Omnidirectional Optical Communicator for CubeSat Swarms and Constellations

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Inter-Spacecraft Omnidirectional Optical Communicator (ISOC)

Outline

1. Description of ISOC
2. Transmit Telescope Design and Testing
3. Examples of Formation Flying and Constellations
4. Conclusions

Acknowledgements

- Collaborators:

  JPL

  Joseph Griffin, Danny Wernicke, Andrew Janzen, John Huleis, Michael Peng, Mark Taylor

  University California - Irvine

  Ozdal Boyraz, Imam-Uz Zaman

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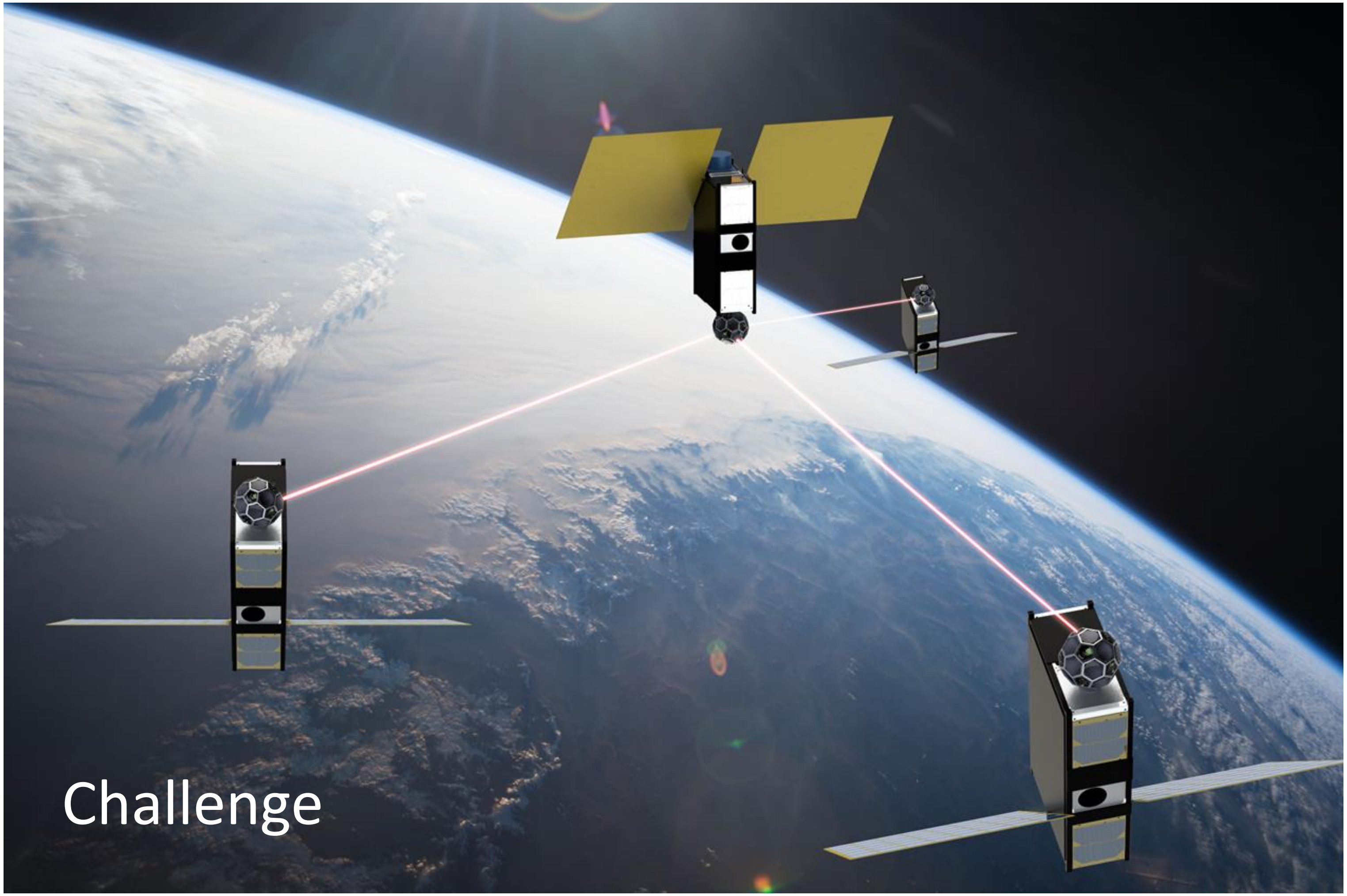
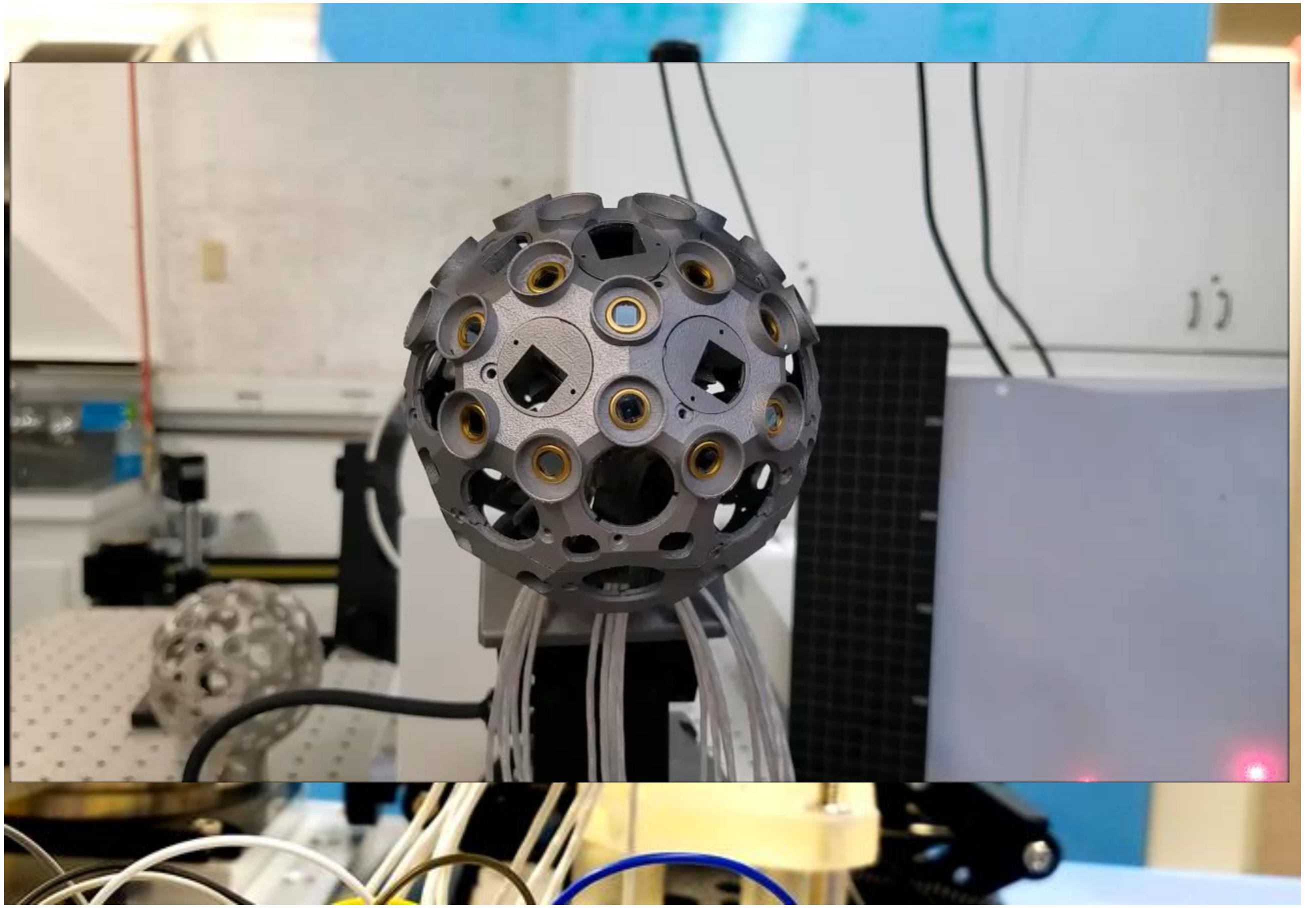
1. Description of ISOC



Description of ISOC: Challenge

1. Description of ISOC

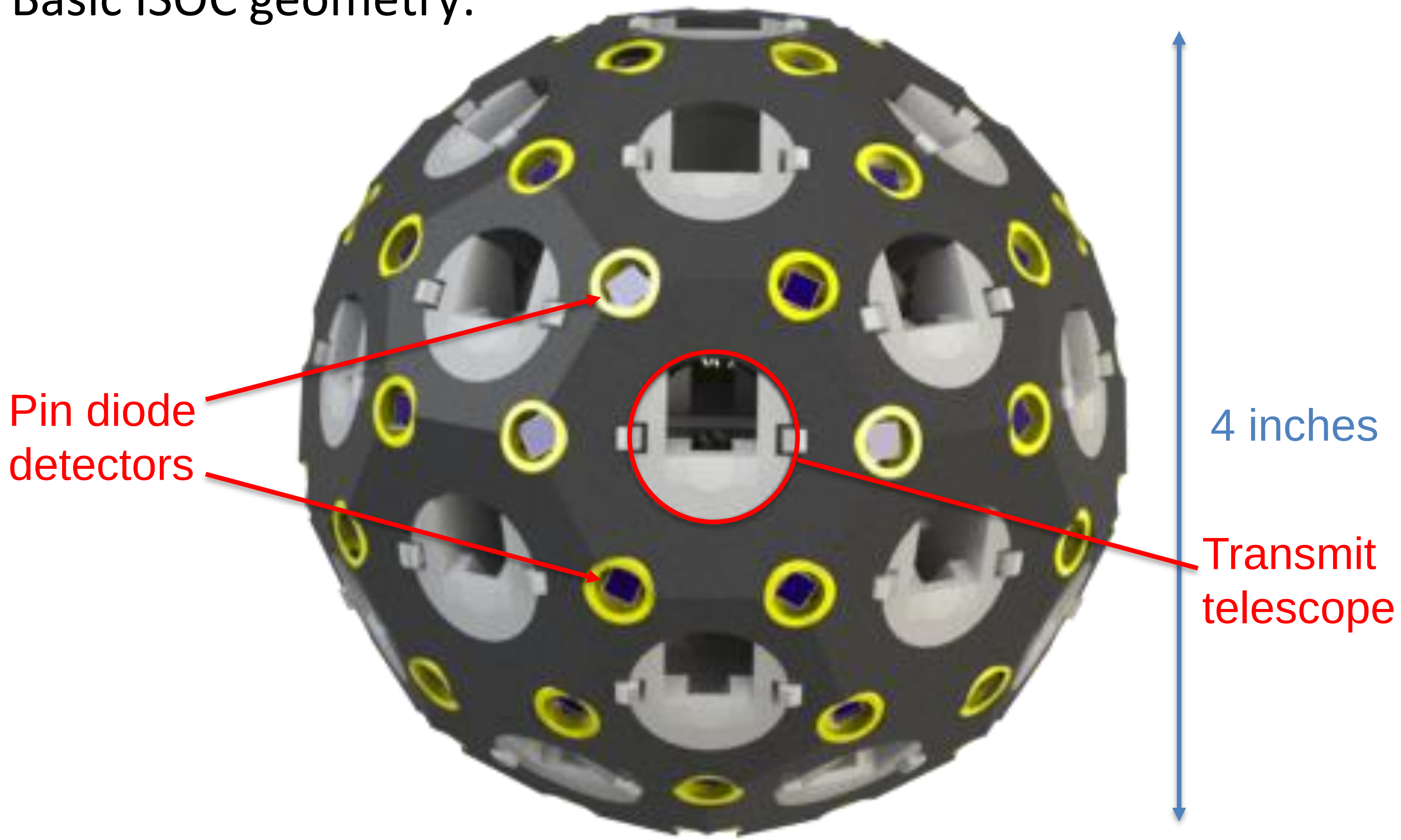
Let me introduce to you the ISOC:



