Regulatory Considerations: Laser Safety and the Emerging Technology of Laser Communication

Robert Lafon (GSFC) robert.lafon@nasa.gov
Janet Wu (JPL) janet.p.wu@jpl.nasa.gov
Bernie Edwards (GSFC) bernard.l.edwards@nasa.gov
A growing number of missions are looking to laser communications to provide high data rates while reducing Size Weight and Power required on spacecraft. LLCD, LCRD, ILLUMA, and LEMNOS to name a few.

Now that Industry is also looking to make use of this emerging technology, regulation regarding its use need to consider the implications of it’s widespread use.

Safety must be ensured in a way that allows the potential of this technology to be fully realized.

In order to keep operations as simple and economical as possible, the laser transmitters on the ground ideally will be operated remotely, without an on-site staff required to ensure safe operations.
Regulatory Considerations: Outdoor Laser Use

• For commercial applications, the regulatory agency that will have to be dealt with most (for operations) is the FAA.

• The starting point for navigating the regulatory environment applicable to Outdoor laser operations is the ANSI Z136.6: *American National Standard for Safe Use of Lasers Outdoors*

• Additionally, ANSI Z136.1: *American National Standard for Safe Use of Lasers*

• These documents serve as the standard from which many of the FAA requirements are derived.

• Most importantly these documents define how to determine the Maximum Permissible Exposure (MPE) level for a given laser.
The goal is to design your laser transmitter system so that it will get a “Letter of non-objection” from the FAA.
## FAA: Notice of Outdoor Laser Operations

### General Information
- **Label:** FAA/NTSB Notice of Outdoor Laser Operations
- **Purpose:** To provide all requested information may delay processing of your notice.

### Laser Configuration Worksheet

#### 1. Configuration Information
- **Configuration Number:**
- **Event/Facility:**
- **Proposed:**
- **Description:**

#### 2. Geographic Location
- **Latitude:**
- **Longitude:**
- **Elevation:**
- **Vertical Datum:**

#### 3. Beam Characteristics and Calculations
- **Wavelength:**
- **Pulse Energy:**
- **Total Energy:**
- **Repetition Rate:**

#### 4. On-Site Operation Information
- **Operator:**
- **Phone:**
- **GPS:**

#### 5. Brief Description of Control Measures
- **Type:**
- **Description:**

### Attachments

- **Number of laser configurations:**
- **List of attachments:**

### Designated Contact Person
- **Name:**
- **Position:**
- **Phone:**
- **Fax:**
- **Email:**

### Statement of Accuracy
- **Signature:**
- **Date:**

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**Form:** FAA Form 740/1 (4-01)

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**FAA:** Federal Aviation Administration

**NTSB:** National Transportation Safety Board

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Example FAA Letter of Non-Objection to Palomar Observatory for their Laser Guide Star system (Visible high power laser)
Ideally, transmitter system design should be optimized to minimize costly safety mechanisms/procedures.
Laser Wavelength

- The wavelength of a laser is the most important factor in determining the level of hazard a laser presents to aircraft.

- Visible wavelength lasers- even at low, safe power can distract a pilot.

- Visible and Near-Infra-Red wavelengths can be focused by the eye and concentrated on the retina- making them especially hazardous.

- Hazardous intensities are typically on the order of 1-5 milliwatts/cm².

- **Wavelengths > 1400nm cannot be transmitted to the retina.** They cannot distract a pilot. A laser at this wavelength becomes hazardous only at intensities high enough to burn: ~100mW/cm² for a duration of >10 seconds.
Intensity Levels

• For a Gaussian laser beam with total power $P$, and $1/e^2$ waist radius $w$, the maximum intensity at the center of the beam is given by:

$$I_{\text{max}} = \frac{2P}{\pi w^2}$$

• All laser beams have some divergence. If $I_{\text{max}}$ exceeds the MPE at the transmitter, then at some distance the beam will diverge enough that it will be safe- this is called the Nominal Ocular Hazard Distance (NOHD)

• If a laser exceeds the MPE for aircraft within Navigable Airspace, the FAA is not likely to issue a ‘Letter of non-Objection’ unless some Hazard Mitigations are included in the system design and Operations plan- Human airplane spotters, radar, cameras etc...
Duration of Exposure

- The period of time over which exposure occurs also factors into the determination of what constitutes a safe level of laser exposure.

