REFLEXPHOTONICS®

Optical Interconnect Design in Space

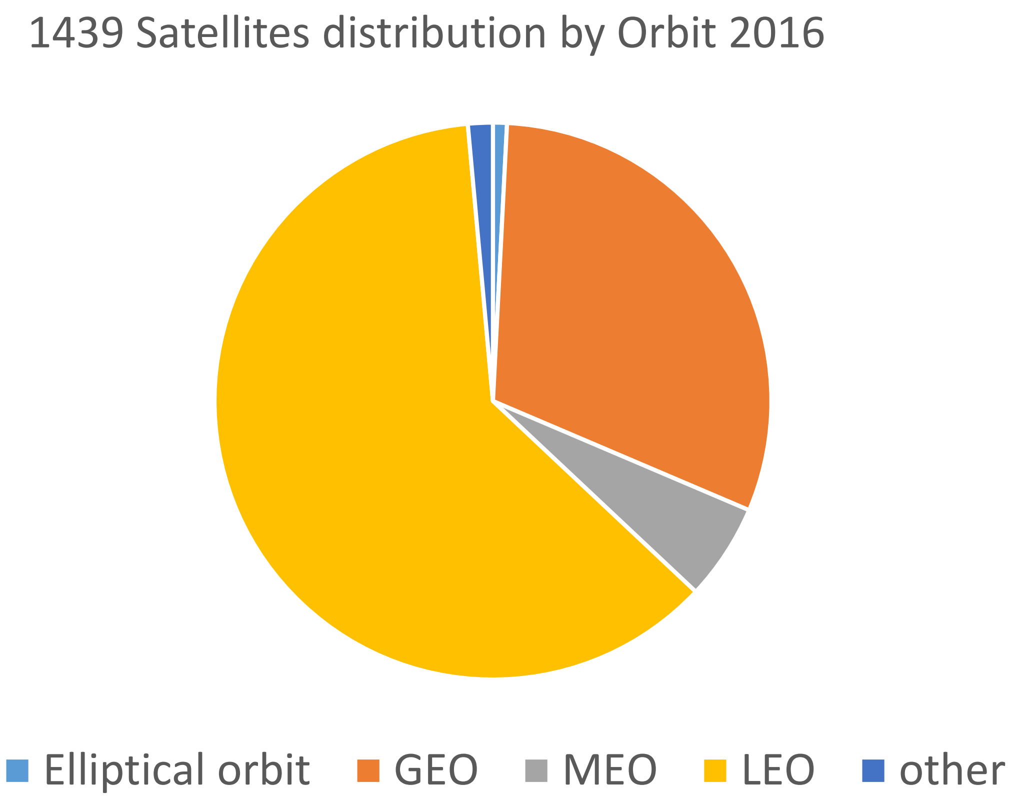
By
Guillaume Blanchette
Space Industry Manager @ Reflex Photonics
01 28 2019

