


Visible Light Communication Between CubeSats During Close Proximity Operations

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Outline

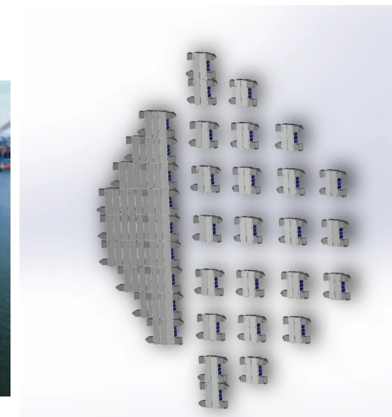
- Introduction and Motivation
- Proposed Solution
- Inspiration
- Related Work
- Advantages of VLC
- Objectives
- Technical Methodology
  - Concept of Operations
  - System Design
  - Proposed Testing Methodology
- Conclusions and Future Work

Introduction and Motivation

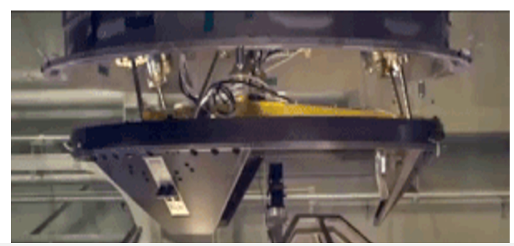
Co-ordination, Co-Operation, Formation Flying:

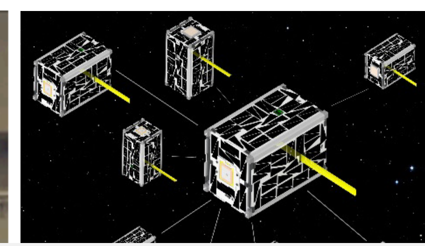
- Required for Space Commerce
- In-Space Assembly
- Rendezvous, Proximity Operations, and Docking
- Mother-Daughter satlet

Figure: Shipping Containers on a ship



In-Space Assembly





Berthing

Requirement for a CubeSat Form Factor Inter-Satellite Communications System

Proposed Solution

Visible Light Communication (VLC)

- Encoding messages (bits) in Visible Light bandwidth (wavelength spectrum of 380 nm to 750 nm corresponding to a frequency spectrum of 430 THz to 790 THz)

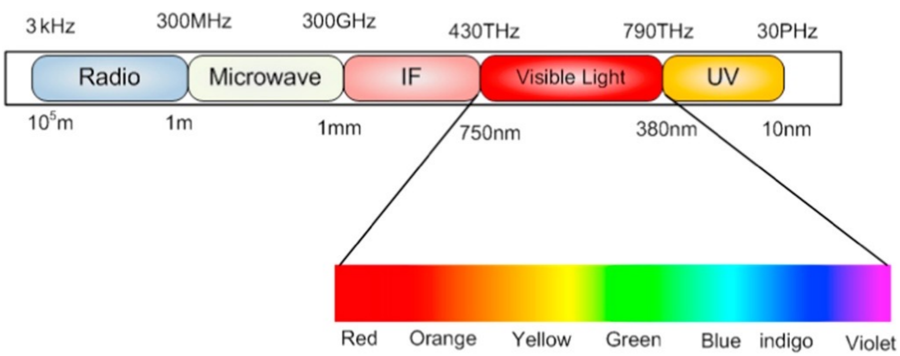


Figure: VLC Spectrum [2]

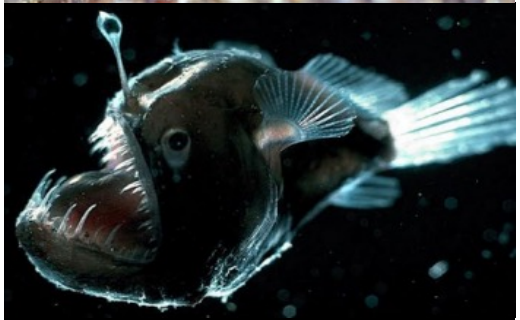
Inspiration

Nature

- Use of Bioluminescence to communicate
- More prevalent in deep-sea areas

Man Made

- Aircraft Strobe Lights



Inspiration from Bioluminescence found in Deep-Sea to apply in Deep Space.

