L3HARRIS
FAST. FORWARD.

CAPABILITIES FOR ORBITAL SPACE DEBRIS TRACKING

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The Institute of OPTICS

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Outline of Capabilities for Orbital Debris Tracking

1. **L3Harris Overview**

2. **Novel concepts for orbital debris tracking modalities enabled by:**
    - Libraries of custom wave propagation and interaction models that feed end to end mission performance models
    - First principal benchmarked models of RF Rydberg sensors, and state of art laboratories for testing

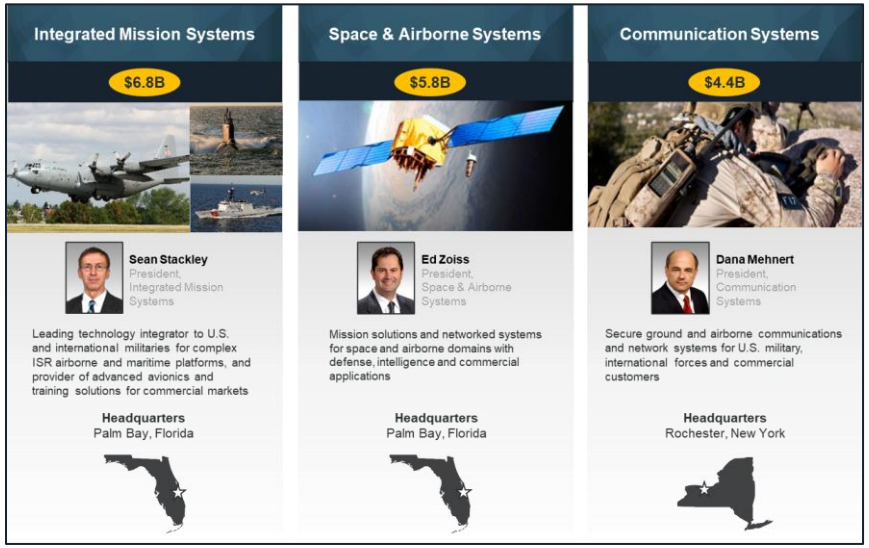
3. **Translating debris field data to risk, damage, and mitigation assessments for specific spacecraft**

4. **Satellite payload design, construction, and testing**

5. **Mission integration**

L3Harris Overview

Three mission-aligned segments

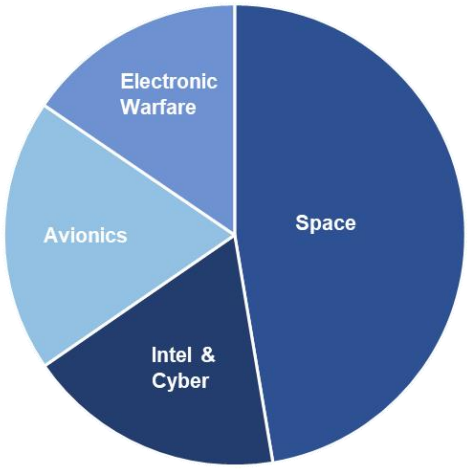


Global footprint

Space and Airborne Systems

2020 Revenue
$5.8B

2020 Op Margin
~15.5%



Space Systems & Solutions
Payloads, sensors and full-mission solutions for classified, civil and commercial customers

Intel and Cyber
Situational awareness, optical networks and advanced wireless solutions

Mission Avionics
Sensors, hardened electronics, release systems, data links and antennas supporting fixed wing and rotary platforms