Description of ISOC: ISOC Introduction

1. Description of ISOC

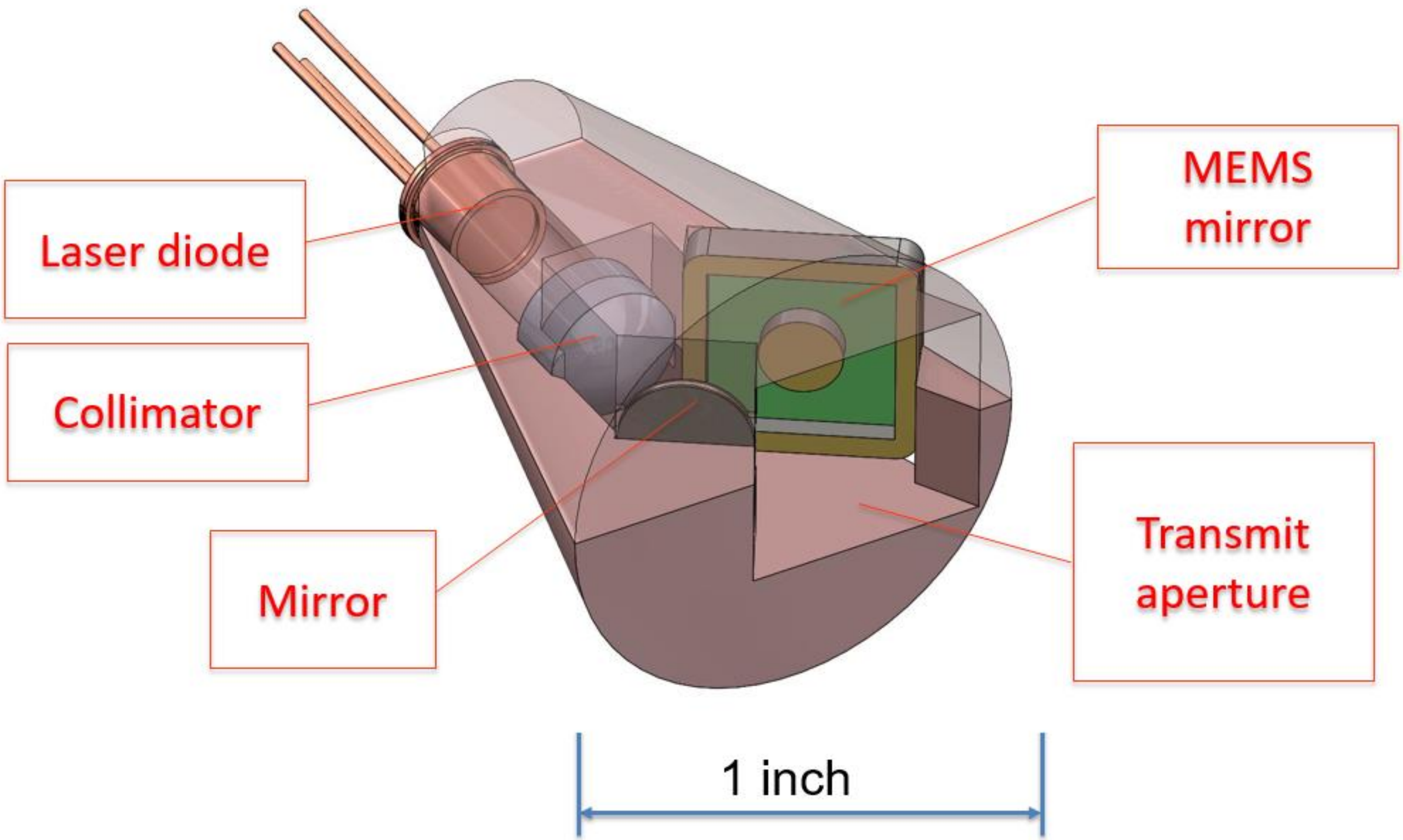
Basic ISOC geometry:



