Inter-satellite Omnidirectional Optical Communicator for CubeSat Swarms

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Inter-Spacecraft Omnidirectional Optical Communicator (ISOC)
Outline

1. Description of ISOC
2. ISOC Design and Testing
3. Technology Demonstration Mission Concept
4. Swarm Testbed
5. Examples of Science Missions
6. Conclusions
Acknowledgements

• Collaborators:

  **JPL**
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  **California State University – Northridge (CSUN)**
  James Flynn and student team

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1. Description of ISOC

Description of ISOC: Inspiration
1. Description of ISOC

Main Goals
Enable constellations and swarms
1. Gigabit per second communications
2. Full sky coverage
3. Multiple simultaneous links

Description of ISOC: Challenge

Omnidirectional Optical Communicator for CubeSat Swarms
1. Description of ISOC

Let me introduce to you the ISOC:

Description of ISOC: ISOC Introduction
1. Description of ISOC

Basic ISOC geometry:

- Pin diode detectors
- Transmit telescope

Description of ISOC: **Basic ISOC geometry**

Omnidirectional Optical Communicator
1. Description of ISOC

ISOC Transmit Telescope

Description of ISOC: Transmit Telescope
1. Description of ISOC

Multiple link capability

Simultaneously

Omnidirectional Optical Communicator for CubeSat Swarms
1. Description of ISOC

ISOC Transmit Telescope
1. Description of ISOC

NRZ - OOK (On-Off Keying)
- Bandwidth (BW) = Bitrate ($R_b$)

```
1 0 1 1 0 1
```

\[
\text{NRZ Waveform}
\]

\[
\text{Binary data}
\]

- **Tx aperture**: 1 cm
- **Rx aperture**: 2.5 cm
2. ISOC Testing

Preliminary results of miniature telescope testing

ISOC Telescope: Tx Telescope Testing
2. ISOC Testing

Preliminary results of miniature telescope testing
ISOC Testing

Inter-satellite Omnidirectional Optical Communicator for CubeSat Swarms

ISOC 1

ISOC 2
ISOC Testing

Laptop 1

Serial Terminal

Transmitting FPGA

ISOC 1

ISOC 2

10110010100

10011000111

Receiving FPGA

Serial Terminal

Pin JB1

Oscilloscope

Omnidirectional Optical Communicator
3. Technology Demonstration Mission

Q4

- LEO mission
- 400 km polar orbit
- 4 CubeSats
- Test ISOC capabilities
3. Technology Demonstration Mission
3. Technology Demonstration Mission

- ISOC Assay
- ISOC Deployer
- XACT ADCS
- MiPS Cold Gas Thruster

- S Band Antenna
- IRIS
- GPS
- EPS
- 38 Wh Battery
- Computer
- P31u
- Power Supply
- SLX
- UHF Antenna

*eHAWK 72W Solar Panels (not shown)*
Inter-satellite Omnidirectional Optical Communicator for CubeSat Swarms

3. Technology Demonstration Mission

- ISOC Assy
- ISOC Deployer
- XACT ADCS
- UHF Antenna
- MiPS Cold Gas Thruster
- C&DH
- GPS
- EPS 38 Wh Battery
- P31u Power Supply
- eHAWK 72W Solar Panels
- S Band Antenna
- Omnidirectional Optical Communicator
3. Technology Demonstration Mission
Orbital Dynamics

- Clohessey-Wiltshire Equations
  - Describe chaser motion in target frame
- Same semi-major axis, same period
  - Relative motion is repetitive

\[
\begin{align*}
\ddot{x} - 2n\dot{y} - 3n^2x &= f_x \\
\ddot{y} + 2n\dot{x} &= f_y \\
\ddot{z} + n^2z &= f_z \\
n &= \sqrt{\frac{\mu}{a^3}}
\end{align*}
\]
3. Technology Demonstration Mission

Orbital Dynamics

Possible Configurations

- Homogenous Analytical Solution

\[
\begin{align*}
x &= A_x \cos(nt + \alpha) \\
y &= -2A_x \sin(nt + \alpha) + y_{off} \\
z &= A_z \cos(nt + \beta)
\end{align*}
\]

- X,Y motion coupled
- Z motion free
3. Technology Demonstration Mission

Chosen Configuration
4. Swarm Testbed

Swarm emulator using automated platforms

Omnidirectional Optical Communicator
4. Swarm Testbed

Swarm emulator using automated platforms

Omnidirectional Optical Communicator
5. Mission Examples

RePAR
• Reconfigurable Phase Array Radar
• Formation Flying CubeSats form a large synthetic aperture
• All CubeSats furnished with ISOCs
5. Mission Examples

**LidarCon**
- Constellation of CubeSat furnished with Lidar and ISOCs
- Remote sensing of wind and ocean waves
5. Mission Examples

iSATcon
- Constellation of 66 CubeSats to form a superfast communications platform
- 6 orbits, 11 CubeSats per orbit
- Platform for Remote Sensing, emergency and military communications
5. Mission Examples

iSATcon
• Constellation of 66 CubeSats to form a superfast communications platform
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CADRE Radio Telescope

Lunar CADRE Concept
CADRE will use HF sensors to measure RF emissions produced by Exoplanet magnetospheres
5. Mission Examples

Relay Station

CubeSat swarm

Mars

Earth

Swarms for Communications

Omnidirectional Optical Communicator
5. Mission Examples

Radio telescope

Lunar constellation

Mars constellation

Jupiter constellation

Omnidirectional Optical Communicator
6. Conclusions

- A novel Omnidirectional Optical Communicator has been presented.
- We presented design considerations and preliminary results of the ISOC testing.
- We also discussed Q4 - a technology demonstration mission for the ISOC and mission examples enabled by the ISOC.
- The ISOC is a potential enabler for future swarm and constellation missions.
Thank You

Questions?