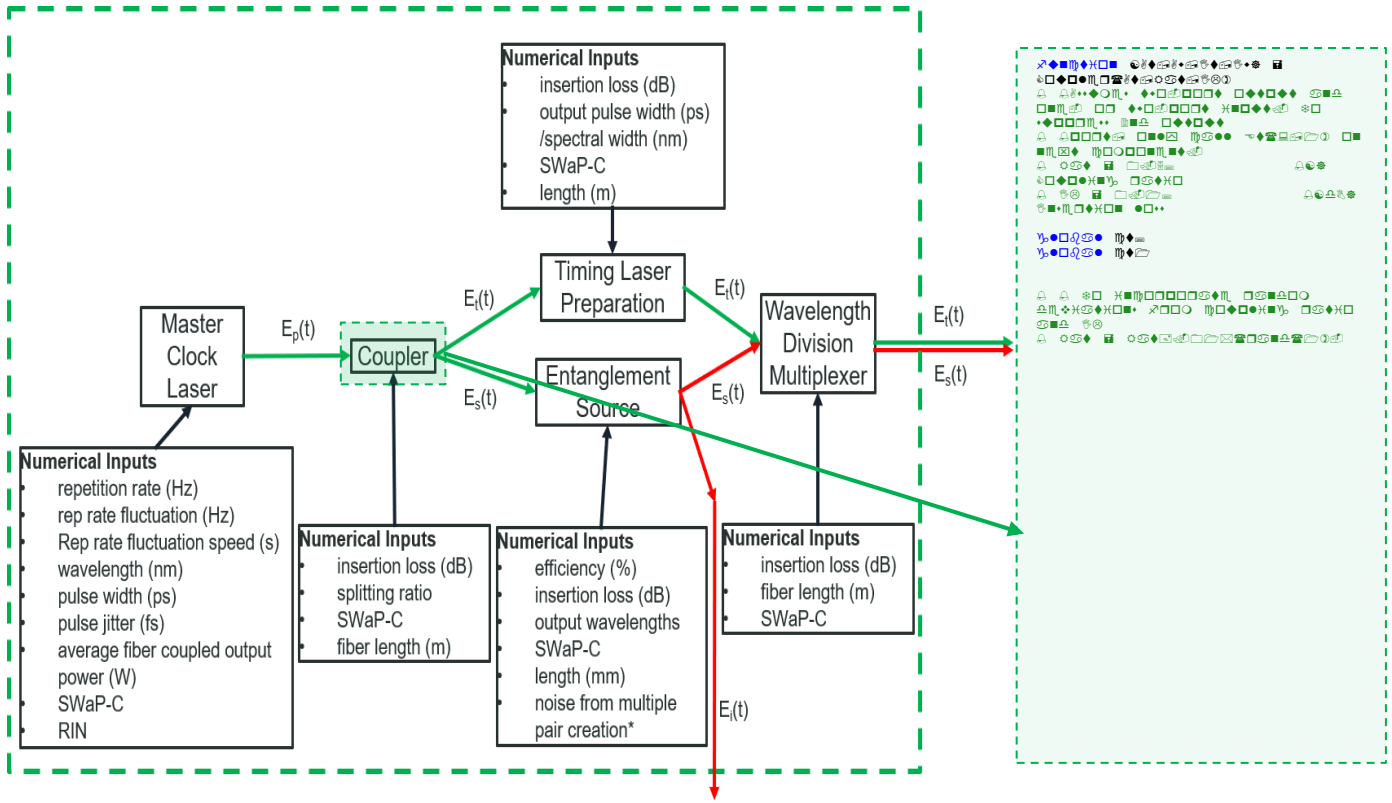
Electronic Warfare
Multi-spectral situational awareness, threat warning and countermeasures capabilities for airborne and maritime platforms

Mission Networks
Communications and networking solutions for air traffic management

Novel Orbital Debris Detection Modalities Enabled By:

Proprietary modeling software for end to end mission performance models from custom components describing propagation of waves across custom channels

- Based on spatiotemporal wave propagation models, covering RF, optical, with plasma propagation components in development
- Extensive component libraries feed modularly built models for quickly assessing and optimizing trade spaces.
- Enables full field simulation of phenomena that COTS or custom lumped loss software can't handle



Generic example of linking custom components together with the modeling architecture

Novel Orbital Debris Detection Modalities Enabled By:

