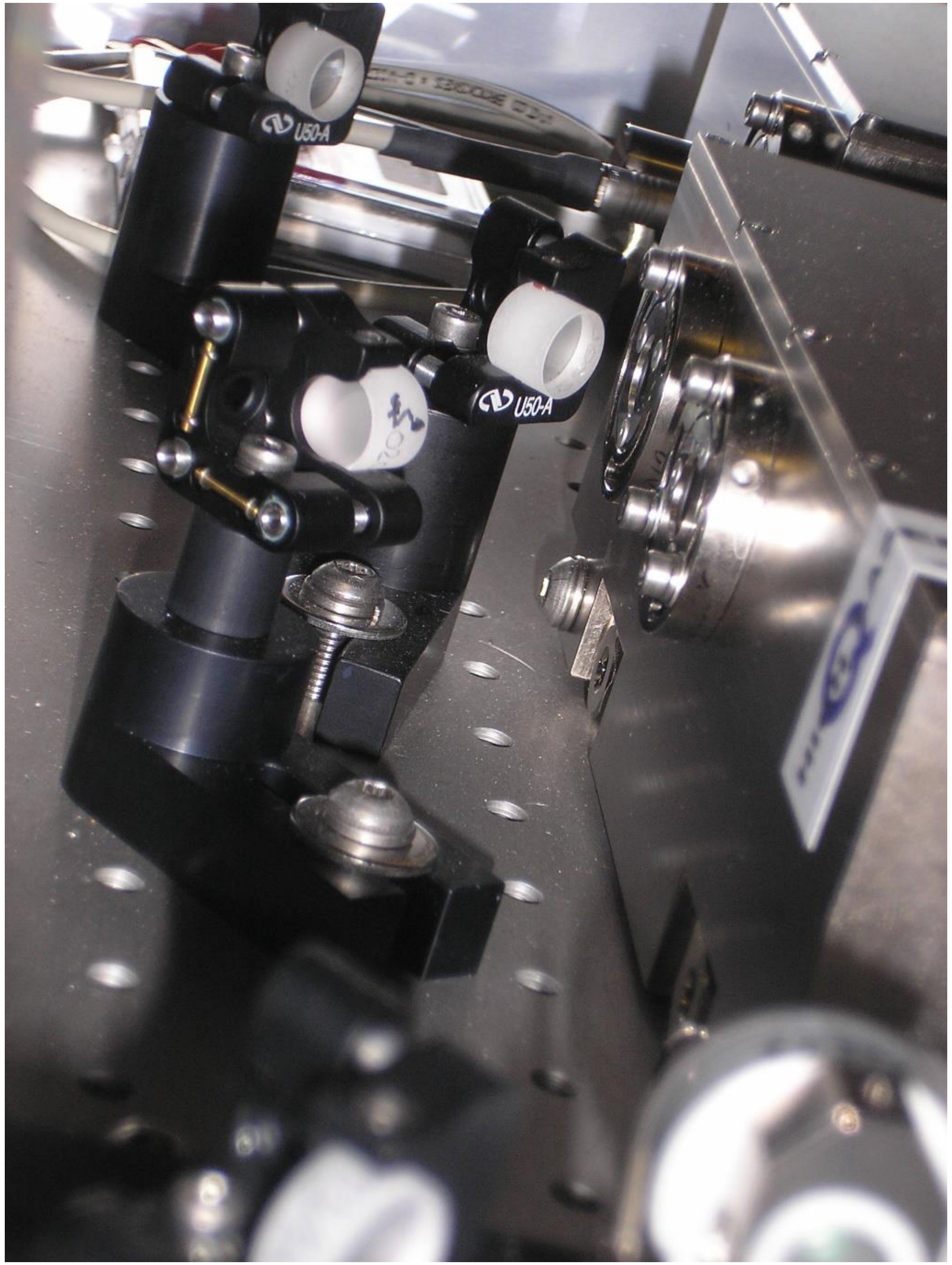
ACTIVE AIRCRAFT DETECTION

Shooting high-power, non-eye safe, laser pulses in to the atmosphere is a hazard for those flying onboard aircraft. SLR stations need to actively avoid firing in the direction of any aircraft passing overhead.

EYE-SAFETY

The laser pulses that are used for precise SLR are a hazard largely due to the very short pulse lengths.