Airplane Strobe Lights [3] (Bottom)

Related Work

- Used in Aircraft and Maritime activities as a standard
- Demonstrated commercially for localization

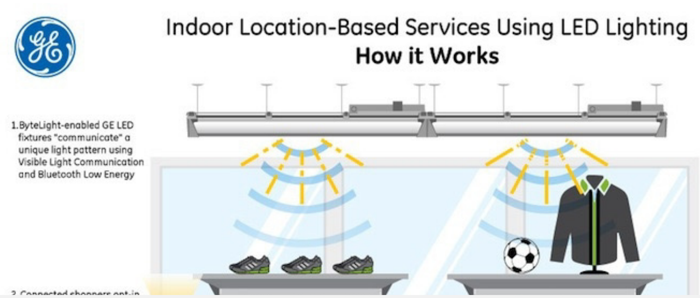


Figure: VLC Demonstration by GE and ByteLight [5]

SpaceX Dragon – ISS Docking using strobe lights (Credit: NASA/SpaceX)

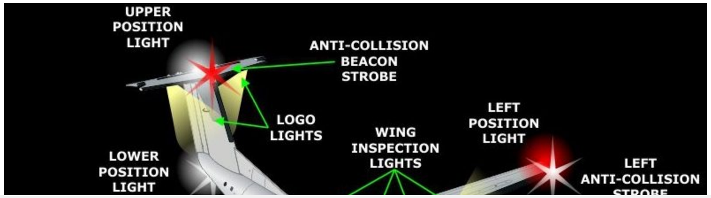
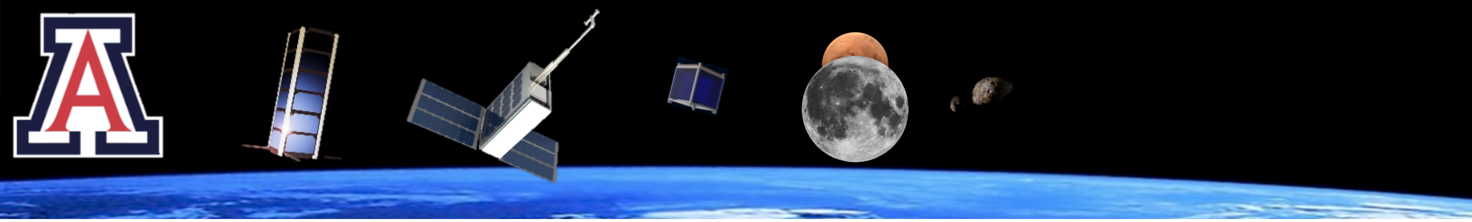


Figure: Exterior Lighting System of an Aircraft [4].

Lighting Cues as a standard for Aircraft and Maritime applications



Advantages of VLC

Traditional Advantages (Terrestrial)

- Higher Speed – Up to 10 Gbps ✓
- No EMI ✓
- Lower Cost ✓
- Spectrum: RF is getting saturated; VLC is 10000 times larger in Bandwidth ✓
- Dynamic Load Balancing

Traditional Disadvantages (Terrestrial)

- Requirement for Line of Sight
  - Not an issue in space
- Lower Range
  - Not an issue for proximity operations
- Interference by external noise

We get the best of both worlds using VLC in space

Objectives

- Develop a system to identify a target 3U CubeSat in Deep Space
- Must fit in a 3U CubeSat Form factor (mass, volume, power)
- Develop a VLC system with the following key specifications:
  - Target Identification Range = 50 m (TBR)
  - Bit Rate = 100 Mbps (TBR)

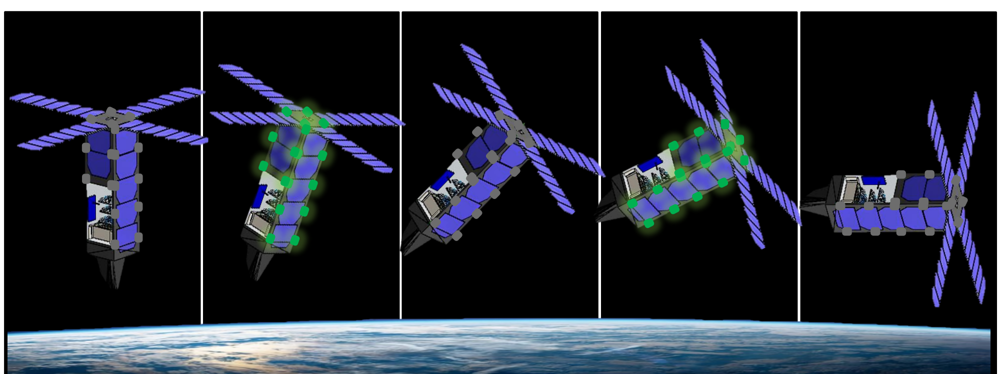
Concept of Operations

Phase 1: Initial Rendezvous

“Active Lighting Cues"