Benchmarked RF Rydberg sensing models

- Promise for high sensitivity across extremely broad bandwidths (MHz – THz)
- Receiver minimum size not constrained by RF frequency
- Proprietary solutions for applying sensors for orbital debris detection

Atomic state populations:

$$\rho_{11} + \rho_{22} + \rho_{33} + \rho_{44} = 1$$

$$\dot{\rho}_{11} = i\frac{\Omega_p(t)}{2}(\rho_{12} - \rho_{21}) + \Gamma_{21}\rho_{22} + \Gamma_{31}\rho_{33} + \Gamma_{41}\rho_{44}$$

$$\dot{\rho}_{22} = -i\frac{\Omega_p(t)}{2}(\rho_{12} - \rho_{21}) + i\frac{\Omega_c(t)}{2}(\rho_{23} - \rho_{32}) - \Gamma_{21}\rho_{22} + \Gamma_{32}\rho_{33} + \Gamma_{42}\rho_{44}$$

$$\dot{\rho}_{33} = -i\frac{\Omega_c(t)}{2}(\rho_{23} - \rho_{32}) + i\frac{\Omega_{RF}(t)}{2}(\rho_{34} - \rho_{43}) - (\Gamma_{32} + \Gamma_{31})\rho_{33} + \Gamma_{43}\rho_{44}$$

$$\dot{\rho}_{44} = -i\frac{\Omega_{RF}(t)}{2}(\rho_{34} - \rho_{43}) - (\Gamma_{41} + \Gamma_{42} + \Gamma_{43})\rho_{44}$$

Coherences:

$$\dot{\rho}_{21} = i\frac{\Omega_p(t)}{2}(\rho_{22} - \rho_{11}) - \frac{i\Omega_c(t)}{2}\rho_{31} - (\gamma_{21} + i\Delta_1)\rho_{21}$$

$$\dot{\rho}_{31} = i\frac{\Omega_p(t)}{2}\rho_{32} - \frac{i\Omega_c(t)}{2}\rho_{21} - \frac{i\Omega_{RF}(t)}{2}\rho_{41} - (\gamma_{31} + i\delta)\rho_{31}$$

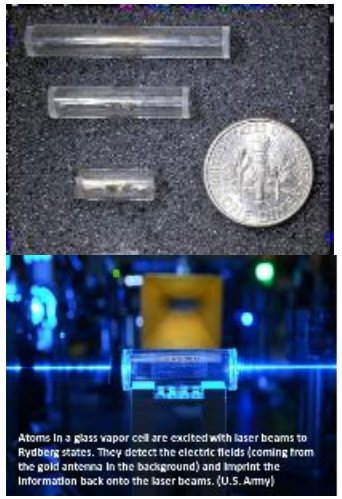
$$\dot{\rho}_{41} = i\frac{\Omega_p(t)}{2}\rho_{42} - \frac{i\Omega_{RF}(t)}{2}\rho_{31} - (\gamma_{41} + i\tilde{\Delta})\rho_{41}$$

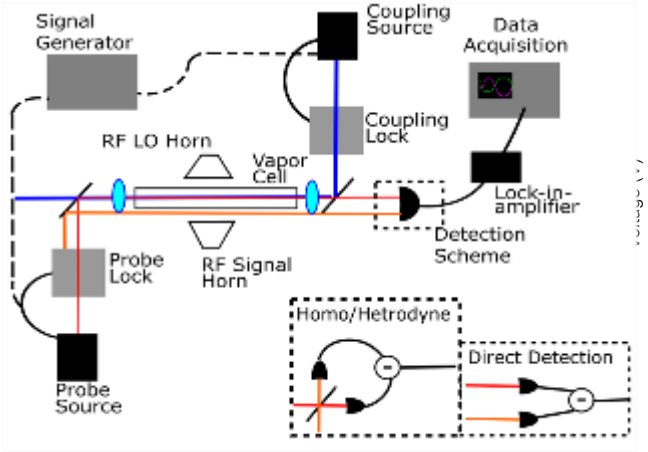
$$\dot{\rho}_{32} = \frac{i}{2}\Omega_c(t)(\rho_{33} - \rho_{22}) + \frac{i}{2}\Omega_p(t)\rho_{31} - \frac{i}{2}\Omega_{RF}(t)\rho_{42} - (\gamma_{32} + i\Delta_2)\rho_{32}$$