At the SGF, Herstmonceux, for example, we fire 1mJ pulses at a rate of 1kHz. This is a small amount of energy. However, each laser pulse is emitted near instantaneously and therefore 1mJ released in a 10ps pulse and is high power (100MW).

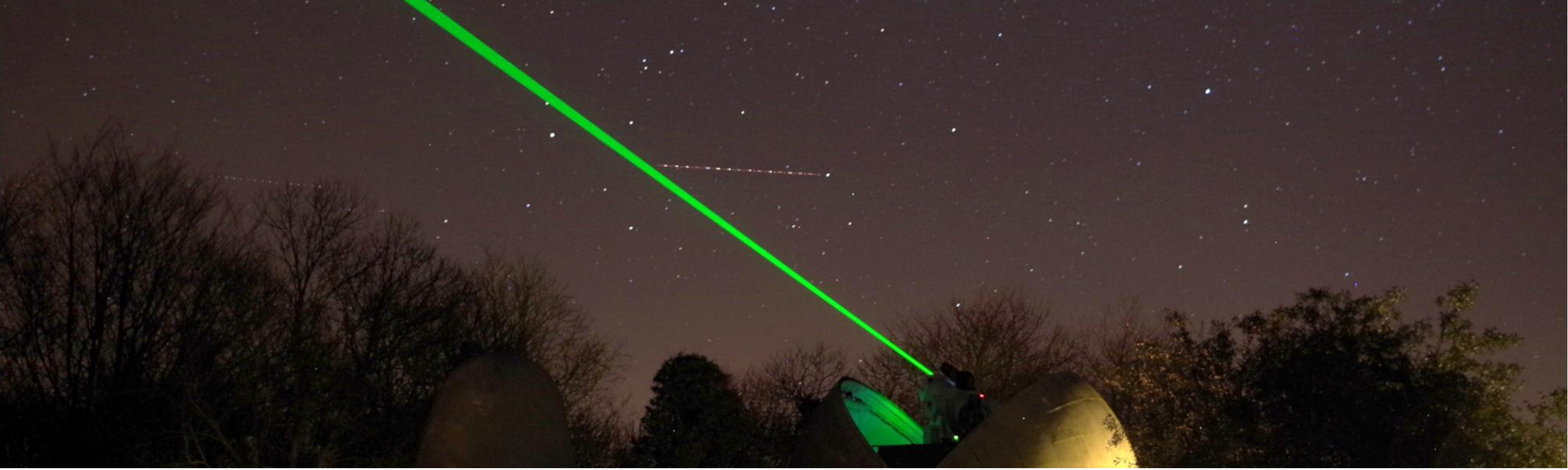


EYE-SAFETY CALCULATIONS

Regulations that set the exposure limits for eye-safety can vary across different countries. **The International Commission on Non-Ionising Radiation Protection** looks at different types of exposure and set exposure limits. [https://www.icnirp.org/cms/upload/publications/ICNIRPlaser400nm.pdf]

Exposure limits are set for:

- **Sub-ns** exposures ($0.015\mu J/cm^2$)
- Photochemical > 1 second and > 100 seconds
- Thermal > 1 second
- Repetitive exposure (multiple shots)
- Continuous wave exposure
- Skin



HOW TO PERFORM SLR SAFELY?

1. Lower the laser power density to a safe level by:
    - Low pulse energy
    - Greater repetition rates
    - Increased pulse length
    - Increased beam width and divergence