Description of ISOC: Basic ISOC geometry

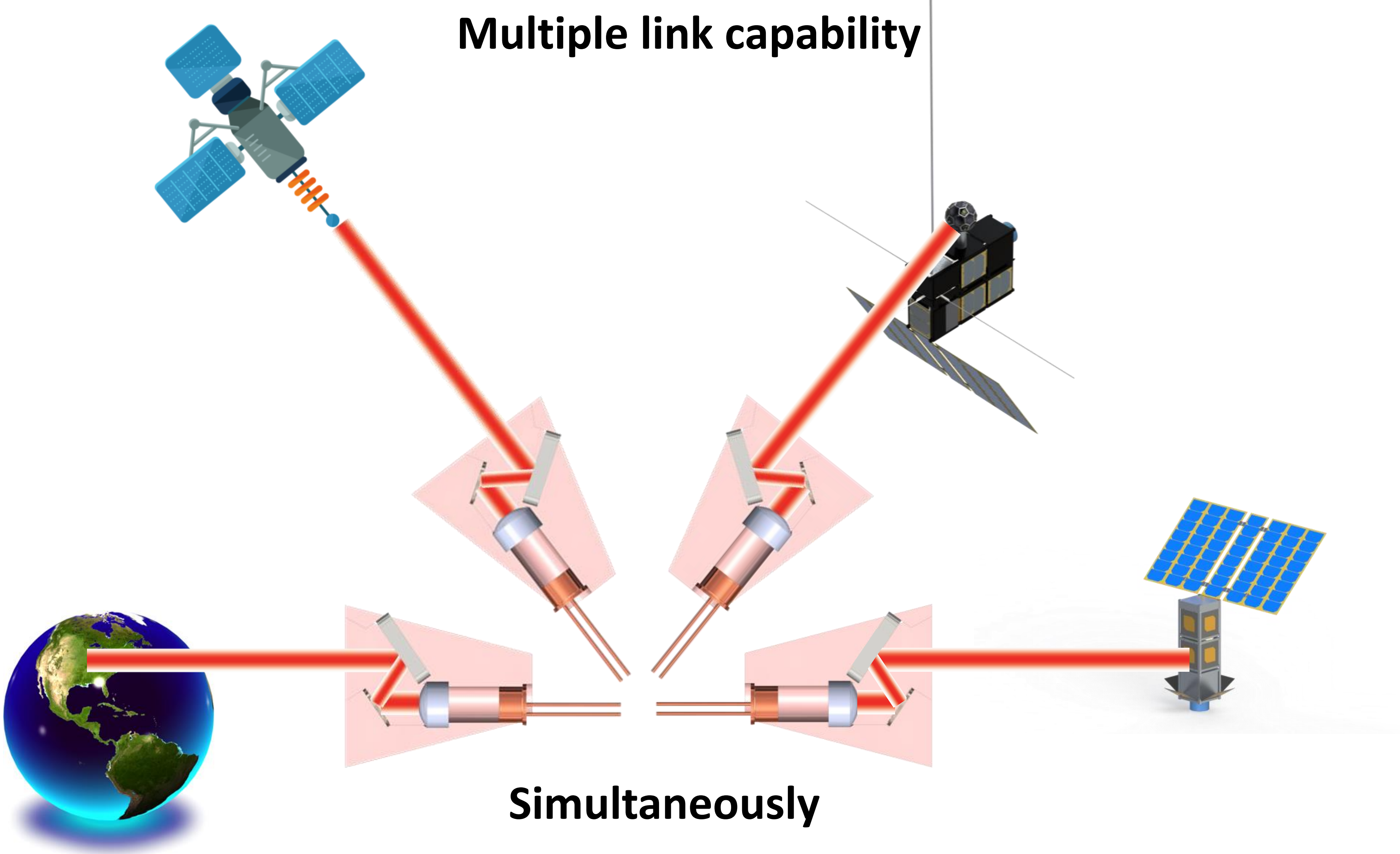
1. Description of ISOC

ISOC Transmit Telescope



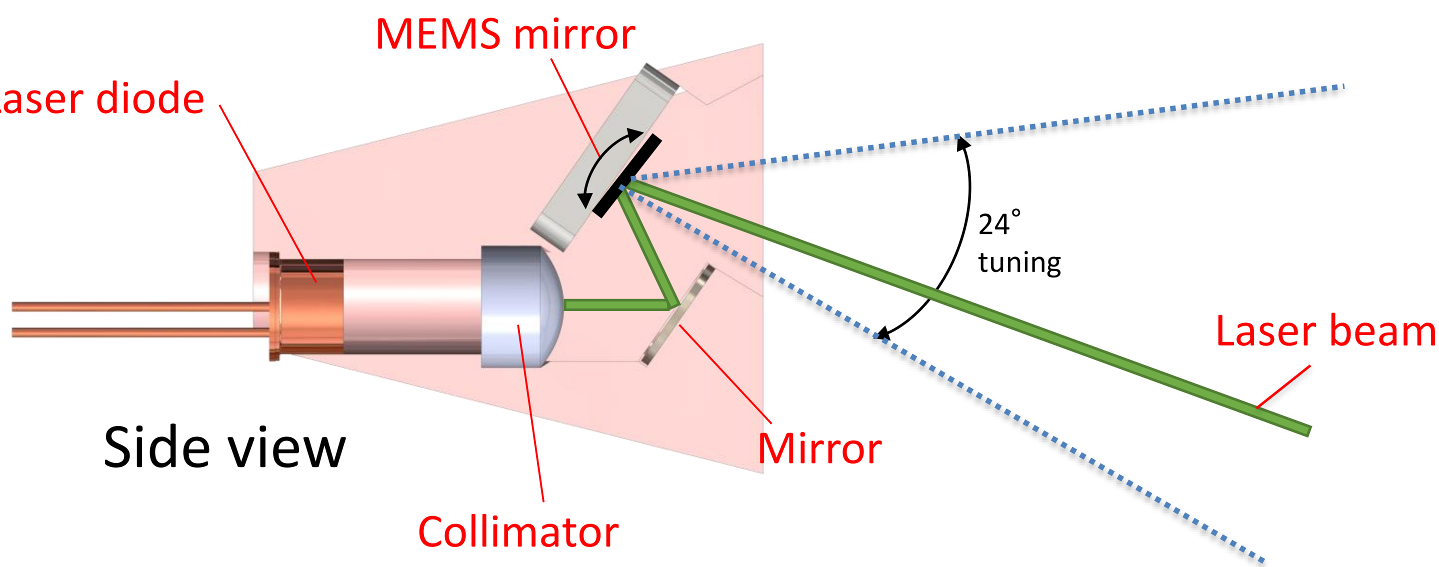
Description of ISOC: Transmit Telescope

1. Description of ISOC



1. Description of ISOC

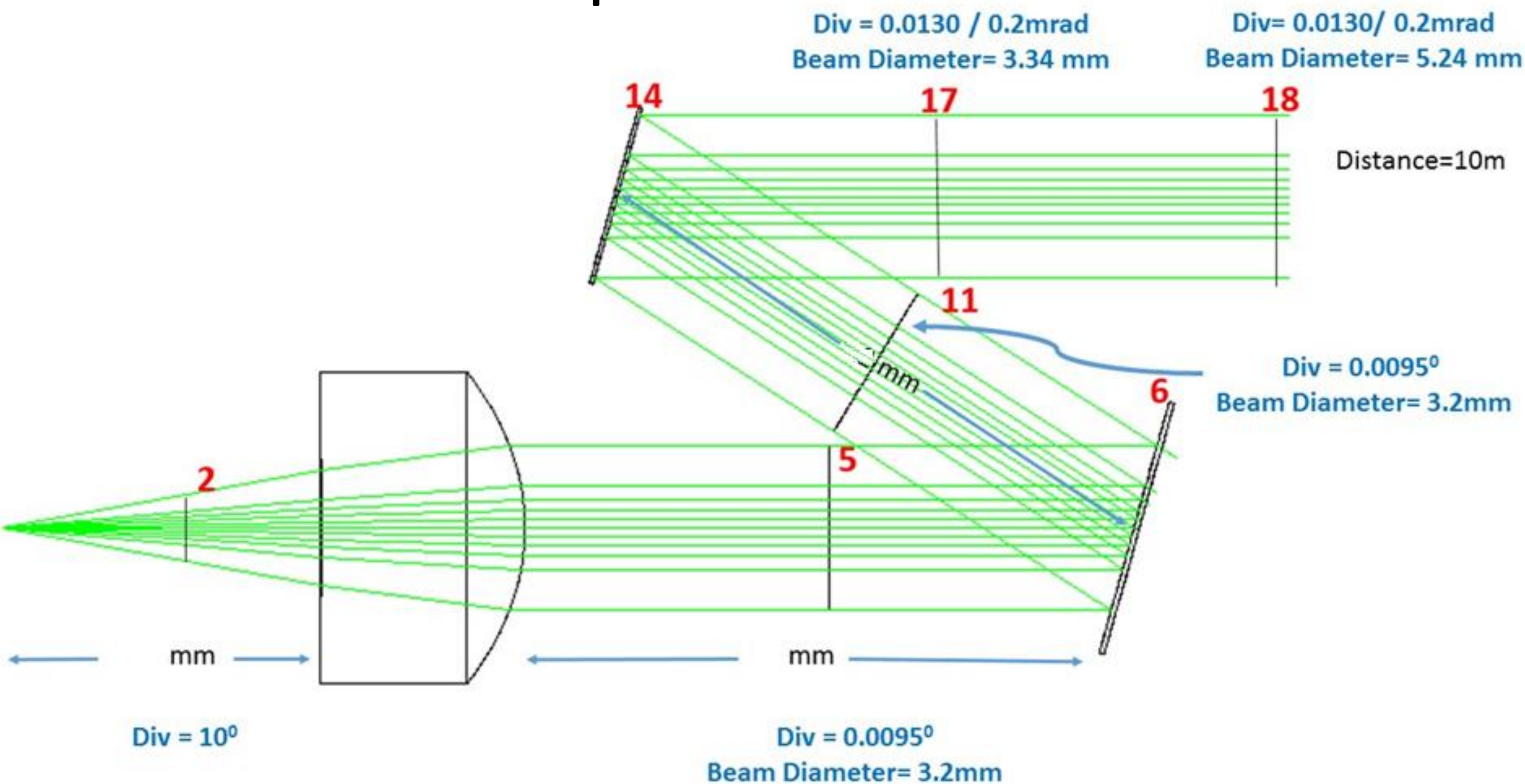
ISOC Transmit Telescope



Description of ISOC: Transmit Telescope

1. Description of ISOC

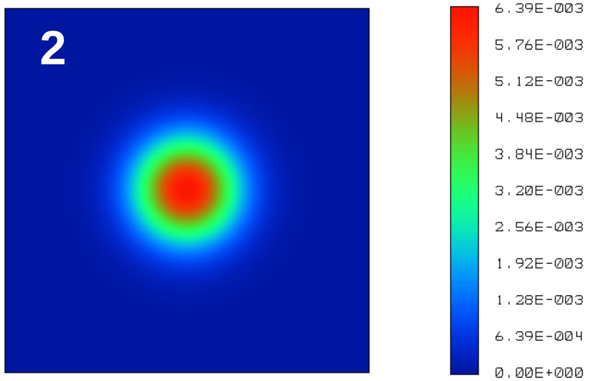
ISOC Transmit Telescope



ZEMAX simulation of ISOC transmitter telescope

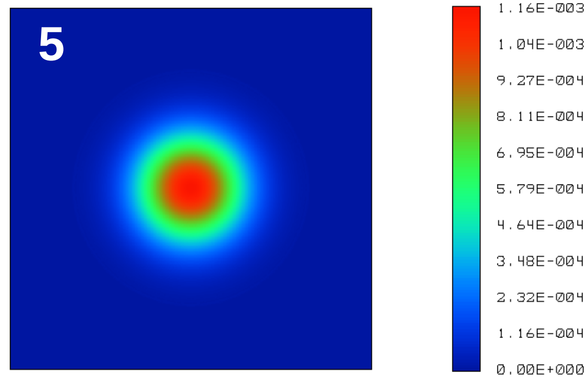
1. Description of ISOC

Zemax Simulations ISOC Transmit Telescope



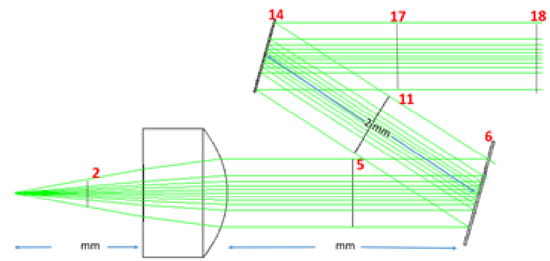
TOTAL IRRADIANCE SURFACE 2 DUMMY_SOURCE

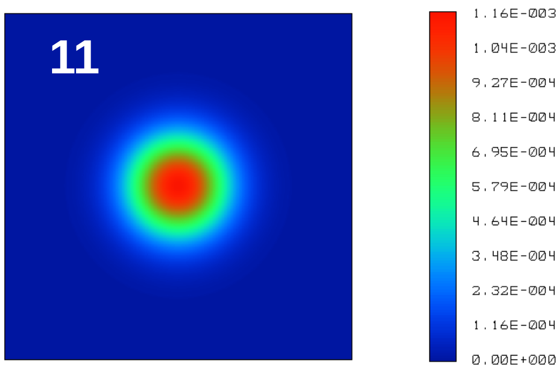
TUE MAY 2 2017
WAVELENGTH 0.85000 µm IN INDEX 1.00000 AT 0.0000, 0.0000 DEG
DISPLAY X WIDTH = 3.4816E+000, Y HEIGHT = 3.4816E+000 MILLIMETERS
PEAK IRRADIANCE = 6.3949E-003 WATTS/MILLIMETERS^2, TOTAL POWER = 5.0000E-003 WATTS
X PILOT: SIZE= 7.0551E-001, WAIST= 1.5340E-003, POS= +4.0000E+000, RAYLEIGH= 8.6972E-003
Y PILOT: SIZE= 7.0551E-001, WAIST= 1.5340E-003, POS= +4.0000E+000, RAYLEIGH= 8.6972E-003



TOTAL IRRADIANCE SURFACE 5 DUMMY LENS-FIX MIR

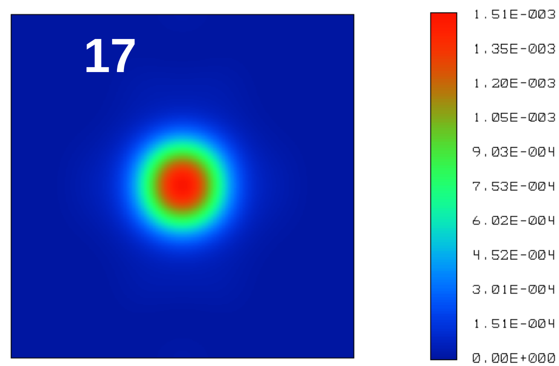
TUE MAY 2 2017
WAVELENGTH 0.85000 µm IN INDEX 1.00000 AT 0.0000, 0.0000 DEG
DISPLAY X WIDTH = 7.9829E+000, Y HEIGHT = 7.9829E+000 MILLIMETERS
PEAK IRRADIANCE = 1.1589E-003 WATTS/MILLIMETERS^2, TOTAL POWER = 4.9784E-003 WATTS
X PILOT: SIZE= 1.6177E+000, WAIST= 1.6154E+000, POS= +5.1597E+002, RAYLEIGH= 9.6446E+003
Y PILOT: SIZE= 1.6177E+000, WAIST= 1.6154E+000, POS= +5.1597E+002, RAYLEIGH= 9.6446E+003





TOTAL IRRADIANCE SURFACE 11 DUMMY_FIX AND MEMS

TUE MAY 2 2017
WAVELENGTH 0.85000 µm IN INDEX 1.00000 AT 0.0000, 0.0000 DEG
DISPLAY X WIDTH = 7.9829E+000, Y HEIGHT = 7.9829E+000 MILLIMETERS
PEAK IRRADIANCE = 1.1590E-003 WATTS/MILLIMETERS^2, TOTAL POWER = 4.9783E-003 WATTS
X PILOT: SIZE= 1.6178E+000, WAIST= 1.6154E+000, POS= -5.2797E+002, RAYLEIGH= 9.6446E+003



TOTAL IRRADIANCE SURFACE 17 DUMMY HALFWAY

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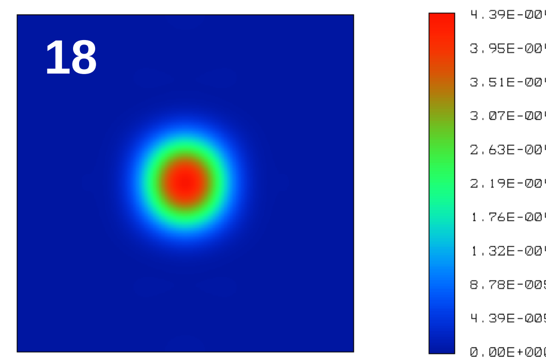
WAVELENGTH 0.85000 µm IN INDEX 1.00000 AT 0.0000, 0.0000 DEG
DISPLAY X WIDTH = 7.7869E+000, Y HEIGHT = 7.7869E+000 MILLIMETERS
PEAK IRRADIANCE = 1.5053E-003 WATTS/MILLIMETERS^2, TOTAL POWER = 4.8885E-003 WATTS
X PILOT: SIZE= 1.6718E+000, WAIST= 1.1692E+000, POS= +5.1637E+003, RAYLEIGH= 5.0523E+003