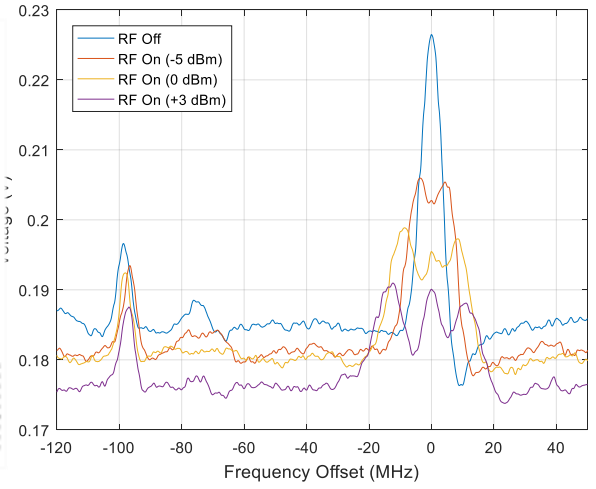
$$\dot{\rho}_{42} = \frac{i}{2}\Omega_c(t)\rho_{43} + \frac{i}{2}\Omega_p(t)\rho_{41} - \frac{i}{2}\Omega_{RF}(t)\rho_{32} - (\gamma_{42} + i(\Delta_2 + \Delta_3))\rho_{42}$$

$$\dot{\rho}_{43} = \frac{i}{2}\Omega_{RF}(t)(\rho_{44} - \rho_{33}) + \frac{i}{2}\Omega_c(t)\rho_{42} - (\gamma_{43} + i\Delta_3)\rho_{43}$$

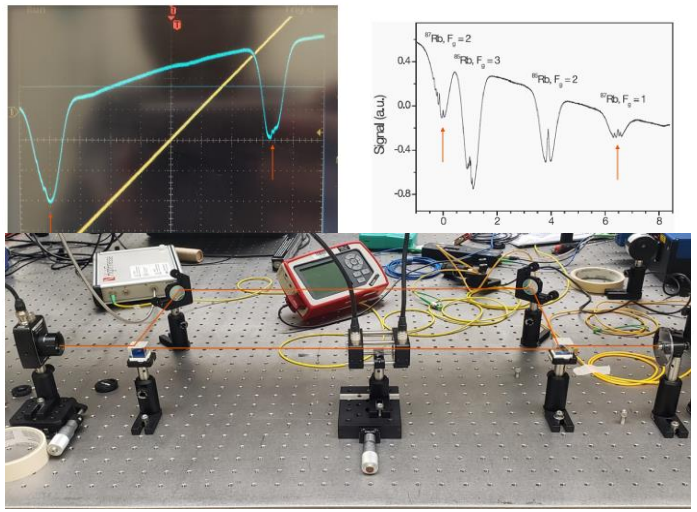
State of art laboratories for receiver testing