- Use of Blinking LED lights on all surfaces of each S/c
- Identification using Light-to-digital converters (Photodetectors)
- If S/c does not exit "Searching" mode after a set time, it executes a manual spin using thrusters/magnetorquers

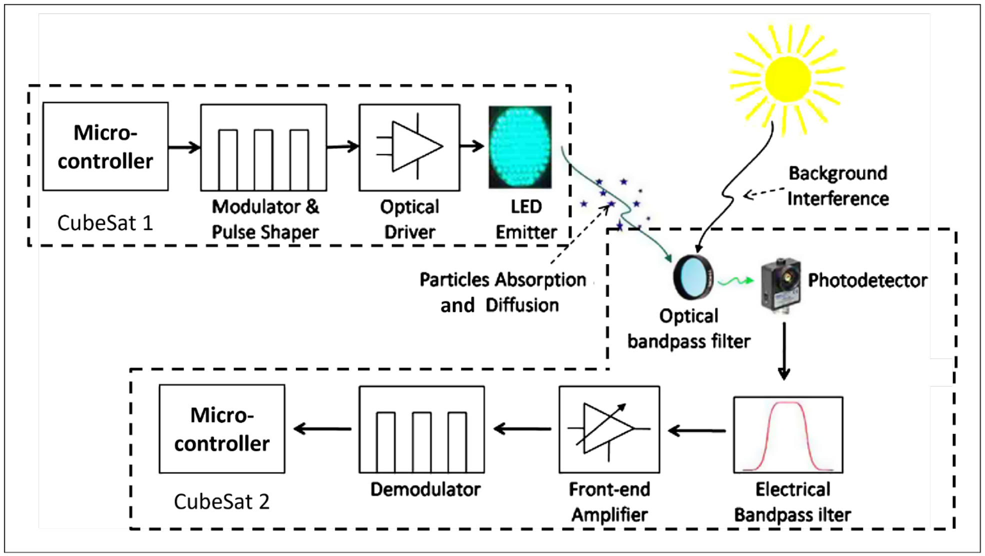
Blink Frequency	Message
1 Hz	“Searching” Mode
2 Hz	“Target Identified” Mode
3Hz	“Contact Established” Mode
4Hz	Distance = 50 to 10 meters (TBR)
5 Hz	Distance = 10 to < 1 meters; Close contact
Off	End of Initial Rendezvous Phase; Switching to Soft Capture Phase



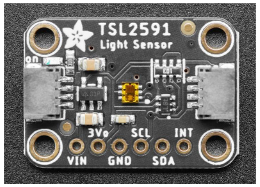
T + 0 seconds: LED Off	T + 1 seconds: LED On	T + 2 seconds: LED Off	T + 3 seconds: LED On	T + 4 seconds: LED Off

Chaser CubeSat in "Searching" mode, executing a manual spin with blink frequency of 1 Hz