or

2. **Stop** laser firing when an aircraft approaches

ACTIVE RADAR

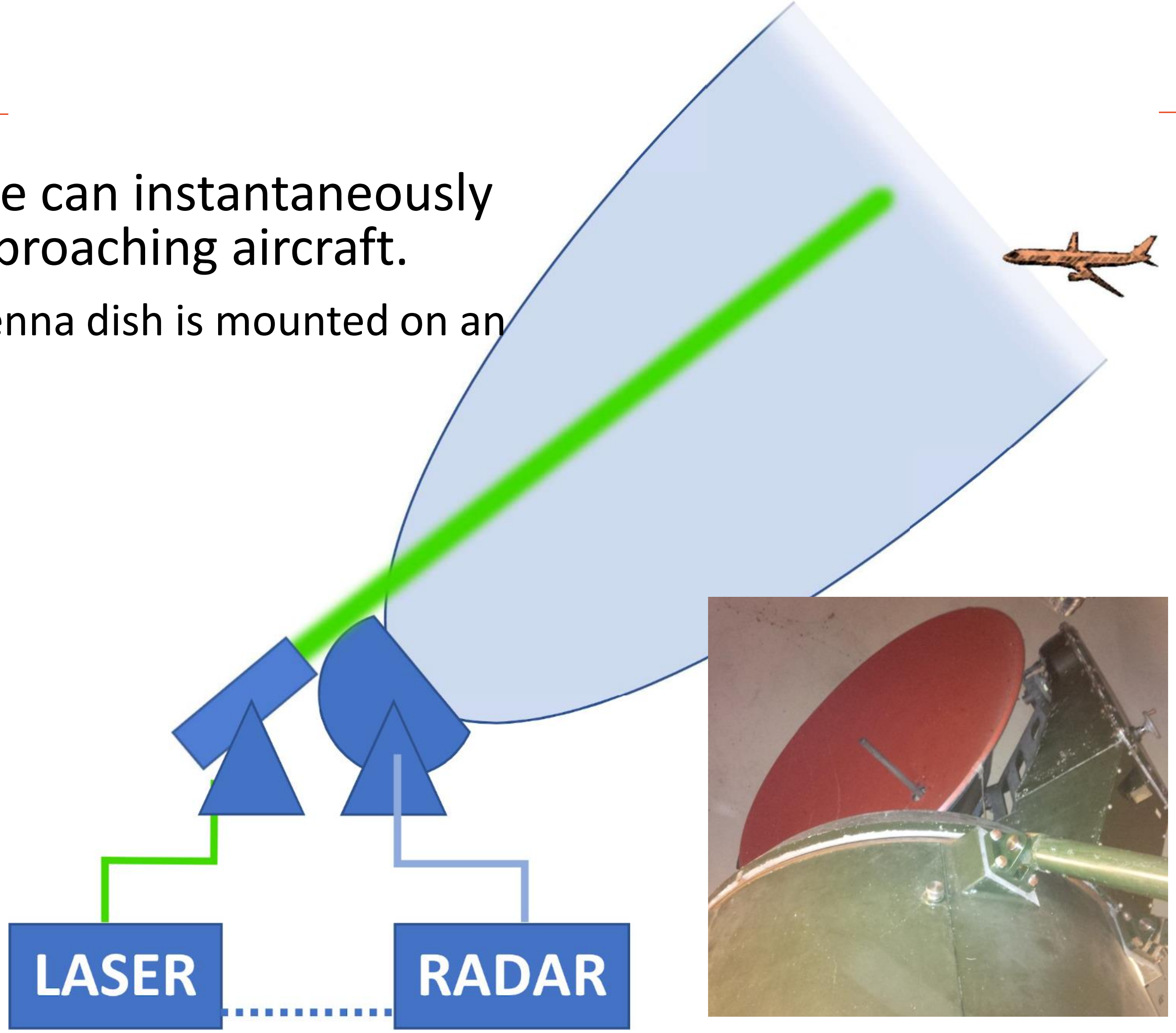
A radar dish moving with the SLR telescope can instantaneously inhibit the laser on the detection of an approaching aircraft.

At the SGF, Herstmonceux, a 150cm diameter antenna dish is mounted on an alt-az mount and is independently driven.

The X-Band transceiver produces 25 kW pulses (peak power) at a frequency of 9410 MHz (+-30 MHz), a pulse duration of 0.9 microseconds and a Peak Repetition Frequency of 750 pps.

It can detect returning reflections from objects in the beam path up to 40km away. To avoid false alarms triggering on nearby ground objects, the radar **does not detect below 2km**.

The high power radiated from radar systems causes interference with VLBI radio telescopes and they are **not** VLBI 2010 compatible.



OBSERVER

The observer at the SGF, Herstmonceux, is positioned beside the laser telescope. The dome opens wide and the sky is fully visible in all directions.

Once a pass is chosen and the telescope has started to track the target, the observer looks that the sky is clear in the direction that the telescope is pointing before firing the laser.