- For example, at 1550nm for an exposure duration of 10 seconds or more the MPE is 100mW/cm². If the duration is reduced to 1 second the MPE is 1W/cm².

- Thus the motion of the beam relative to a person can be considered a mitigating factor.
Prior to the adoption of AS-6029A, the MPE for 1550nm lasers was calculated based on a 10 second exposure.

This meant that for 1550nm lasers, intensities greater than 100mW/cm² were considered hazardous to aircraft and would be required to implement safety systems to prevent illumination of aircraft.

AS-6029A takes a more reasonable view, acknowledging the fact that aircraft will be moving relative to the beam:

“For unintended exposure to aircraft from visible or infrared laser beams from ground based or airborne platforms, a maximum exposure duration of 0.25 second is used in the computation of the MPE or visual effects, due to natural relative motion between the beam and aircraft related to wind and other stabilization issues.”

This greatly raises the Intensity laser transmitters can operate at without implementing costly avoidance systems.

The MPE for aircraft is increased by a factor of 40! From 100mW/cm² to 4W/cm².
Impact of SAE AS-6029A

- When you look at the implications of AS-6029A, the benefit of operating at wavelengths >1500nm becomes clear.
- For a Gaussian beam at 1550nm with a waist radius of 5cm the maximum non hazardous (for aircraft) total power:
  - Before AS-6029A was ~4W, now it is ~160W.
- This is far more power than is likely to be needed for transmitting to LEO or GEO... or even the Moon!
Implications for Remote, Unmanned Operations

• The acceptance of AS6029A and the 0.25 second rule paves the way for remote, unattended operations for laser transmitters that demonstrate they are below the MPE for exposures of 0.25 seconds.

• The non-hazardous intensities are especially high for wavelengths longer than 1.5 microns.

• As long as intensities are kept below 4W/cm², transmitters at 1.5 microns will likely get a letter of non-objection from the FAA with no requirements on safety systems. (However, if the intensities exceed 0.1 W/cm² precautions will have to be taken to protect personnel on the ground).

• A new AS6029 is being reviewed to address proper safety systems for the remote, unattended operations of lasers that exceed the MPE for aircraft.
Laser Clearing House (LCH)

- The Laser Clearing House (LCH) is tasked with ensuring orbital assets are not negatively impacted by lasers.
  - The LCH only considers DoD laser programs to be REQUIRED to coordinate laser activities with them...
  - ANSI Z136.6 “American National Standard for Safe Use of Lasers Outdoors” advises:

  Operators of lasers that have a divergence less than $10 \mu\text{rad}$, or that exceed a peak irradiance greater than $1 \text{mW cm}^{-2}$ above $18 \text{ km (60,000 feet)}$ in altitude above sea level, should contact U.S. Space Command regarding “Laser Clearinghouse” screening.

  **ONLY LASER PROJECTS WITH DoD INVOLVEMENT ARE REQUIRED TO COORDINATE WITH THE LCH. HOWEVER MANY NON-DoD LASER PROJECTS DO COORDINATE WITH LCH TO ENSURE NO DAMAGE TO SATELLITES.**

- The full process of coordinating with the LCH can be quite lengthy and may take many months. Outdoor laser projects should establish contact with the LCH as early as possible to understand the process.

- It may be possible to reduce the negative impact of LCH restrictions by making smart decisions early in the design of your system.
  - For example, ensuring that the laser system will quickly shutter itself if laser pointing drifts could allow you to request and justify a smaller Keep Out Cone from the LCH – GREATLY reducing the number of predictive avoidance outages your mission will have during operations.
  - LCH usually requires personnel to be co-located with the laser and reachable by phone to ensure laser can be immediately turned off in the event that the LCH issues a cease operations order.