System Design

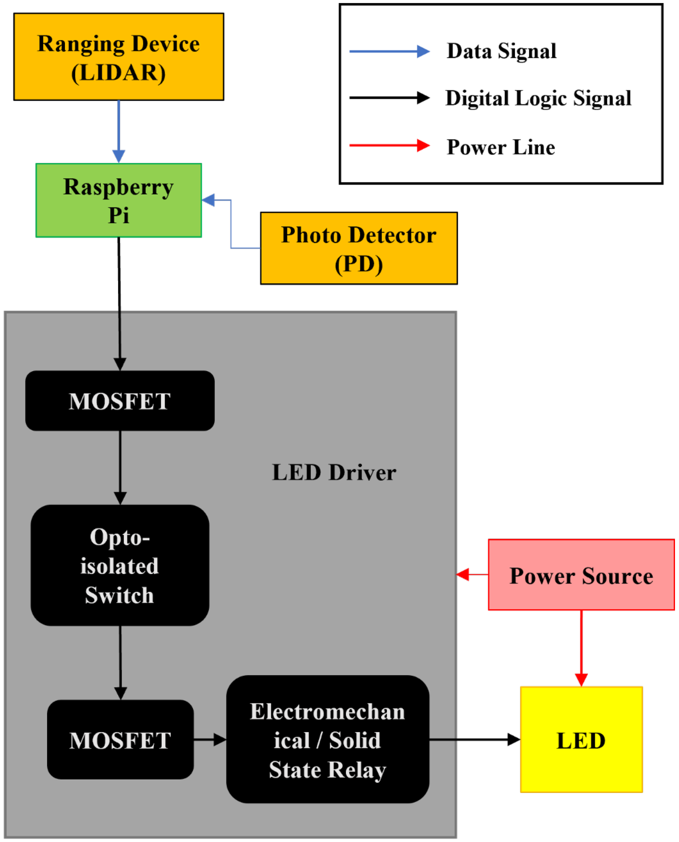


LED Lighting Cues System Architecture, modified from[6]



TSL 2591 Light Detector

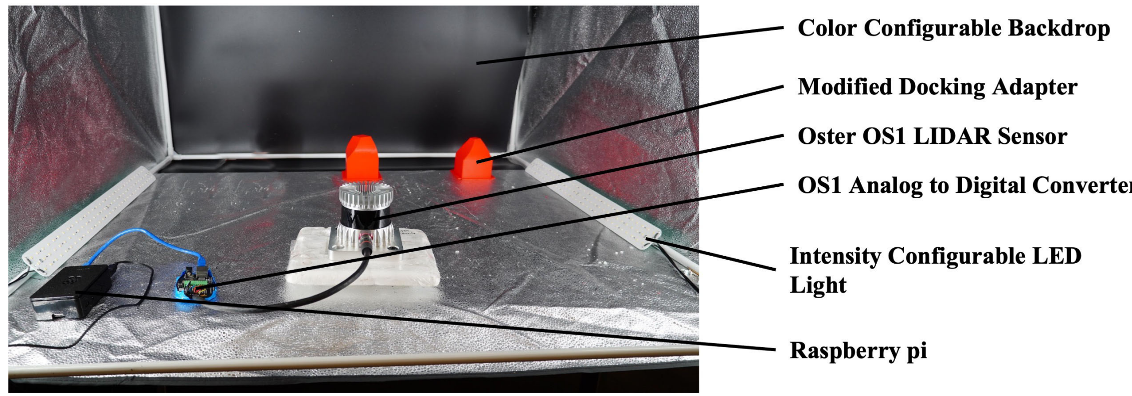
amsOSRAM High Power LED used in testing



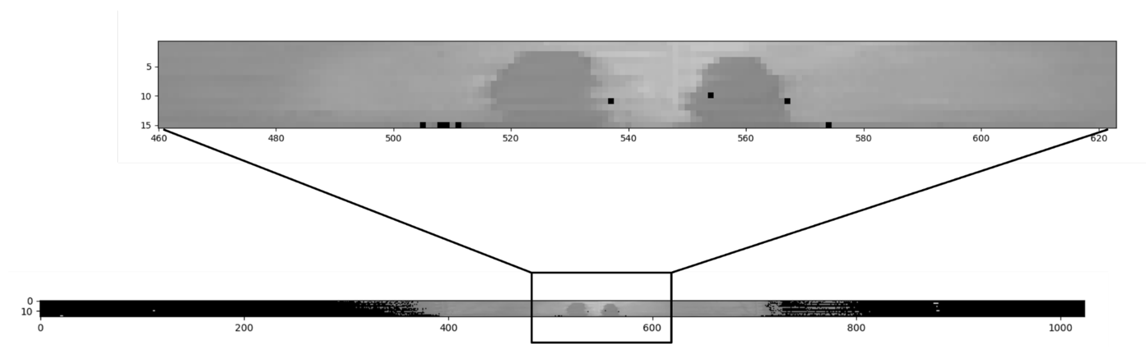
Block Diagram of High-Power LED Driver Circuit with Photo Detector and Lidar Input

Testing Methodology

Light Adjustable Lighting Studio



Ranging Proof of Concept Example Test Setup



Scan of 1U Docking Adapters by the OS1 Sensor

Conclusions and Future Work

- Fabrication of LED-Photo Detector circuit to validate Lighting Cues as a proof of concept complete.
- Identification of 1U Docking Adapter using available LIDAR hardware complete.
- Experimental verification of design over various distances and lighting conditions underway

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