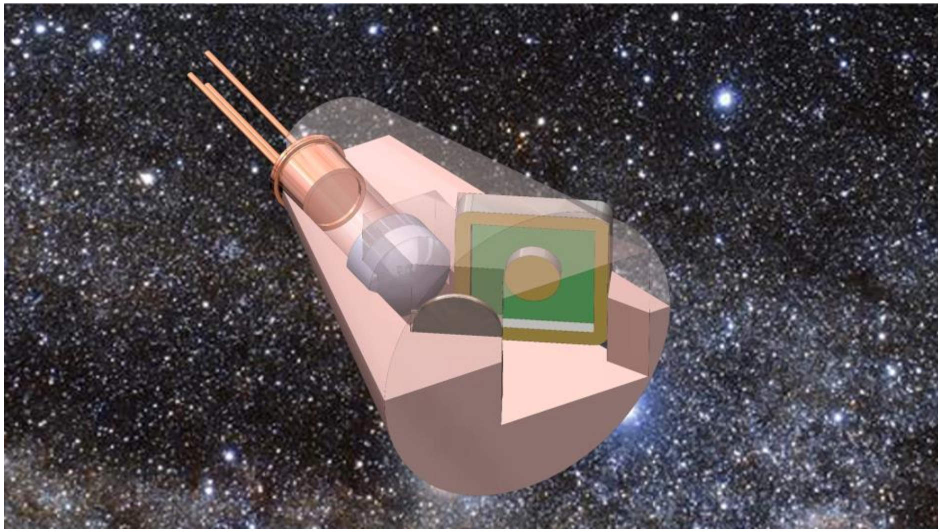
TOTAL IRRADIANCE SURFACE 18

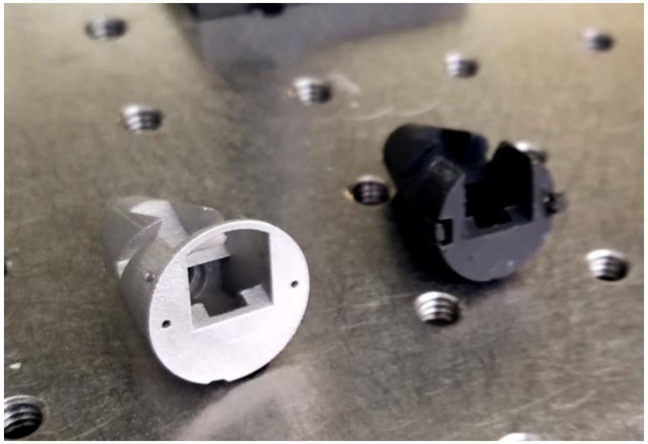
TUE MAY 2 2017
WAVELENGTH 0.85000 µm IN INDEX 1.00000 AT 0.0000, 0.0000 DEG
DISPLAY X WIDTH = 1.5327E+001, Y HEIGHT = 1.5327E+001 MILLIMETERS
PEAK IRRADIANCE = 4.3896E-004 WATTS/MILLIMETERS^2, TOTAL POWER = 4.8885E-003 WATTS
X PILOT: SIZE= 2.6266E+000, WAIST= 1.1692E+000, POS= +1.0164E+004, RAYLEIGH= 5.0523E+003
Y PILOT: SIZE= 2.6266E+000, WAIST= 1.1692E+000, POS= +1.0164E+004, RAYLEIGH= 5.0523E+003

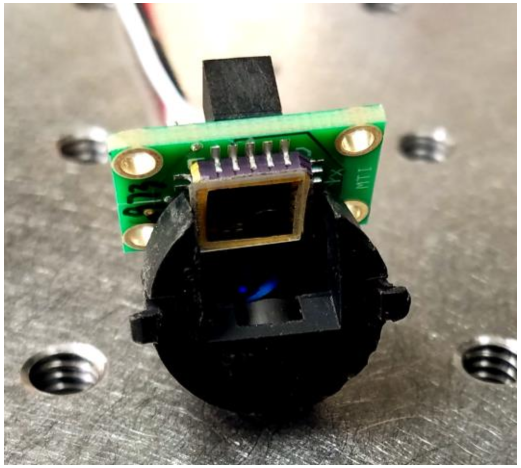
Description of ISOC: TX Telescope – Zemax simulations

1. Description of ISOC

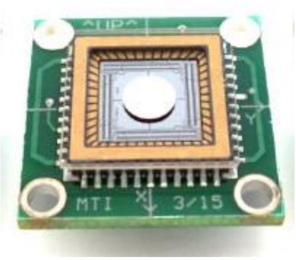
ISOC Transmit Telescope

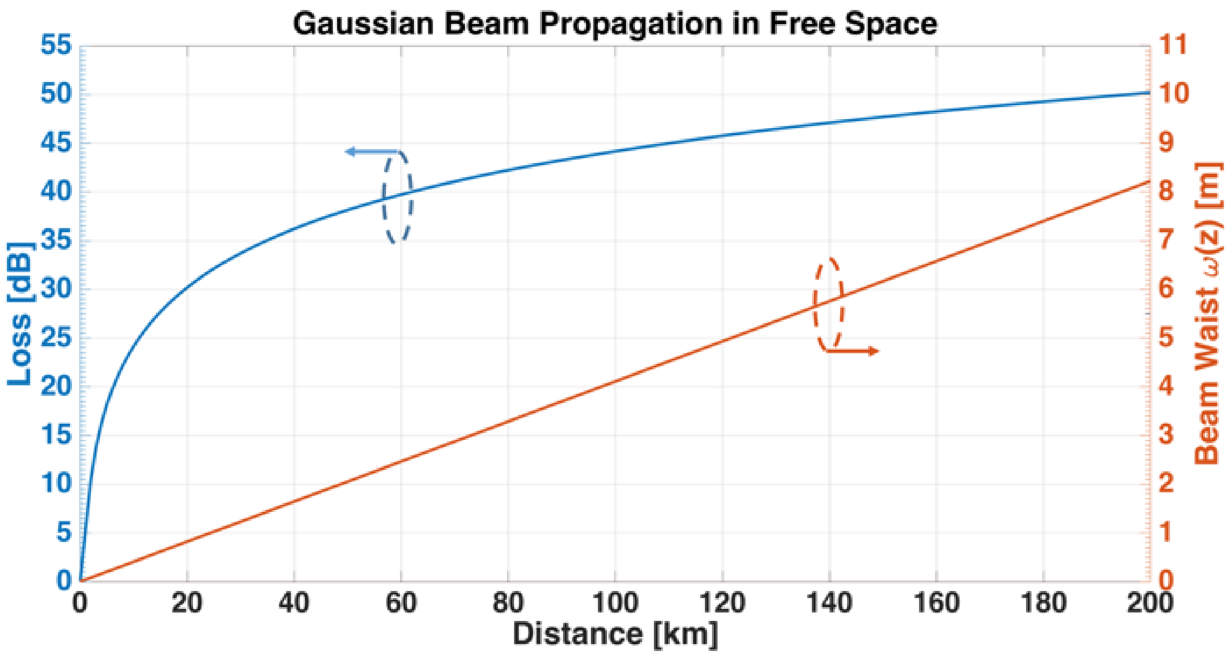






1. Description of ISOC



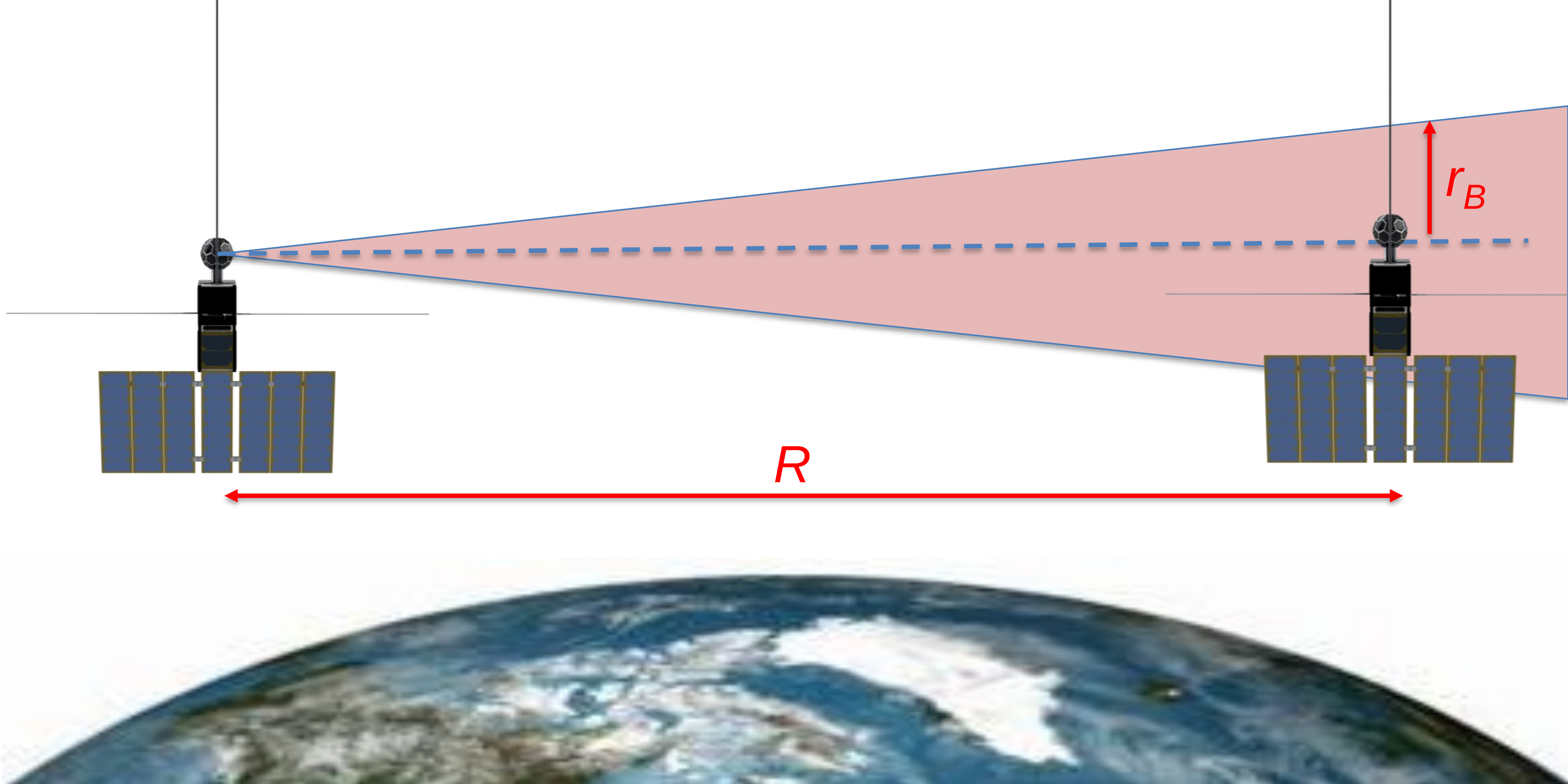


Beam divergence as a function of distance R for a transmit aperture of 1.2 cm and a receive aperture of 3.6 cm.