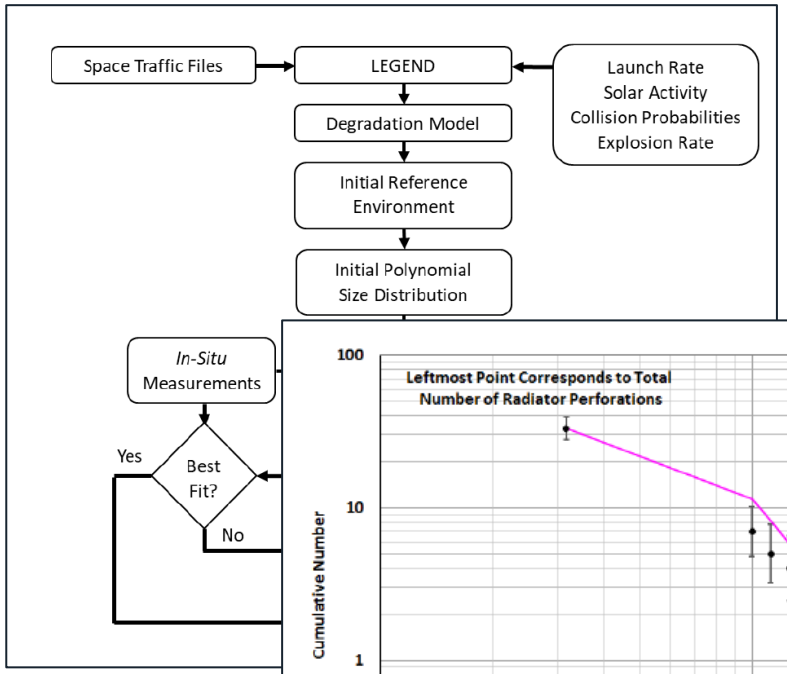
Rb 87 fine and hyperfine lines

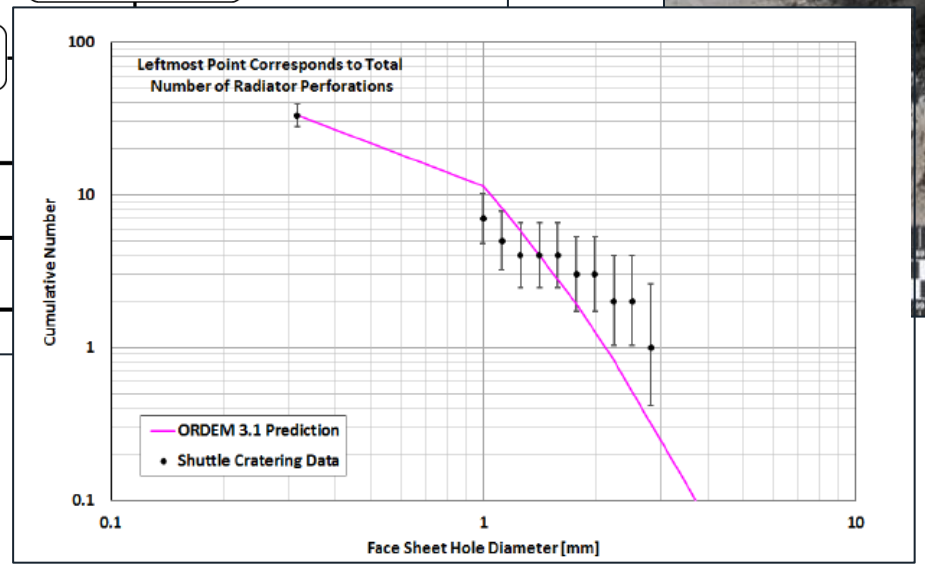


Meyer, D. H., Castillo, Z. A., Cox, K. C., & Kunz, P. D. (2020). Assessment of Rydberg atoms for wideband electric field sensing. *Journal of Physics B: Atomic, Molecular and Optical Physics*, *53*(3), 034001.