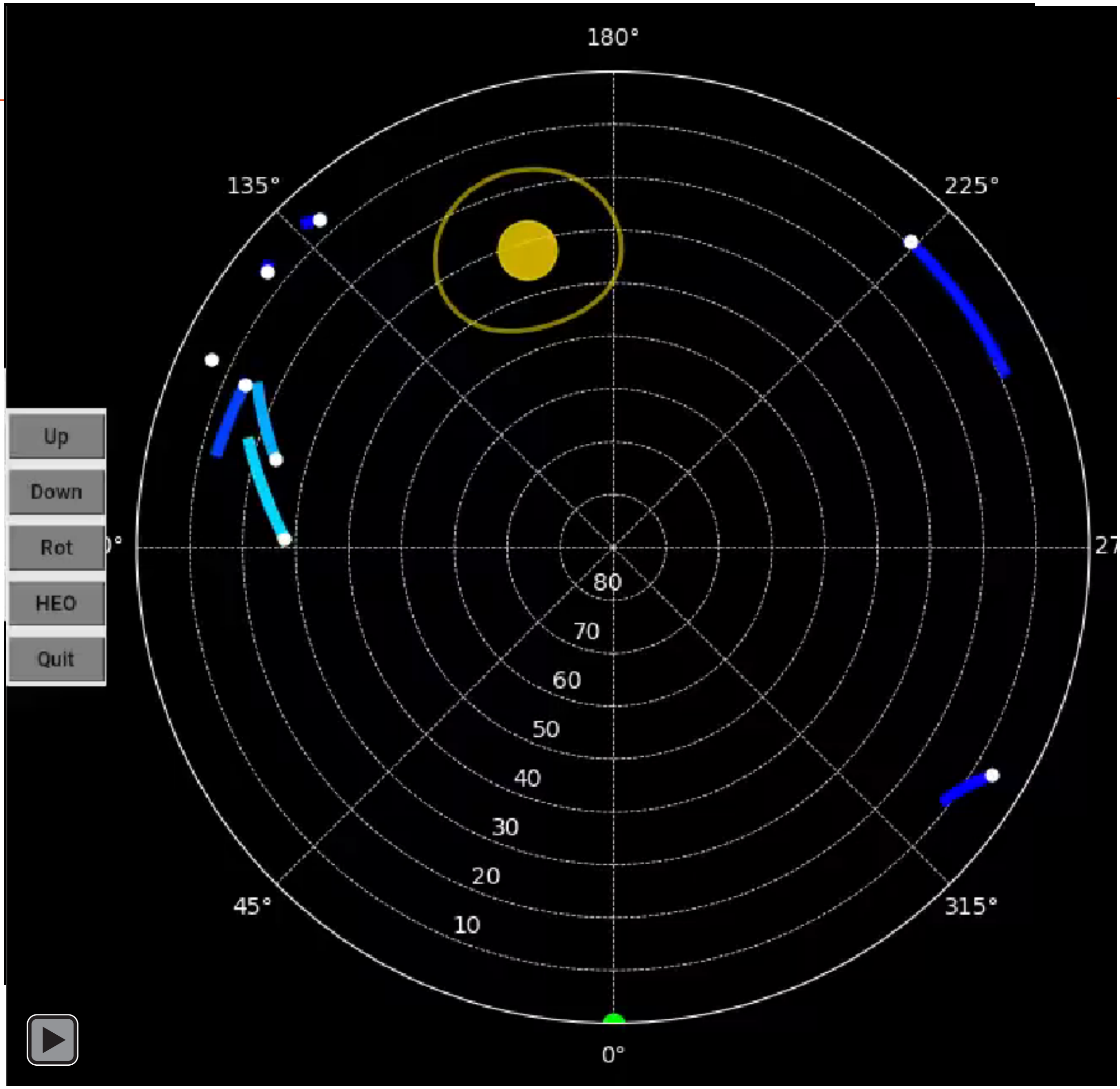
The observer looks out for all aircraft but small planes, gliders and balloons in particular.

The observer could be distracted or bored. Observers outside in the winter nights can get cold.

ADS-B

Automatic dependent surveillance—broadcast (ADS-B) installed on an aircraft will broadcast its latitude, longitude and altitude positions and velocities at approximately 2Hz. These signals can be intercepted with an antenna and receiver and then de-coded.

The majority of commercial aircraft operate ADS-B systems and this is becoming obligatory. For example, it will become a requirement in the USA and Europe in 2020.



ADS-B

At the SGF, Herstmonceux, we use a reliable SBS-3 receiver from Kinetic Avionics with a TCP/IP server and clients interpret, share and display the data.

[https://cddis.nasa.gov/lw18/docs/papers/Session8/13-03-07-Wilkinson.pdf]

TBAD

A directional antenna was designed at the University of California San Diego for laser ranging safety use. It is named “Transponder Based Aircraft Detector (TBAD)” and it looks out for sources broadcasting on the 1090MHz frequency, which will most likely be aircraft.