Description of ISOC: Beam Spreading

1. Description of ISOC

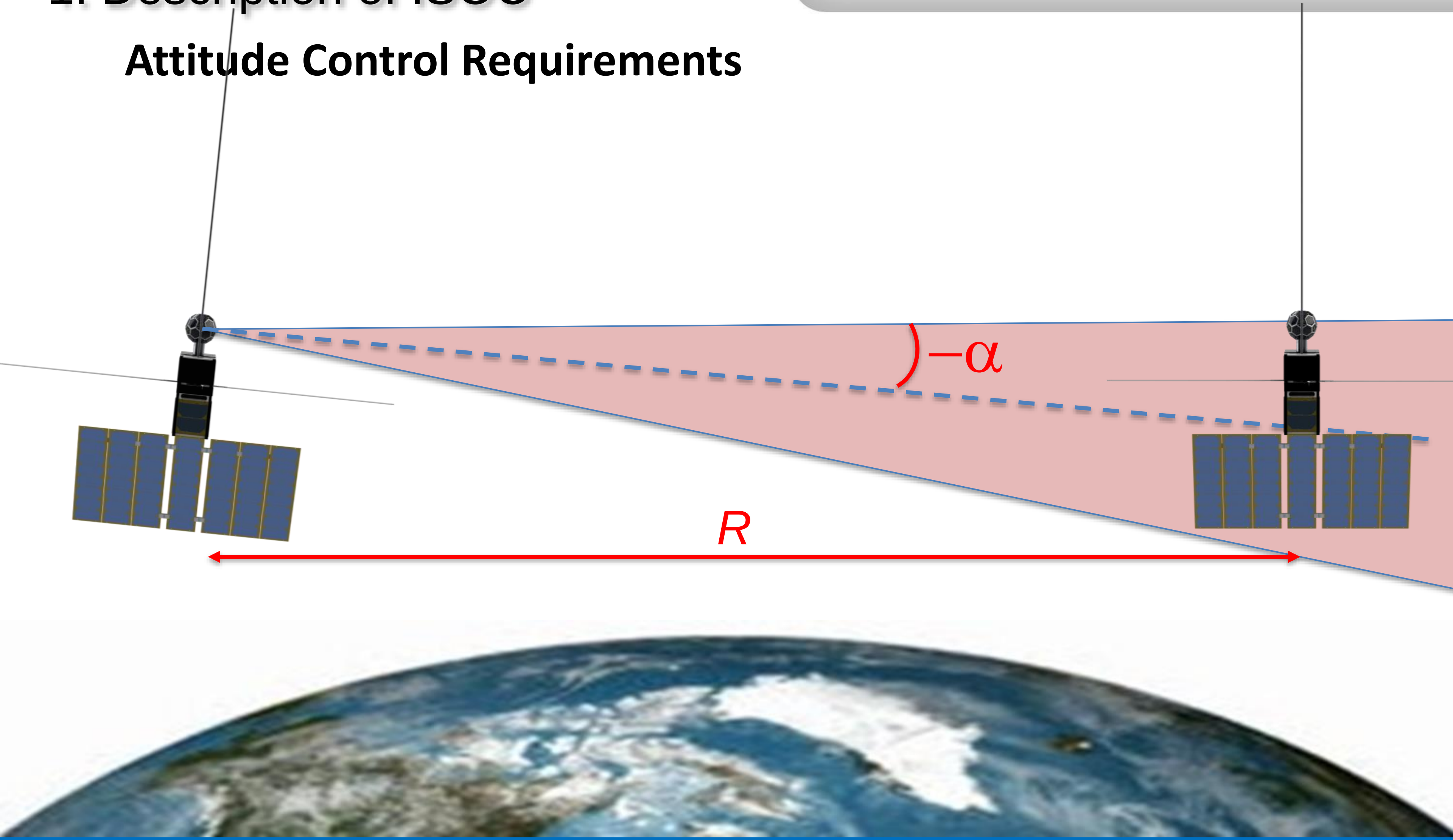
Attitude Control Requirements



Description of ISOC: Attitude Control

1. Description of ISOC

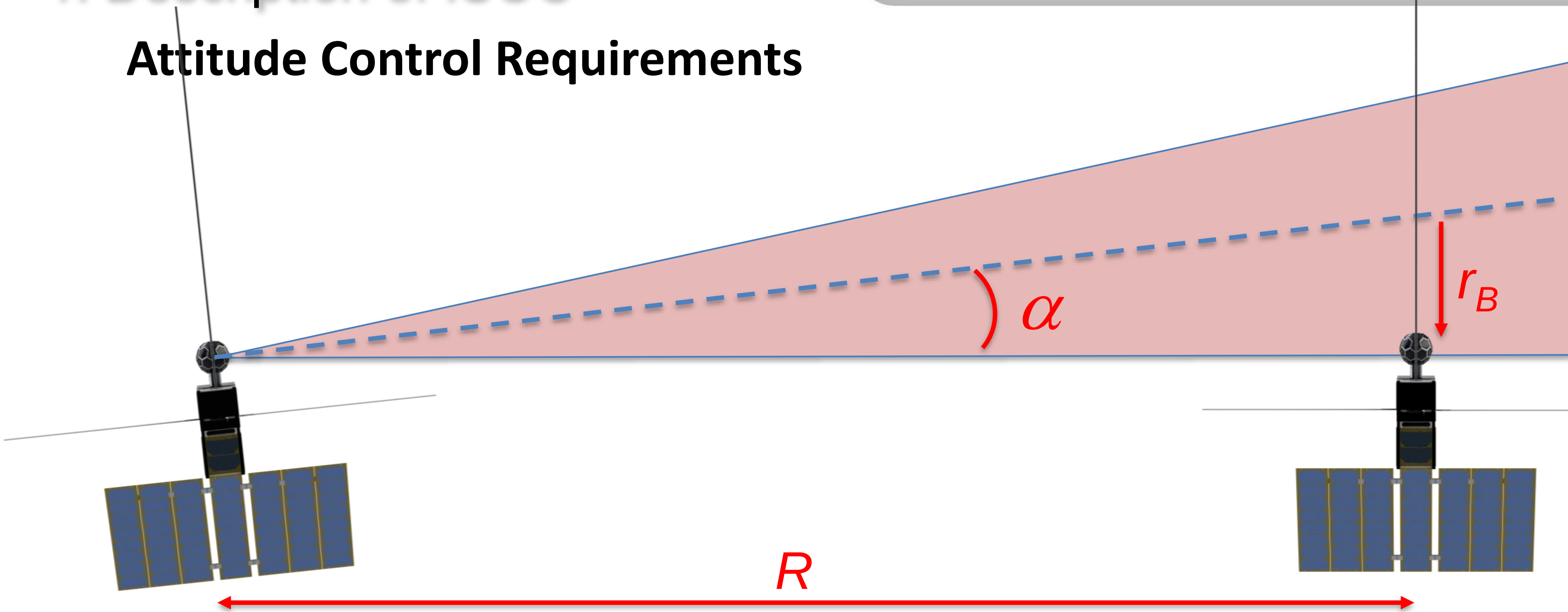
Attitude Control Requirements



Description of ISOC: Attitude Control

1. Description of ISOC

Attitude Control Requirements



$$\alpha = \frac{r_B}{R}$$

$$r_B = \alpha \cdot R$$

$$\alpha = 0.001° = 17.4 \mu rad$$

$$R = 200\ km$$

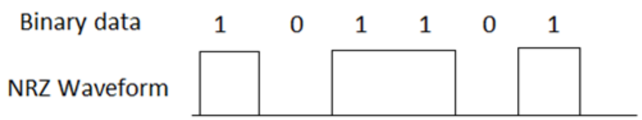
$$r_B = 3.5\ m$$

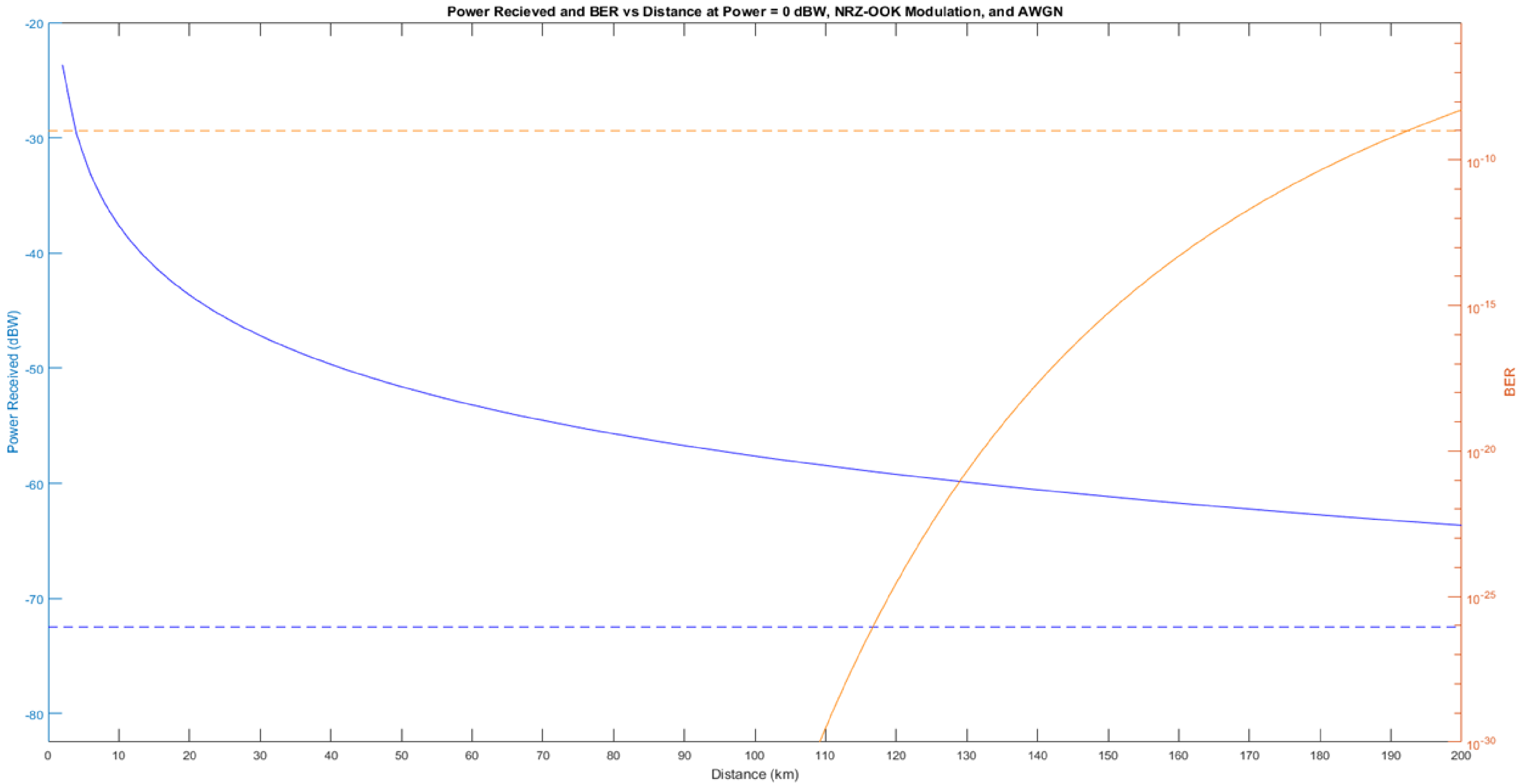
Description of ISOC: Attitude Control

1. Description of ISOC

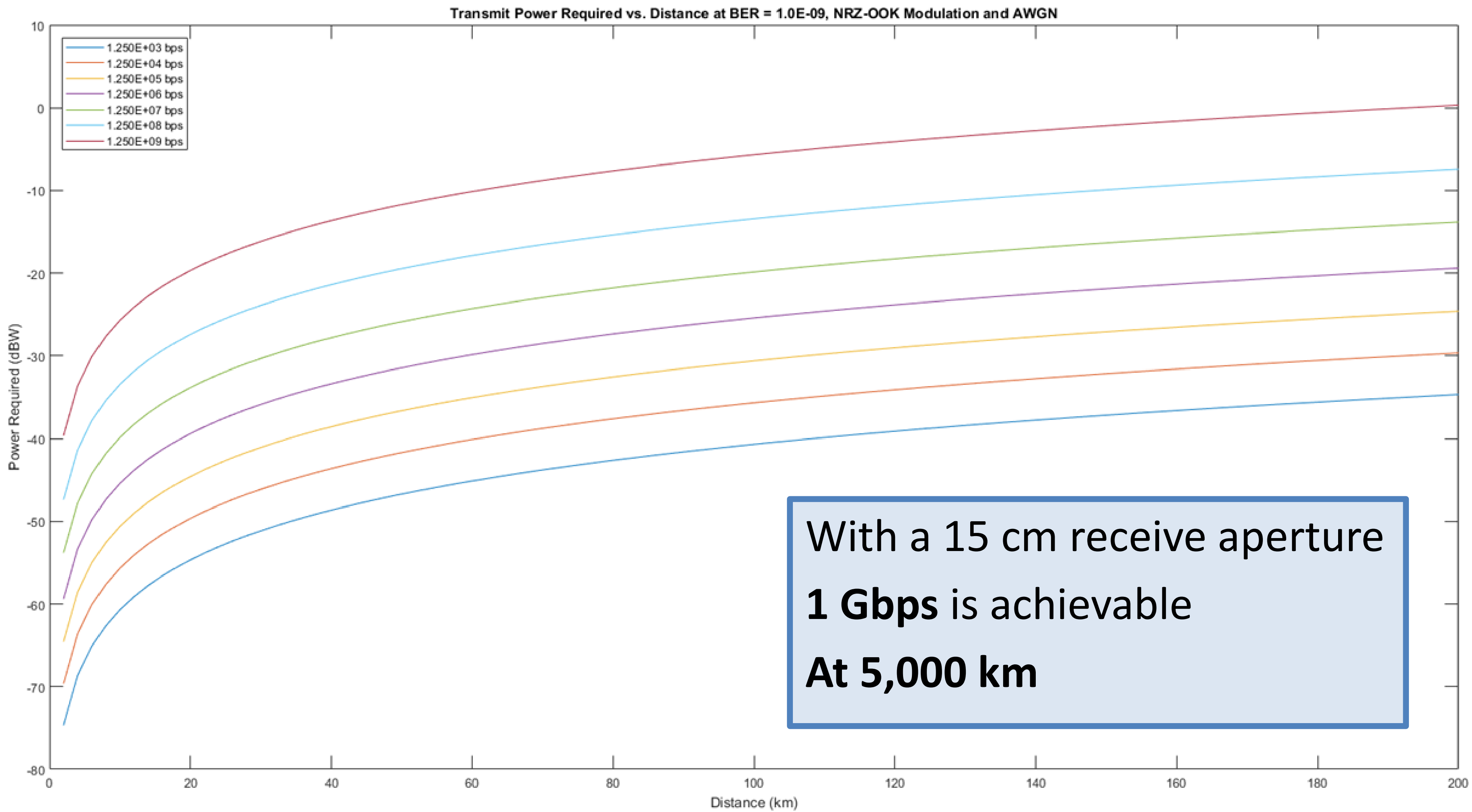
NRZ - OOK (On-Off Keying)

