ELROI: A license plate for satellites that anyone can read

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Motivation: a unique ID for everything that goes into space

17,000+ objects are tracked today. If custody is lost, re-identification is hard.

CubeSats are being launched 100+ at a time. Which one is yours?

Satellites need a “license plate” that anyone can read from the ground.
Outline: Extremely Low-Resource Optical Identifier

1. How ELROI works
2. ELROI-PC104 launching 2018
3. ELROI-UP and future hardware
4. How you can observe our test flights
5. Summary and conclusions
Extremely Low Resource Optical Identifier

Photon timestamp data

$t_1, t_2, \ldots, t_n \rightarrow ID$

Blinking light with milliwatt average power encodes ID number

Photon-counting sensor

Spectral filter

Telescope
Signal structure enables extreme background rejection

1. Monochromatic laser light:
   Most background can be blocked with a narrow spectral filter

2. Precise clock period + short, high-power pulses:
   Remaining background can be removed with “lock in” data analysis

3. Observe with photon-counting sensor

4. Error-correcting code tolerates bit errors
ELROI concept summary

- Extremely low SWaP: optical beacon can be read from the ground in a few minutes with milliwatt optical power
- Not radio, so no RF interference
- Operates for entire orbital lifetime of host object
- Suitable for inert objects and debris
- Successful ground test over 15 km at LEO photon rates

*D.M. Palmer and R.M. Holmes, JSR 2018*
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ELROI-PC104 on NMTSat

NMTSat: 3U student CubeSat from New Mexico Tech
ELROI-PC104 on NMTSat

See SPIE proceedings for signal characteristics and ID numbers doi: 10.1117/12.2306091

- NASA ELaNA launch on Rocket Lab Electron
- Launching December 2018?
- First NASA-sponsored launch with CubeSats as primary payload

ELROI laser diodes in pre-launch testing
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ELROI-UP: Autonomous Universal Prototype

- Self-powered with small solar cell
- Can receive power and/or data from host, but doesn’t need to
- 250 g, 9.8 x 9.2 x 3.4 cm
- Mounts to host or in a CubeSat standard frame (< 1/2 U)
ELROI-UP: successful vibration test 7/30/18
Next design: ELROI 1.0

Target size is \(~2 \times 2 \times 0.5~\text{cm}^3\) (thick postage stamp)

Size limited by power/solar cell
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LANL ground station near Jemez Springs, NM

35-cm Celestron telescope
Paramount ME tracking mount
LANL-developed single-photon camera

Photonis camera is a COTS equivalent
Want to observe ELROI?

• Reading an ELROI ID requires a single-photon sensor
• An imaging sensor makes tracking much easier
• Single- or few-pixel single-photon detectors can also observe ELROI if tracking is good enough
• Example: Satellite laser ranging ground stations

Contact us to discuss ground station designs and flight opportunities
Outline

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Summary

• A milliwatt optical beacon can provide unique ID numbers for everything that goes into space, simplifying identification and tracking
• Made possible by extreme background rejection with photon counting
• ELROI has been successful in long-range ground tests
• ELROI-PC104 is the first orbital prototype, launching this year!
• ELROI-UP is a compact, autonomous design (seeking flights)
• We encourage others to consider observing our test flights
ELROI team

**LANL:** David Palmer (PI), Charley Weaver (EE), David Hemsing (mechanical), Joellen Lansford (software)

**NMTSat:** Anders Jorgensen and students Sawyer Gill, Zach Harris, Riley Myers, and Aaron Zucherman
Extra slides
Long-range ground test

- Ground-to-ground test at 15 km horizontal range
- Atmospheric depth > ground-to-space
- 3 mW average optical power
- Receiver: camera lens on photon-counting sensor
ELROI-UP: technical details

- Size 9.8 x 9.2 x 3.4 cm
- Mass 250 g
- Power (external) < 100 mW
- Internal battery > 1 day
- Can hold four laser diodes
ELROI-PC104 on NMTSat: technical details

• 3 red (638 nm) diodes turn on by default
• Blue (450 nm) diode can be turned on by NMTSat
• North face visible from northern hemisphere (New Mexico), south face visible from southern hemisphere

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