Using sensor data to improve mission outcomes

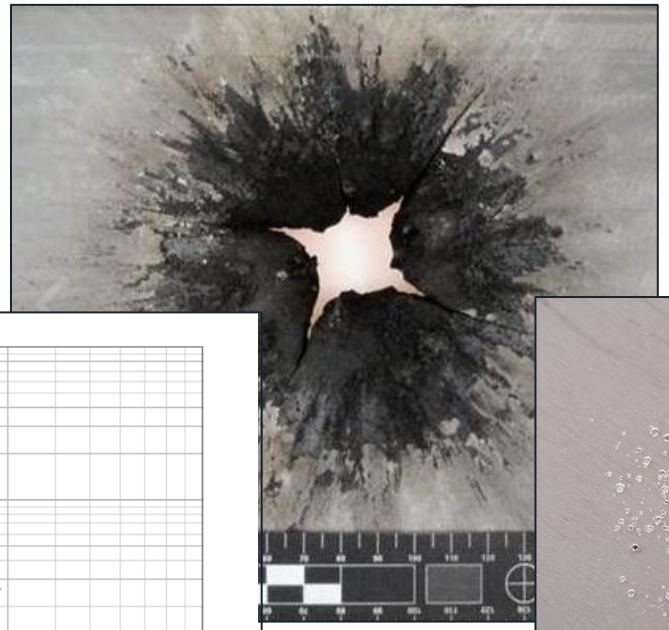
Extract debris properties from sensor data





Probability of critical failure

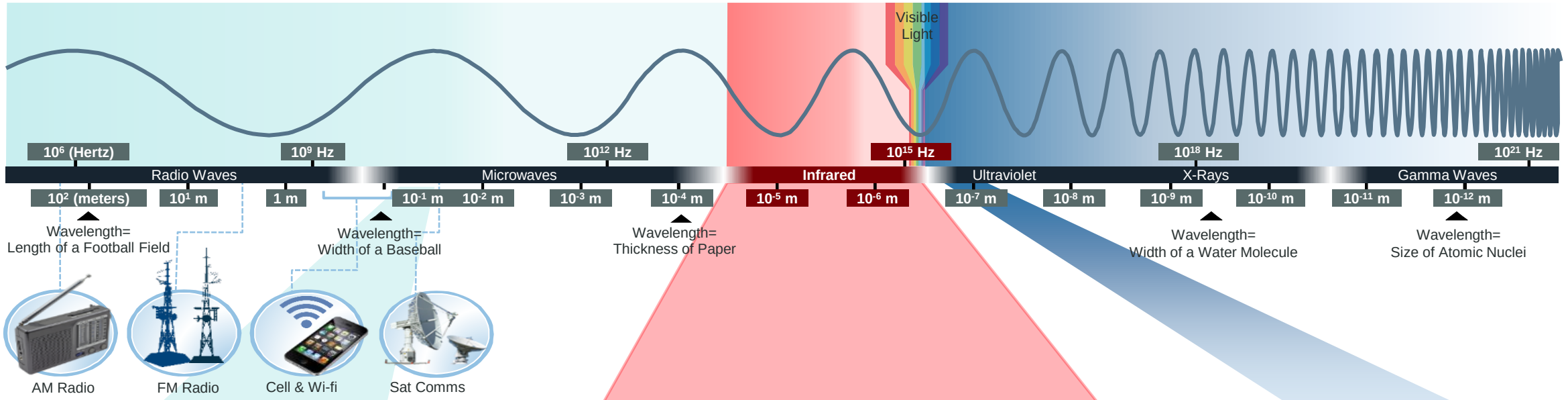
Damage assessments



Mitigation Strategies - Shielding

hvit.jsc.nasa.gov. Exit hole of ISS crew module penetration test – performed to test repair techniques.
Manis, A., Matney, M., Vavrin, A., Seago, J., Gates, D., Anz-meador, P., ... & Xu, Y. L. (2022). NASA Orbital Debris Engineering Model (ORDEM) 3.1 Model Process. *NASA Technical Publication*.