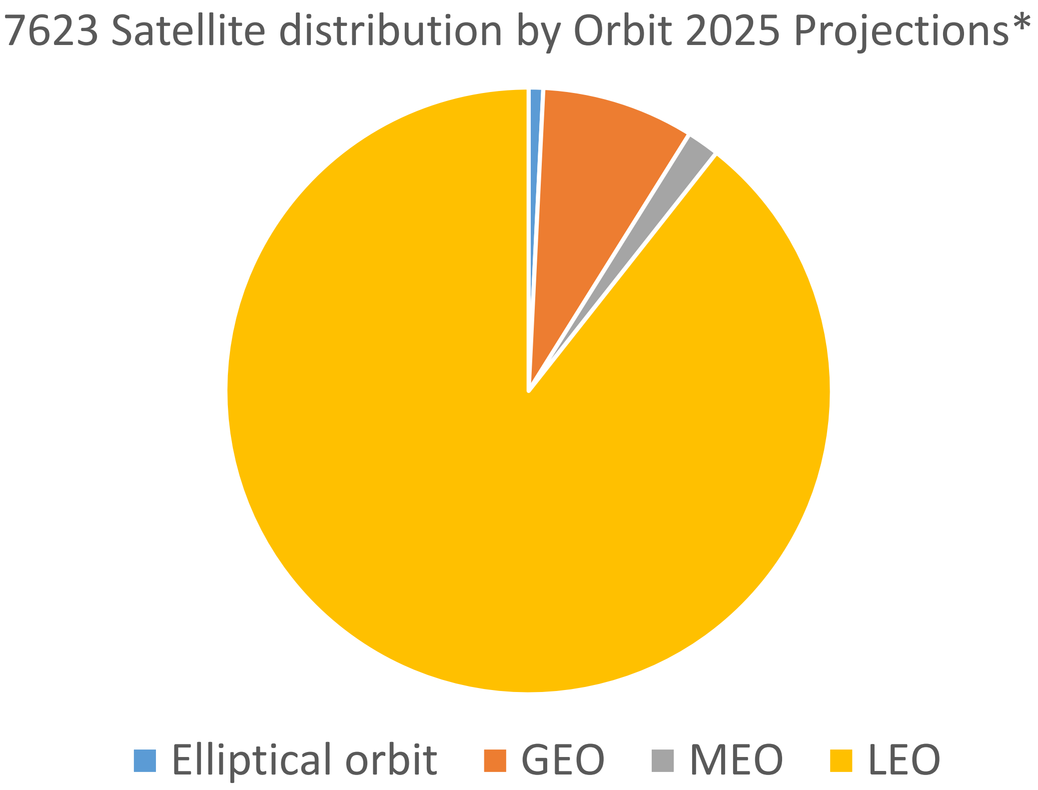
Outline

- Market overview
- Applications overview
- Optical transceivers challenge
- Radiation tests
- Thermal vacuum testing (TVAC)
- Lifetime test

REFLEXPHOTONICS®

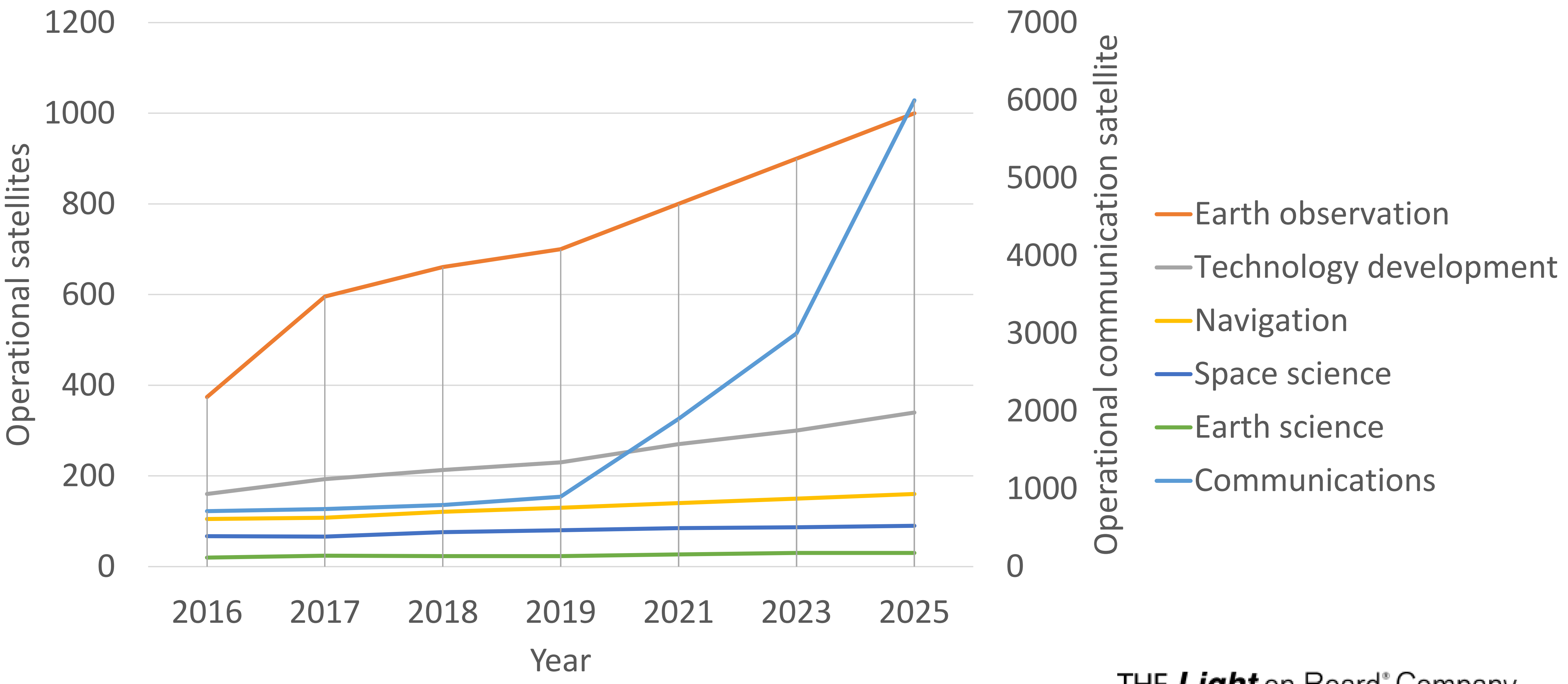
Market – Space – large increase in LEO satellites