- Bandwidth (BW) = Bitrate (R_b)





2. Description of ISOC



With a 15 cm receive aperture

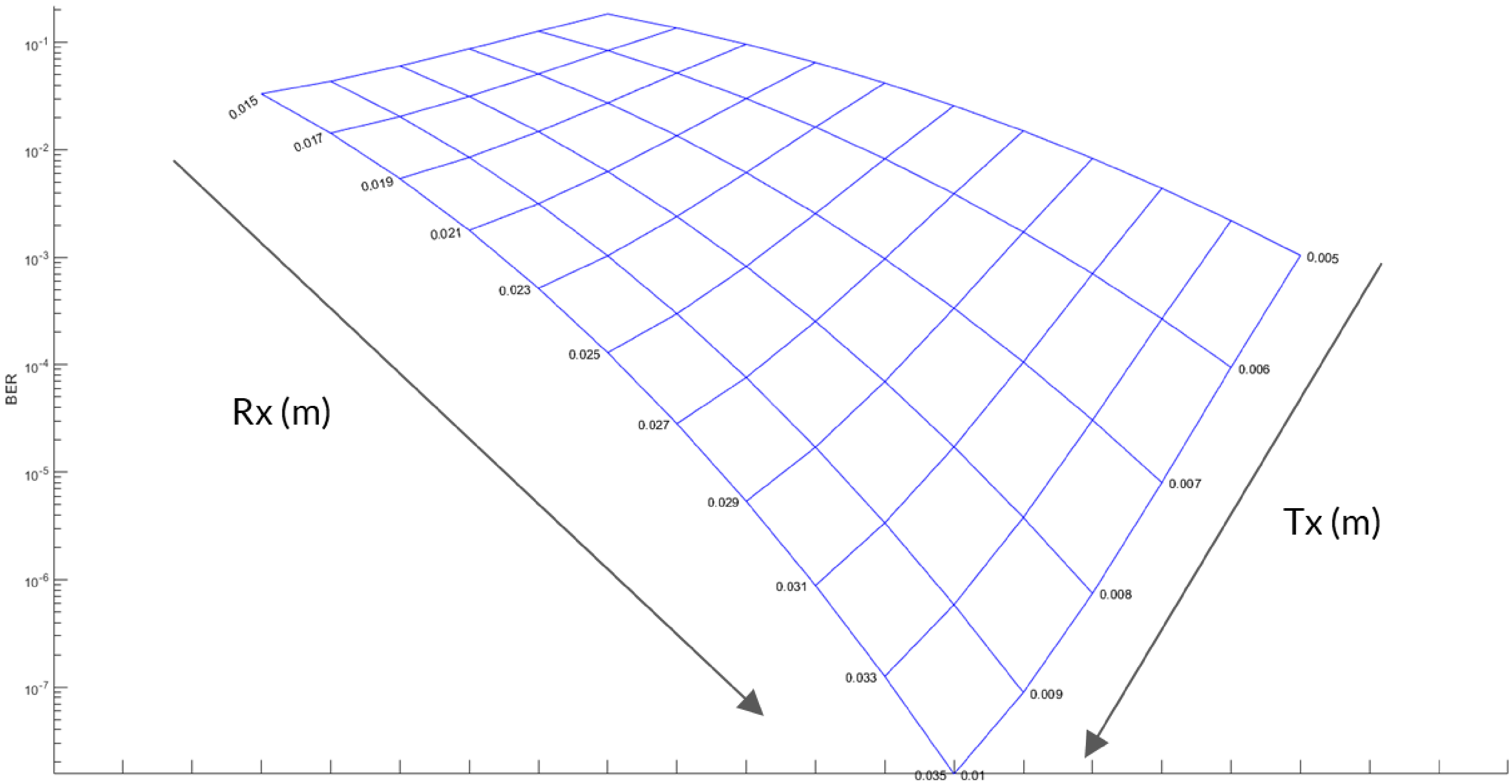
1 Gbps is achievable

At 5,000 km

Description of ISOC: Link Budget

2. Description of ISOC

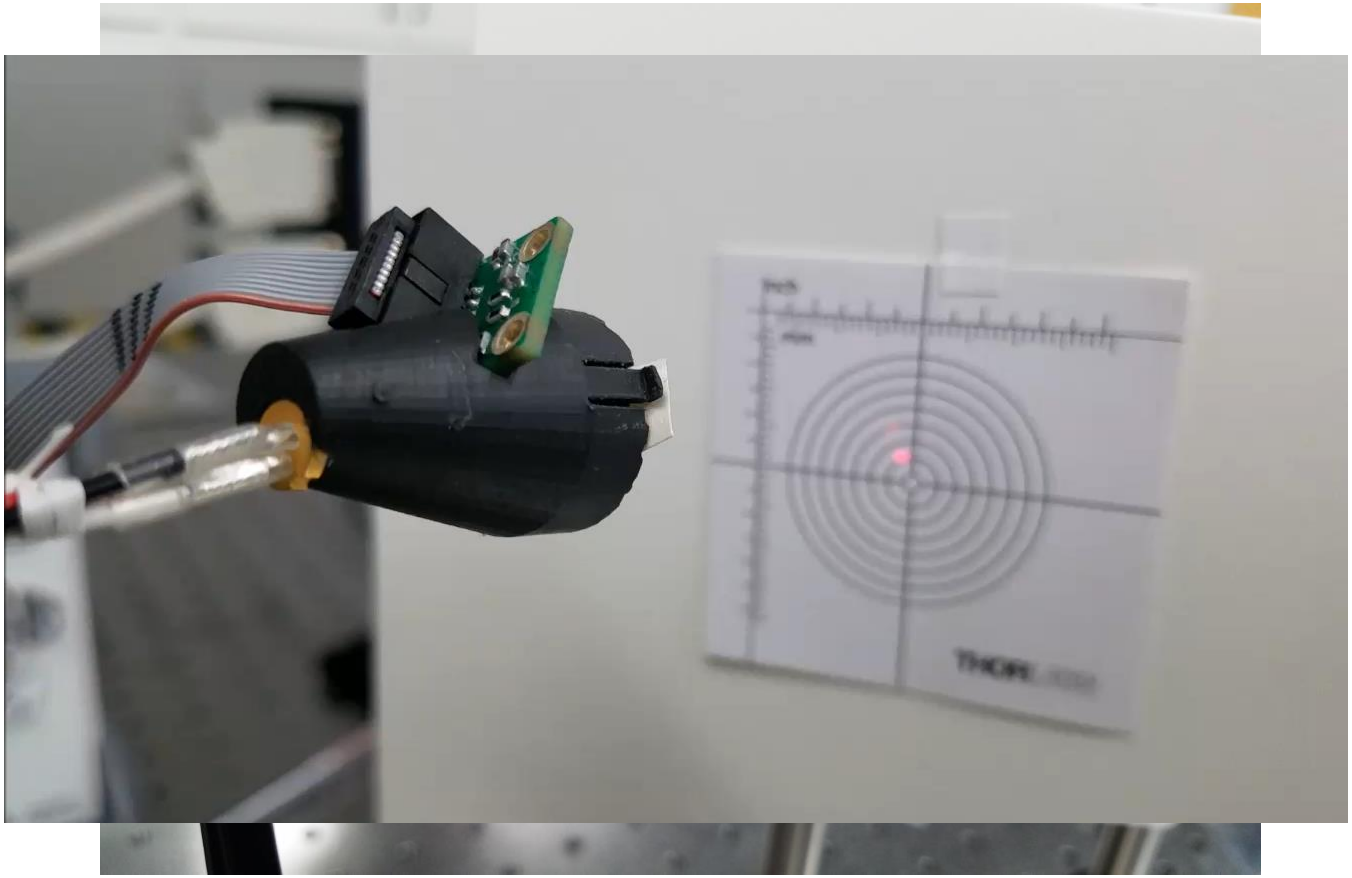
BER and Tx, Rx Aperture Diameter, 1 W at 200 km



Description of ISOC: Link Budget

2. ISOC Telescope

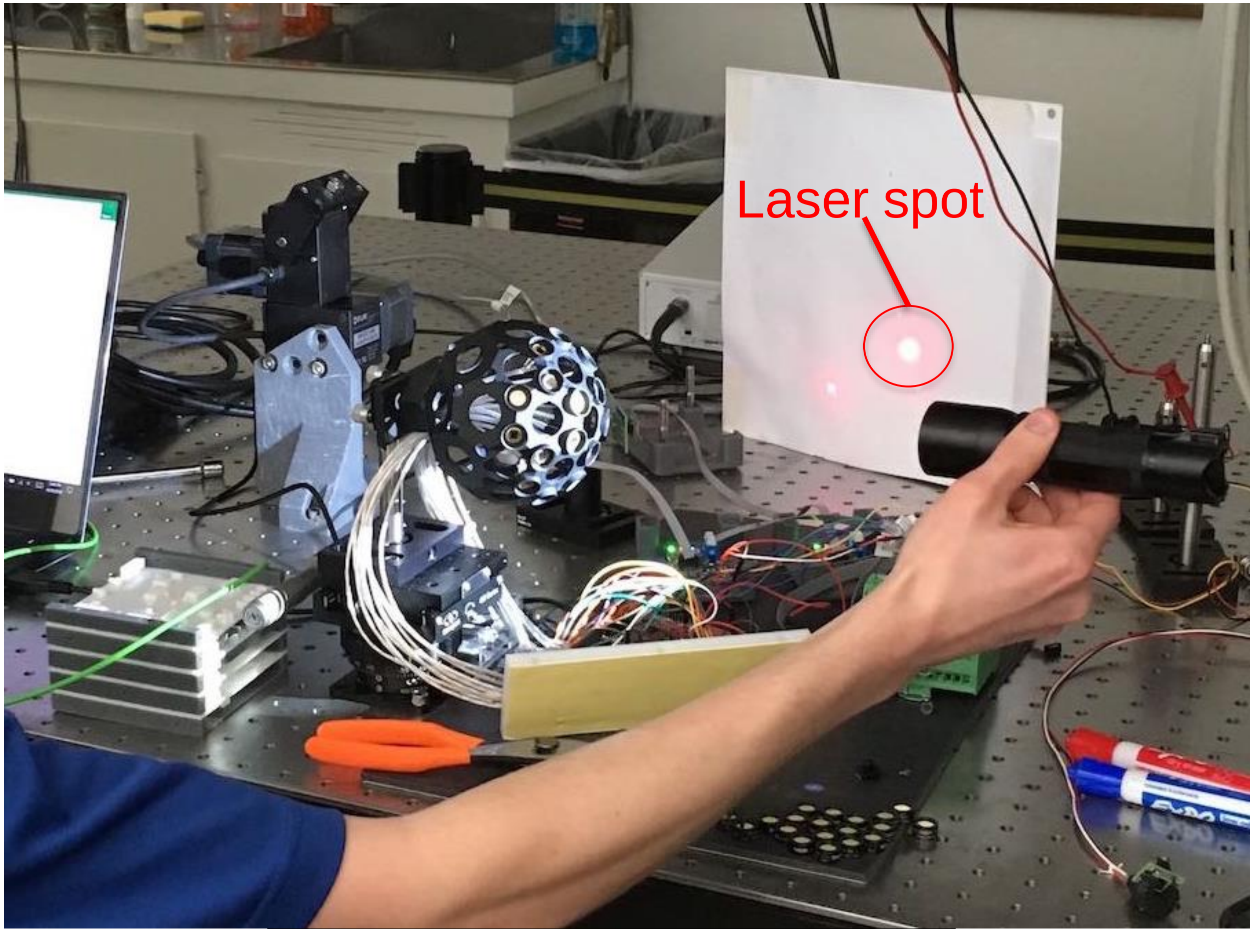
Preliminary results of miniature telescope testing