L3Harris provides payloads across every mission area



RF Systems

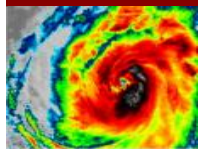
Comms

Sensors

SAR

Spectral Solutions

Weather

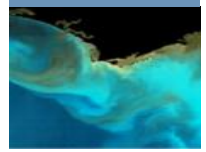


Missile warning/def

Earth Observing

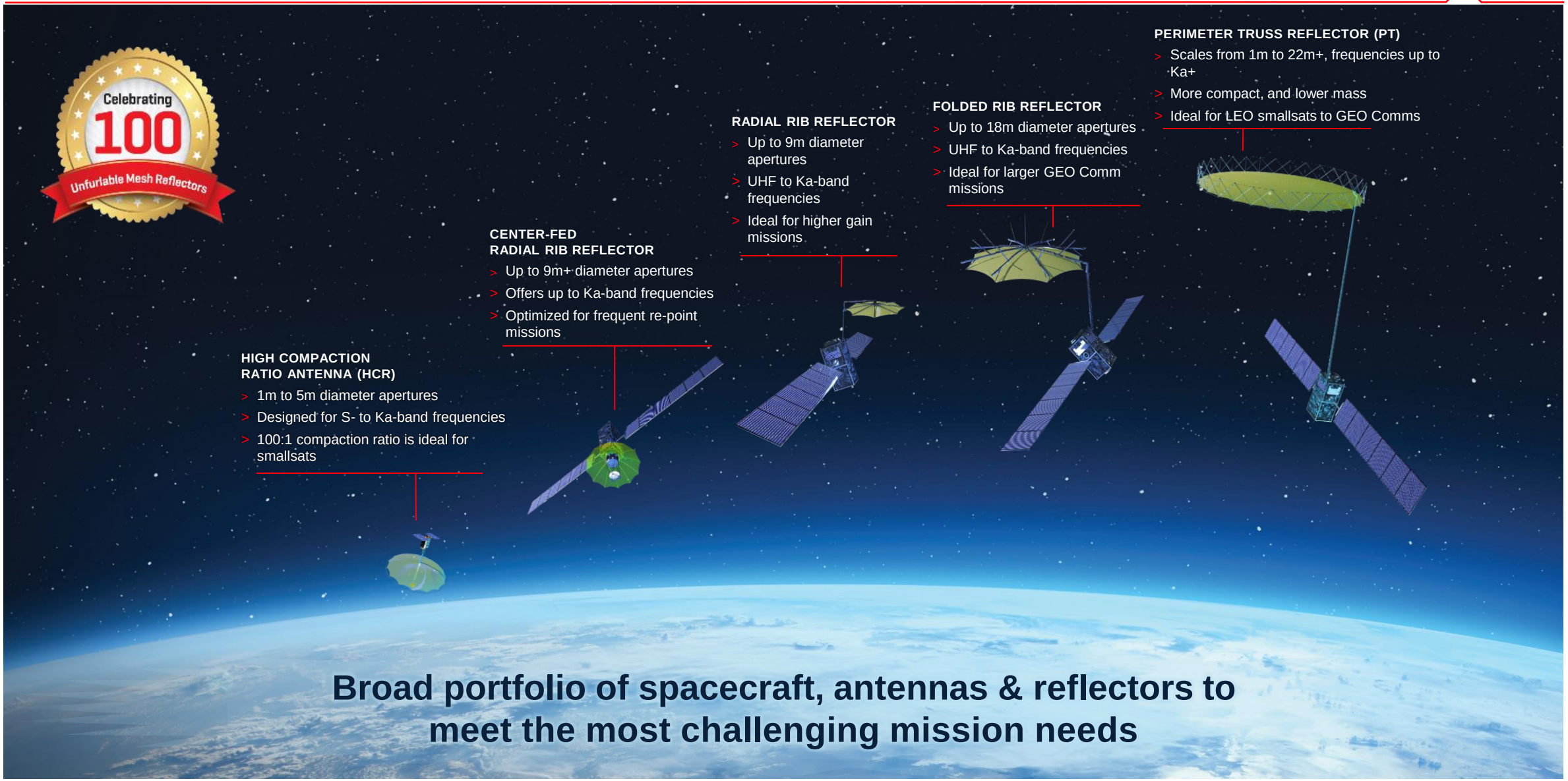
Imaging