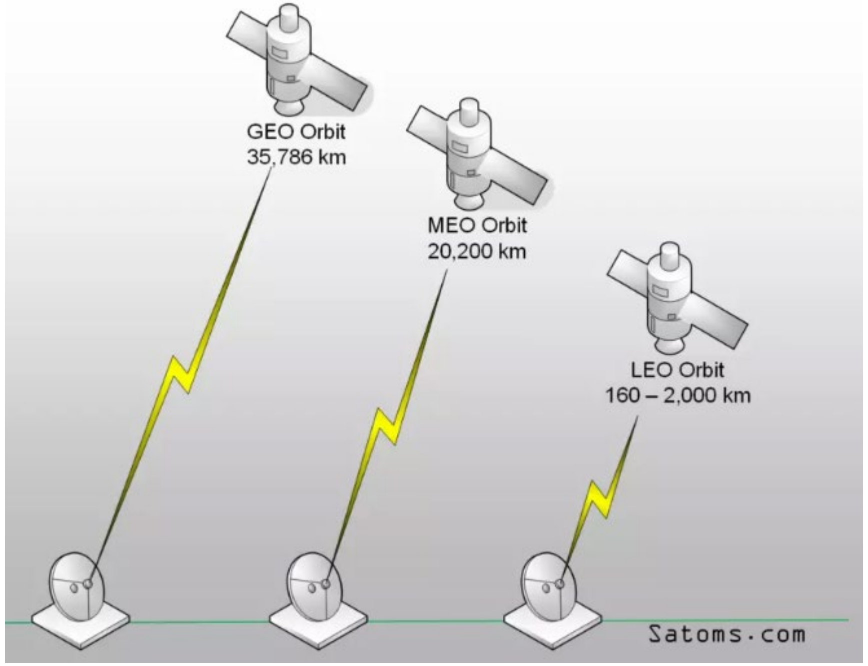


Projections are based on FCC approval given to SpaceX for up to 12000 satellites and on Oneweb, Telesat constellations projections.
ref: Pixalytics website, UCSUSA

Market – Space – Communication satellites increase



Market – Space – LEO applications



Why are satellites set in LEO and VLEO?

In order to offer low latency and compete with Earth's fibered network.

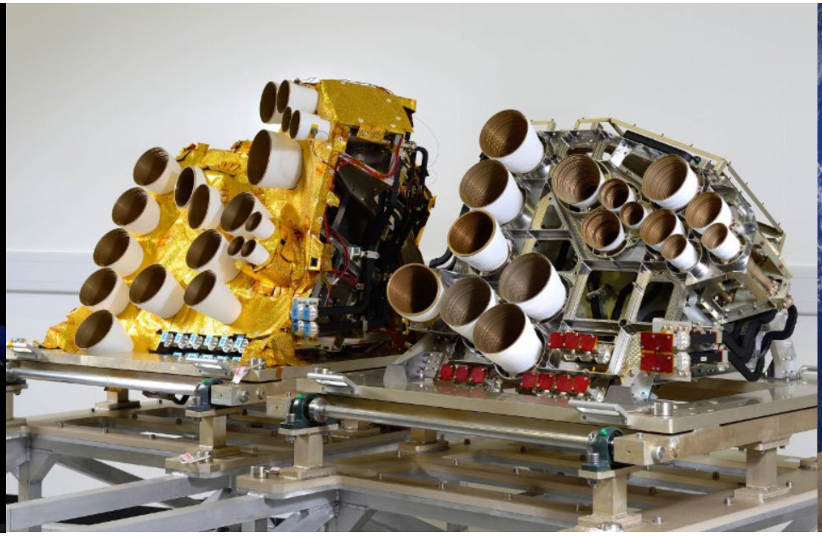
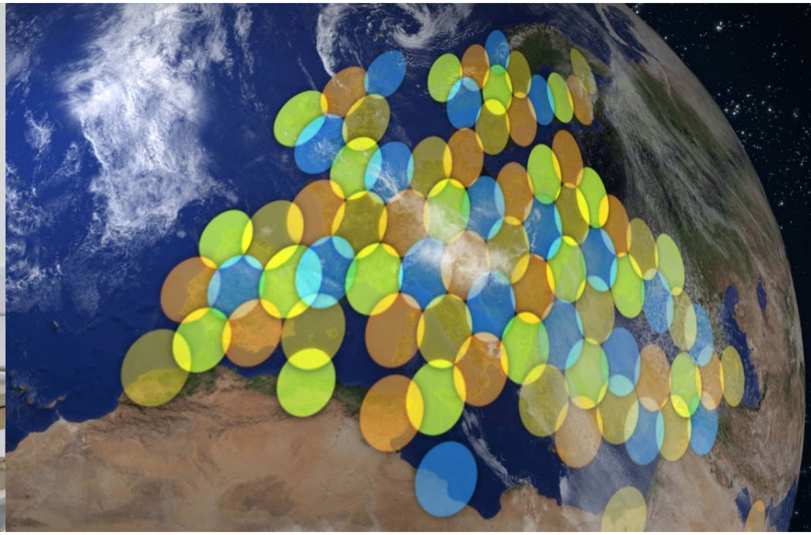
Why do we need a large number of satellite or constellations?