ISOC Telescope: Tx Telescope Testing

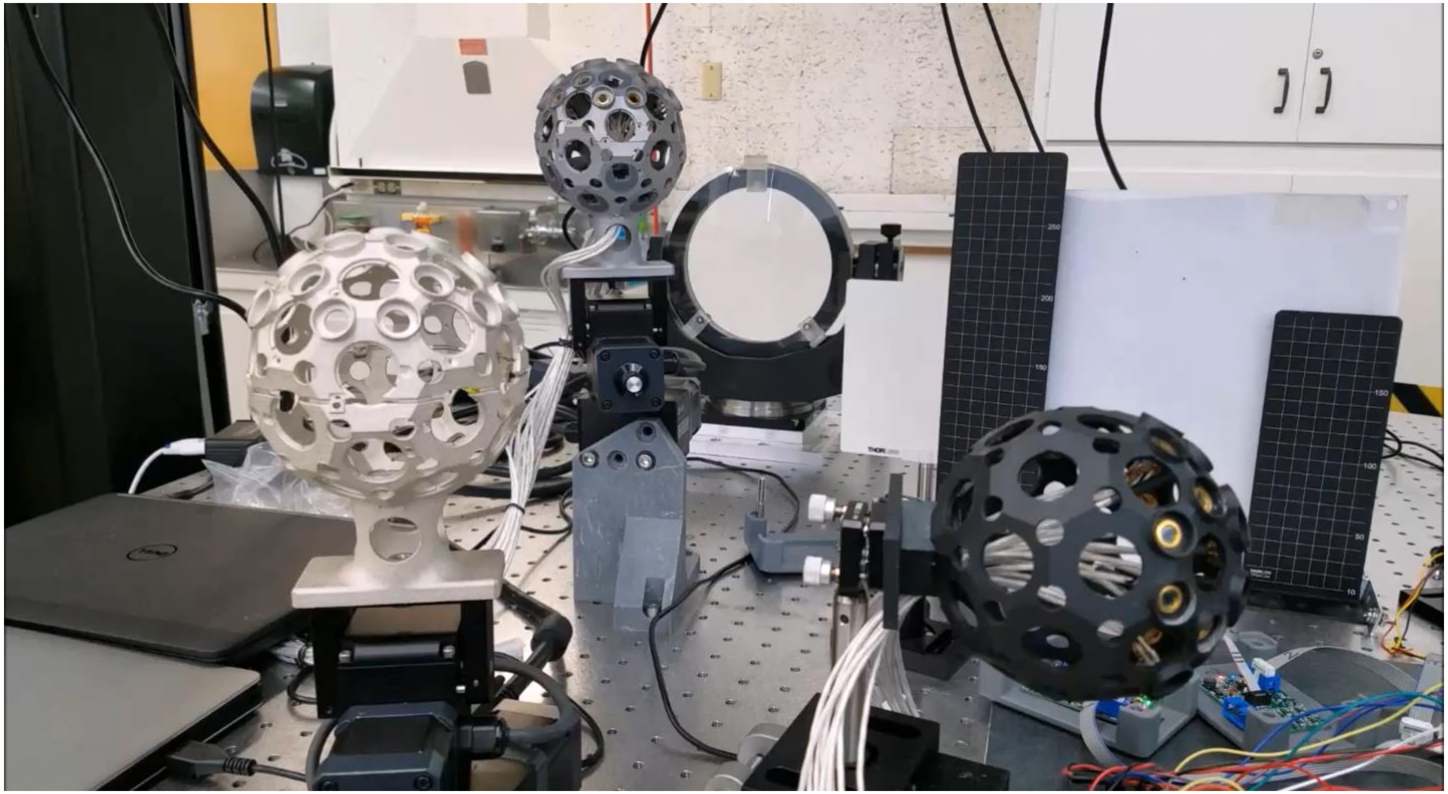
2. ISOC Telescope

Preliminary results of miniature telescope testing



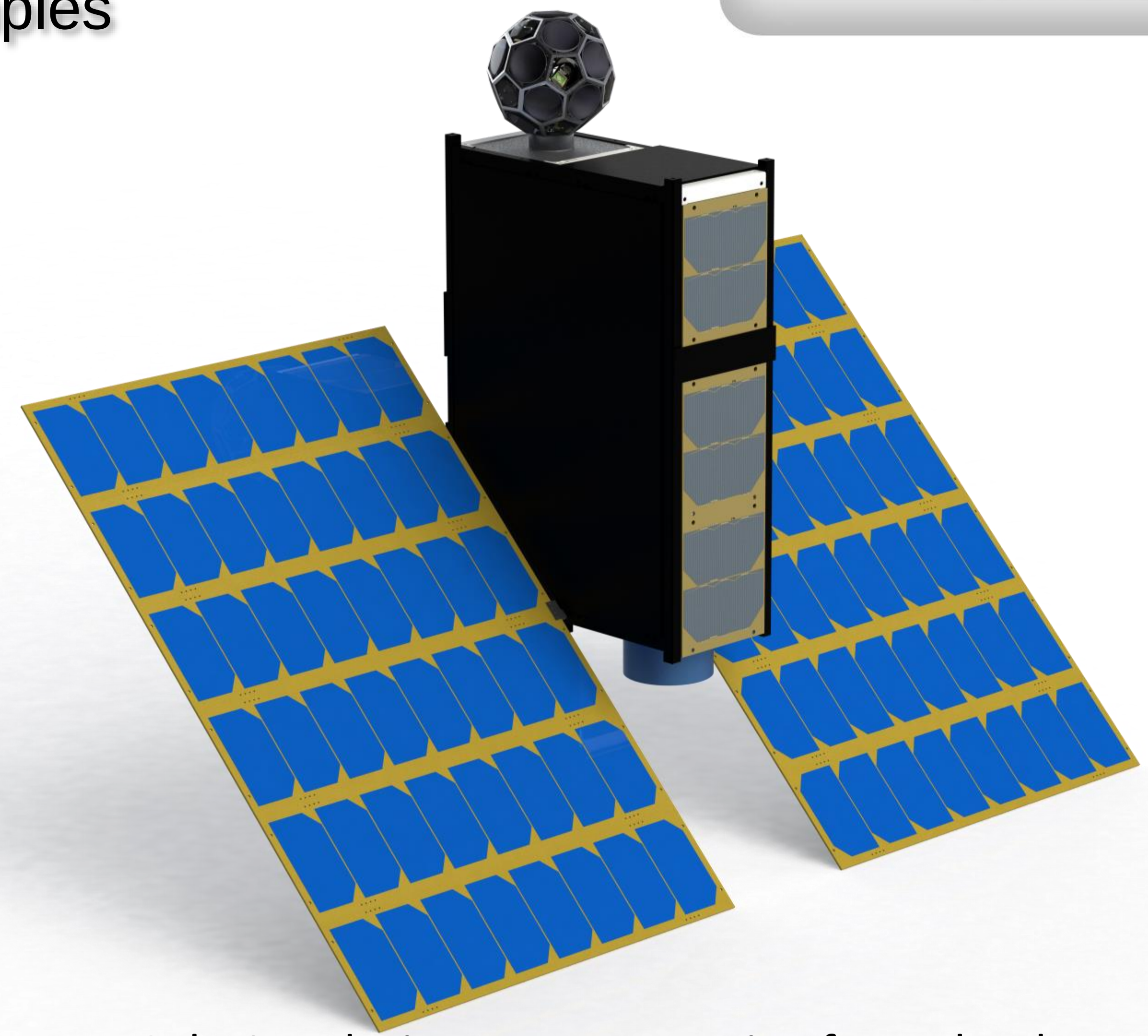
ISOC Telescope: Telescope Testing

3. Examples



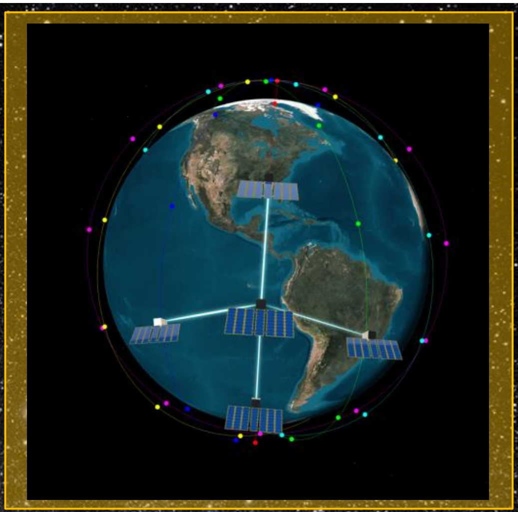
Constellations emulation using pan-tilt platforms