Telescopes & Lasers

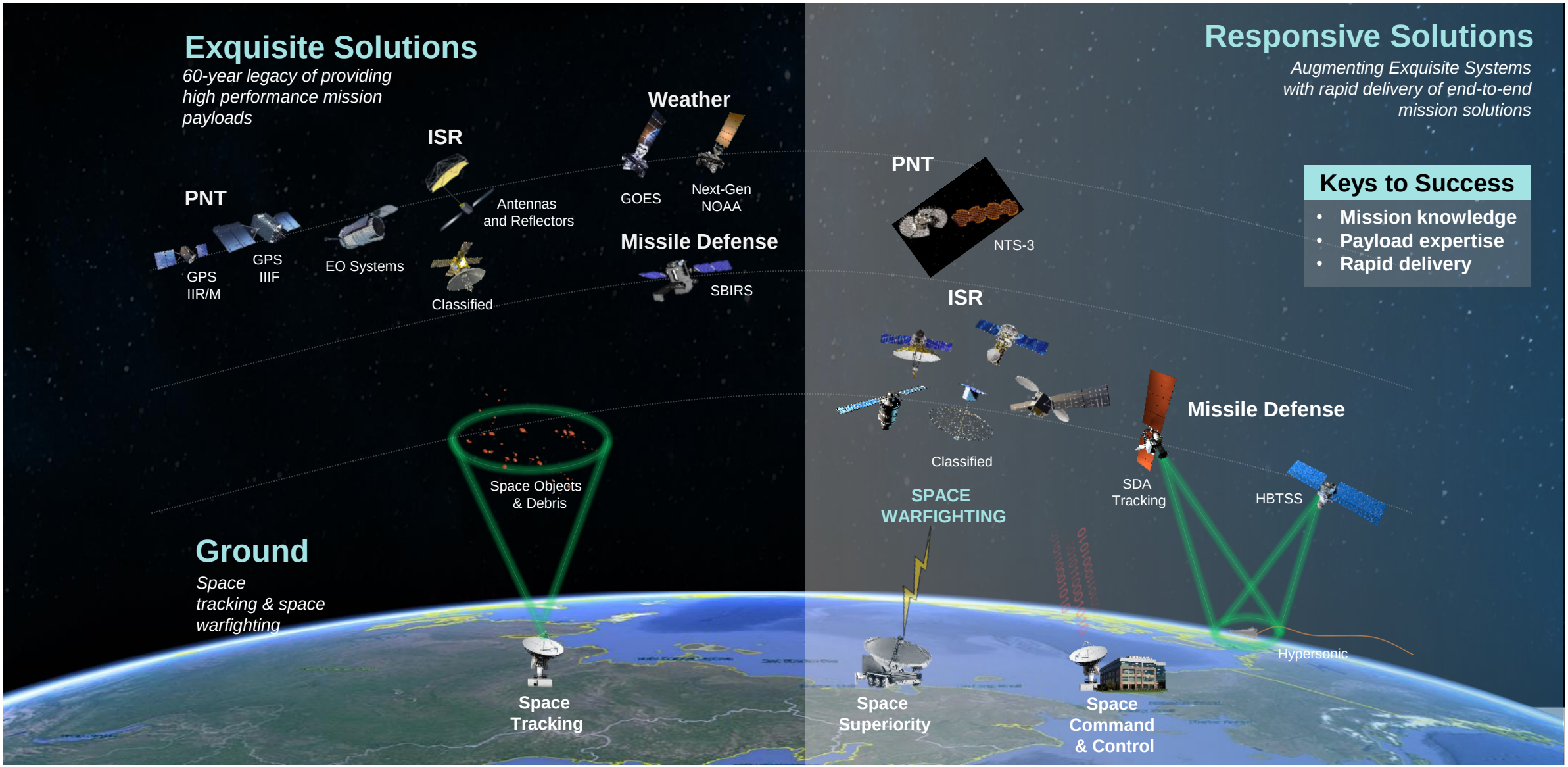


Depth and breadth has enabled us to become Responsive Prime market leader

Spacecraft and Payload Provider



Mission Integrator: Exquisite and Responsive E2E Mission Solutions



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