To offer a global coverage and a low latency. Since LEOs are closer to Earth, they cover less territory because of the limited field of view from the antennas onboard each spacecraft.

Why the need for optical interconnect?

Optical interconnect helps lowering the weight of every satellite which help reducing the launching price and the price per bit for satellite operators.

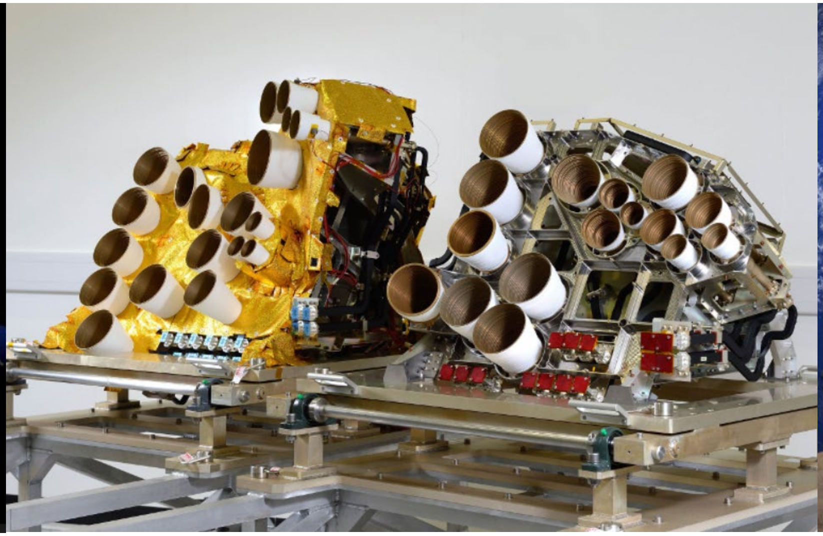
Market – Space – GEO applications

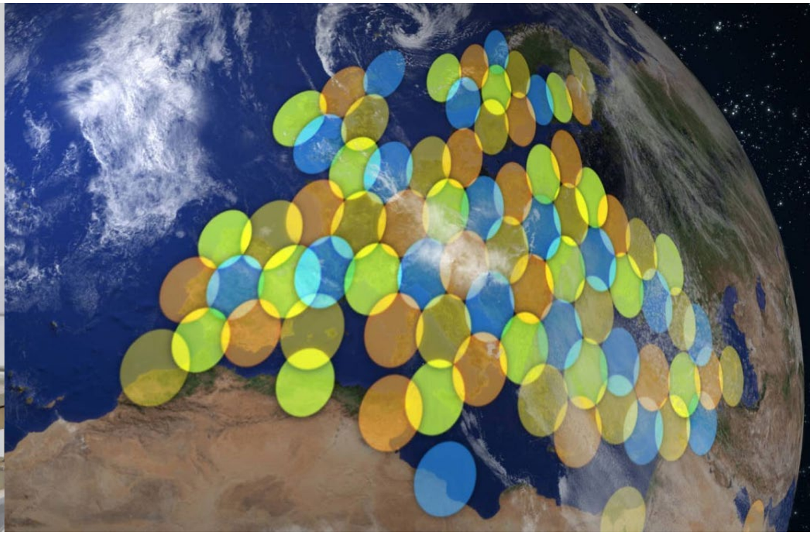




Why do high-throughput geostationary communications satellite have higher data transfer rate than previous technologies?