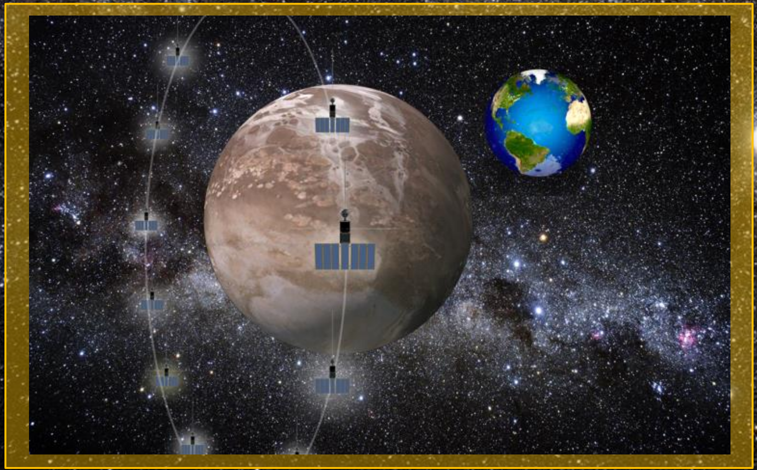
3. Examples



CubeSat design we are pursuing for technology demonstration of ISOC communicator

3. Examples



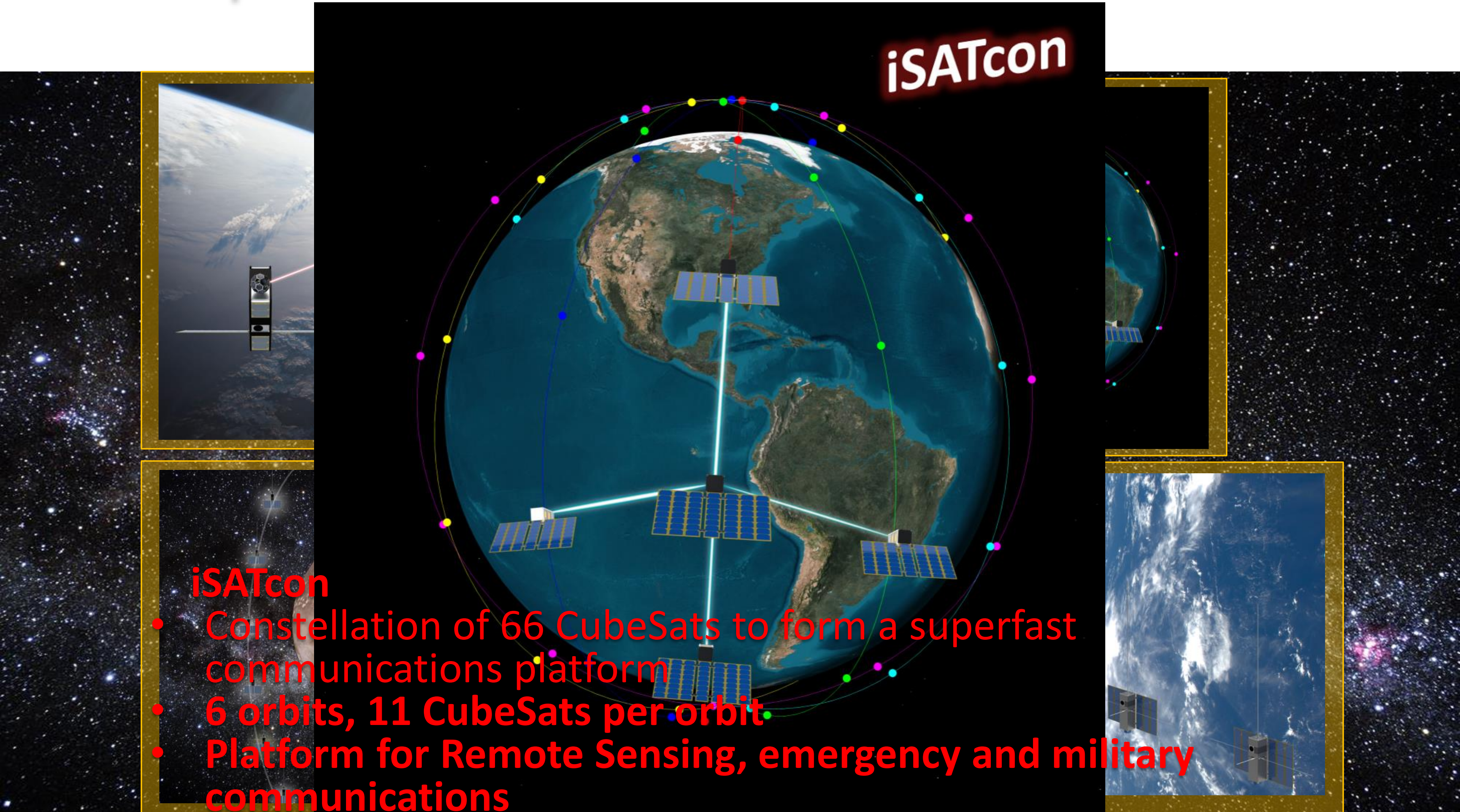


Examples

3. Examples

Examples: Q4 - Formation Flying

3. Examples

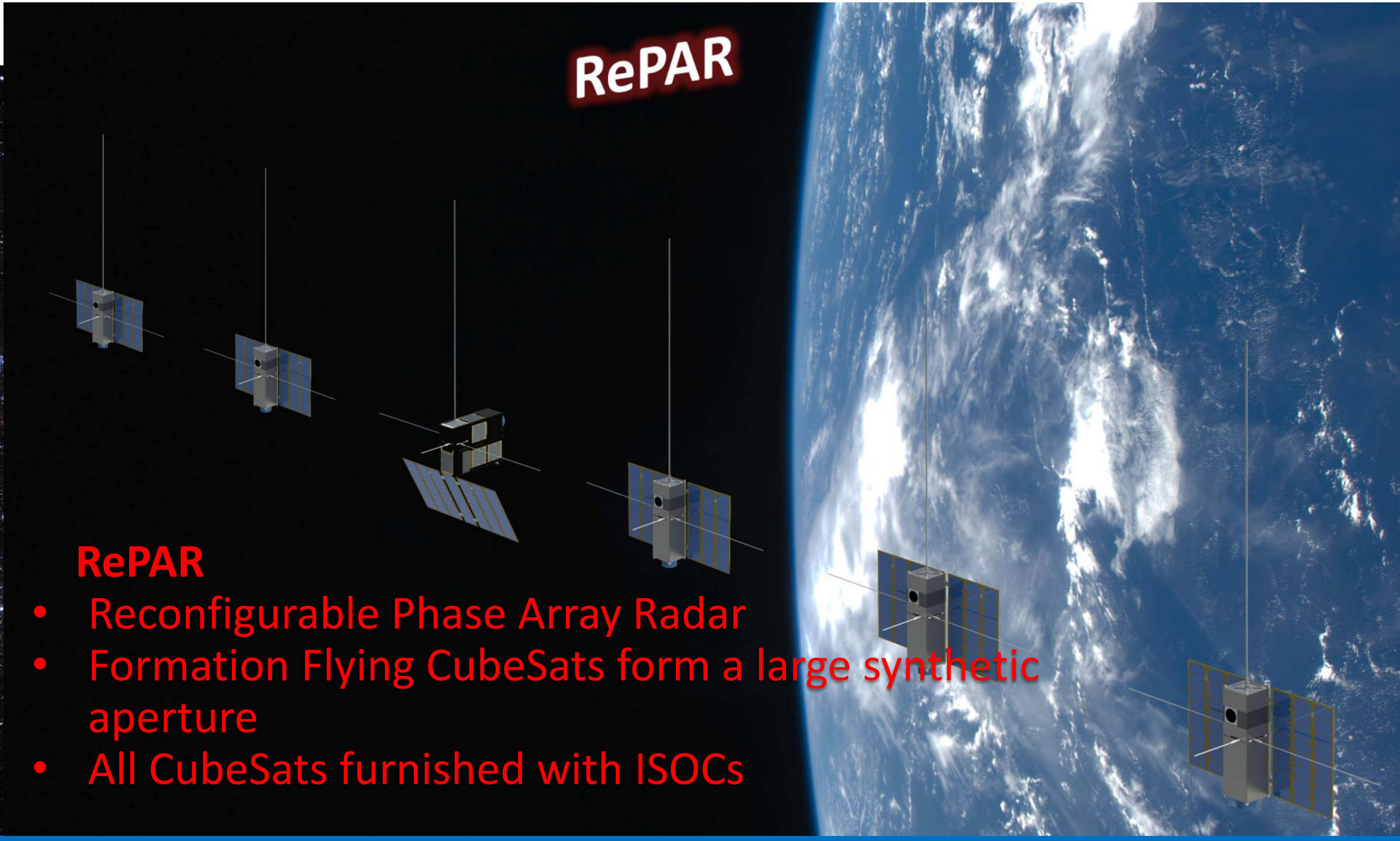


iSATcon

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

Examples: Constellation - iSATcon

3. Examples

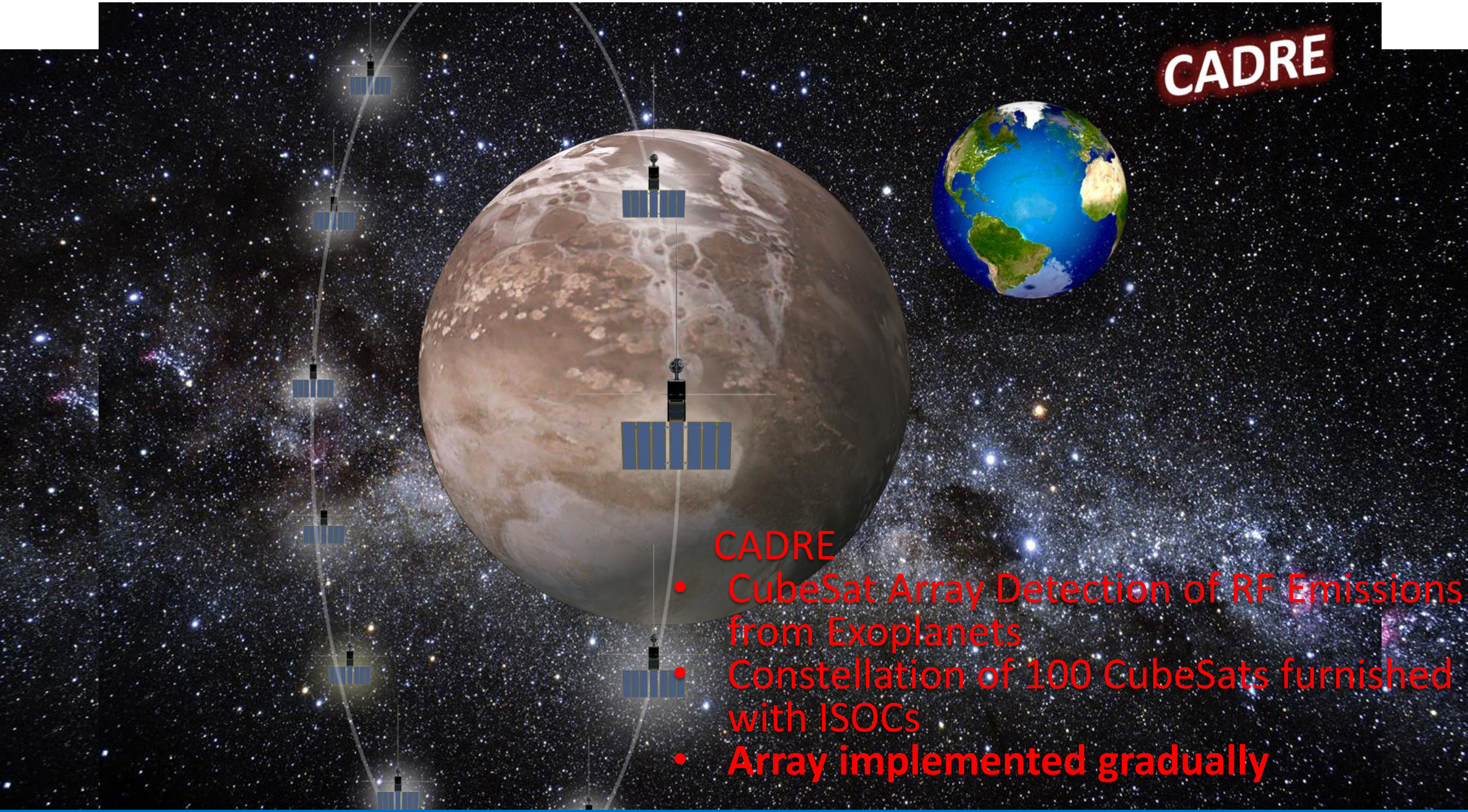


RePAR

- Reconfigurable Phase Array Radar
- Formation Flying CubeSats form a large synthetic aperture
- All CubeSats furnished with ISOCs

Examples: Formation Flying - RePAR

3. Examples



CADRE

- CubeSat Array Detection of RF Emissions from Exoplanets
- Constellation of 100 CubeSats furnished with ISOCs
- **Array implemented gradually**

Examples: Constellation - CADRE

Conclusions

- A novel Omnidirectional Optical Communicator has been presented
- We also presented design considerations and preliminary results of the ISOC transmit telescope
- We described potential formation flying and constellation missions enabled by the ISOC
- Our next goal is to pursue Q4 - a technology demonstration mission for the ISOC