[https://cddis.nasa.gov/lw19/docs/2014/Papers/3058_Murphy_paper.pdf]

FLARM

FLARM is another aircraft proximity awareness system installed on some low flying aircraft.

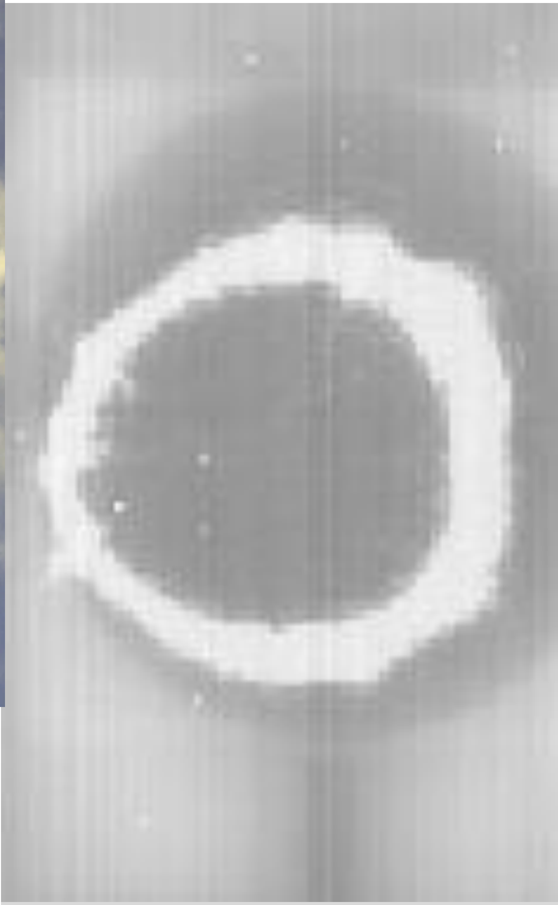
It is intended for collision avoidance for light aircraft and alerts the pilot of nearby traffic. It calculates and broadcasts the plane’s future flight path to nearby aircraft and receives the future flight path from surrounding aircraft.

NEW IN-SKY SAFETY

Digital optical cameras. A camera or series of cameras could monitor the sky in the direction of the laser fire for planes, balloons, gliders and other objects. Infrared cameras could have advantages in identifying aircraft in the sky.

Directional microphones. Often an aircraft is heard before it is seen and a directional microphone could provide additional in-sky safety.

Aircraft Safety LIDAR. A laser ring for aircraft detection has been developed for the SOS-W SLR station in Wettzell, Germany. The LIDAR beam is centred around the SLR laser and any backscatter reflections indicate a possible aircraft approaching the main beam.



[https://cddis.nasa.gov/lw19/docs/2014/Presentations/3131_Riepl_presentation.pdf]

CAN SLR BE EYE-SAFE?

SLR2000 was proposed to NASA in 1994 as a largely autonomous, eye-safe SLR system. The laser was 0.25 mJ at 2 kHz, resulting in approximately the same average power output as the MOBLAS systems.

In order make it eye-safe at the output of the telescope, SLR2000 was designed so that the transmitter and receiver shared the full 40-cm telescope aperture.

Unfortunately, an unforeseen change in ANSI laser safety guidelines in 2000 resulted in a reduction by a factor of 13 lower in acceptable peak laser power at the emitter.

The ILRS Engineering station in **Stuttgart** is firing infrared, 0.12mJ, 13ns pulses at a rate of 100 kHz. This is much closer to being eye-safe and the station must calculate exactly when this is and is not the case.

AUTOMATION IN-SKY SAFETY

There is a trend in the ILRS global network towards automation. This could be a new modern station or the development of an existing station.

There are many different levels of automation, with the most extreme being an independent, robotic system in a remote location.

Such systems will have to ensure in-sky safety for all aircraft at all altitudes without depending on any human input.

CONCLUSIONS

SLR stations must actively minimise the risk of illumination of aircraft flying overhead and the potential damage to human eyes.

There are a number of in-sky safety systems in operation in the ILRS network. It is beneficial to have layers of safety by having more than one system in place.

CONCLUSIONS

Eye-safe SLR, if it is possible and workable, would mean that the additional safety hardware would no longer be required.

An automated, un-manned SLR station would need to detect aircraft at all heights without relying on any human monitoring to quickly interrupt laser fires.

THANK YOU

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