# An automated, intelligent, LHRS (AI-LHRS) for supporting the safety of lasers in airspace and the performance of supporting devices on the ground


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## Abstract

A radar-based Laser Hazard Reduction System (LHRS), for managing the potential for laser radiation hazards in airspace, has gone through extensive indoor and outdoor testing. The system operates at ~600Hz. The airspace monitoring is built with automated features of hardware and software. The system allows the mapping of the safety system functions and parameters throughout its operation. The coordinates of the radar beam pointing in 3-d space, target range, transmit epoch, receive epoch, and target-intercepted signal return strengths are captured in every frame for target interrogation and inferencing. Intelligence is built in the analysis and inferencing of various operational and system parameters to ensure situational awareness, the integrity of operations, and the avoidance of potential system problems that may interfere with the radar safety functions. Certain operational details of this system are discussed.


## <1> Introduction

1. CW & pulsed laser deployments for aerospace applications vary by orders of magnitudes for peak and average powers. Below a certain average or peak power, there is no need for a laser safety surveillance system.
2. Above the Eye Hazard level and especially for longer airspace ranges, we need human/machine intervention to prevent laser intercept of airborne vehicles.
3. Radar technology and related product engineering are well-matured to provide robust, reliable, and continuous operations. Unlike vision-based safety systems, one discernable feature of an RF-based system is its ability to sense through poor sky transmittance conditions during day and night.
4. It is convenient to have a compact laser surveillance system fully protected by a Radome under all conditions of the sky.

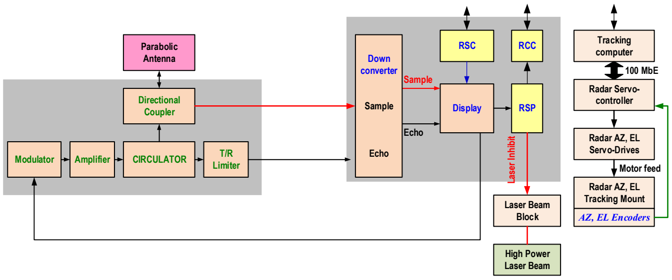
## <2> Cybioms LHRS – *hardware and software*

1. The LHRS radar operates at ~600Hz; airspace monitoring, analysis, and inference are built with automated features in hardware and software.
2. LHRS uses ADCs for radar signal digitizations and an FPGA board for real-time signal analysis and very low latency decision-making. The combination of software and firmware determines the LHRS behavior and inferencing
3. The firmware contains a set of read/write control registers and a set of read-only status registers. The control registers are used to input the user-defined parameters into the firmware, select the desired mode of operation, and perform necessary resets and initializations.
4. The status registers provide detailed status and debug information from the firmware.
5. The software utilizes the FrontPanel USB 3.0 driver and the RegisterBridge HDL module of the FPGA board to read and write the 32-bit registers

## <3> Cybioms *LHRS – radar for aerospace laser surveillance*

1. Cybioms' LHRS radar system is fully enclosed in a sealed fiberglass radome to allow radar system protection under all weather conditions.
2. Cybioms has designed and built several autonomous Laser Hazard Reduction Systems (LHRS) that work collaboratively with aerospace systems.
3. In a data-driven LHRS approach, the software is a critical part of establishing digital intelligence for its operation, performance monitoring, and automation.

## <4> Cybioms LHRS – *hardware and software block diagram*




## <5> Cybioms *LHRS – data space for situational awareness*

The radar system allows real-time mapping of the safety system functions and parameters throughout its operation. The radar operates at a frame rate of 600Hz. The multi-dimensional data also include device-related parameters :

- radar operational parameters
- radar beam pointing coordinates in 3-d space
- radar intercepted target slant range
- radar beam transmit - receive epochs
- target-intercepted radar signal receive-amplitude
- internal radome environmental parameters
- external environmental parameters

SLR and radar parameters are captured in every frame for intelligent interrogation.

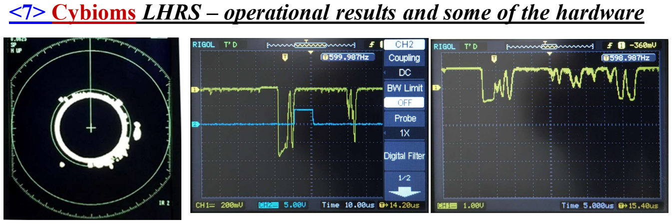
## <6> Cybioms *LHRS – automated HW & SW modes of operation*

Test Mode – Upon receiving a trigger (TR) input, a contiguous stream of samples on ADC channels 1 and 2 are logged to file. The user-configurable duration and epoch of the window are timestamped. During Test Mode and Radar Mode, only ADC channels 1 and 2 are enabled.

Radar Mode – Upon receiving a TR input, contiguous samples during the window on ADC channels, 1 and 2, are monitored to authenticate RX pulse input. The duration of the window, min/max pulse width, voltage threshold, and polarity are user-configurable. The window epoch is timestamped and logged to a file.

Radar and Peak Detect Combined Mode – If a "true RX pulse" is detected before the window expires, the pulse samples, pulse length, index within the window, pulse peak, and pulse peak index within the window are logged to a file. The output trigger defaults to logic high and will be set to logic low if a pulse is detected and will return to logic high after 3 seconds of no detected "valid" return pulses.

## <7> Cybioms *LHRS – operational results and some of the hardware*



## <8> Cybioms *LHRS– digitized target return signal processing*

```
2018, 101, 71385.553852, X, X, 30000, 8, 200, 0
2018, 101, 71385.653851, 0, 29926, 30000, 8, 200, 1
2018, 101, 71385.753850, X, X, 30000, 8, 200, 0
2018, 101, 71385.853849, 29942, 29893, 30000, 8, 200, 1
2018, 101, 71385.953847, X, X, 30000, 8, 200, 0
2018, 101, 71386.053858, 0, 29948, 30000, 8, 200, 1
2018, 101, 71386.153857, 0, 29974, 30000, 8, 200, 1
2018, 101, 71386.253856, 0, 29932, 30000, 8, 200, 1
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2018, 101, 71386.453853, 0, 29949, 30000, 8, 200, 1
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2018, 101, 71386.953848, 0, 29935, 30000, 8, 200, 1
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2018, 101, 71387.653851, 29946, 29938, 30000, 8, 200, 1
2018, 101, 71387.753850, 0, 29929, 30000, 8, 200, 1
```

1. X or 0 → signal level <threshold; S1 and S2 are –ve signals.
2. IF Signal 1 AND/OR Signal 2 > threshold V, THEN, detection =TRUE
3. IF signal 1 AND signal 2 < threshold, THEN detection=FALSE

## <9> Conclusions

1. Cybioms has established an LHRS system with automation and intelligence for the operations and monitoring of the airspace as well as its ground system
2. An AllSky camera provides a 3-d view of the sky at the deployment location. This is further augmented by other cameras on a telescope tracking synchronously with the LHRS to capture the view of the airspace along the line of sight (LOS).
3. Greater emphasis is placed on maintaining situational awareness at all times and using machine intelligence for overall safety management.
4. System is commercially available to the wider aerospace community.