- New multibeam satellites can have around 200 K_a band spot-beams. Those multibeam satellites have increased data lanes that need to be routed and can support higher baud rate given the fact that the transmission frequency is higher. This also has the benefit of reducing the price per bit.
- Information streams are directed from one beam to another inside a data processing switch.
- The data transfer rate of these switches increase by a very large amount as high throughput satellite deal with bandwidth up to 100Gb/s (more than 20 time standard data rate for fixed-satellite service).
- Payload can be made more flexible if all the spot beam signals goes through switches. The same payload can be "repurposed" more easily from one client application to another, thus giving a faster ROI to payload developers and enabling more economical solution for satellite operators.

Market – Space – GEO applications (continued)





Why is optical interconnect needed inside high-throughput geostationary communications satellite?

- Optical interconnect solutions reduce the impact on payload weight and harnessing complexity.
- Optical interconnect makes high-throughput multibeam Ka band satellite a cost-effective solution.

GEO and LEO
Mission Requirements and Optical Transceivers Challenges

Market – LEO vs GEO – Use case analysis

Applications	
LEO constellation satellite	**GEO satellite**
Satellite-based internet (Lower latency than MEO and GEO)	High-throughput geostationary communication satellite
High number of satellite needed by constellation	15 years mission
Small satellite and shorter optical link, around 1−5 meter connection	Larger satellite, up to 15−meter optical link
Around 10 optical transceivers per satellite	Few hundreds optical transceivers per satellite
5−10 years mission	10−20 years mission
Redundancy (downtime permitted)	No redundancy (no downtime permitted)
TAM of approximately 5000−10000 optical transceivers per year over the next 5−10 years	**TAM of approximately 5000 optical transceivers per year over the next 5-10 years**

REFLEXPHOTONICS®

LEO vs GEO – distinct challenges for optical transceivers

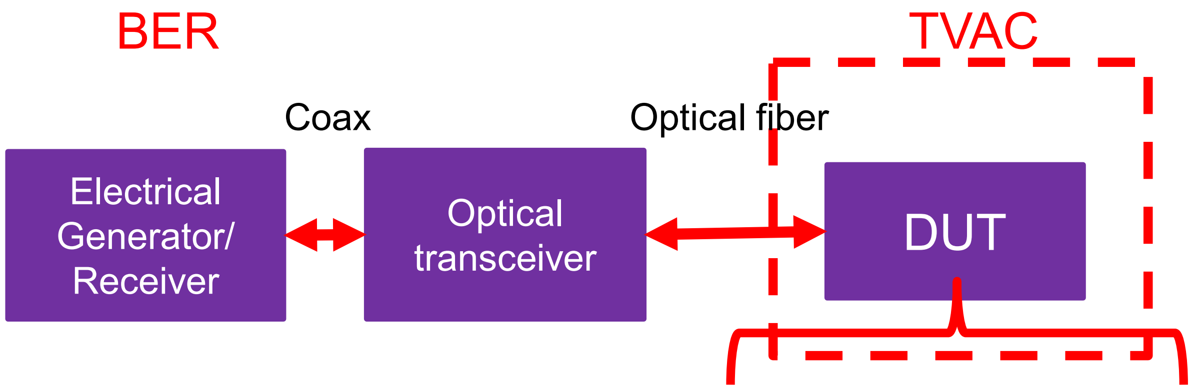
LEO constellation satellite (5−10 years mission from 500 to 2000 km)	GEO satellite (10−20 years at 35 000 km)
84 to 127 minutes orbit period leads to short period temperature cycles. (11 to 17 temperature cycles per day)	1 temperature cycle per day
Total ionizing dose up to 10 krad/year	Total ionizing dose up to 100 krad/year
Cost effectiveness	VCSELs optical power degradation over the whole mission
SEL*, SEB* that can permanently damage the electronics	SEU*, SEL*, SEB* risks
Downtime is permitted, constellation redundancy	Downtime is not permitted
Outgassing, operation under vacuum	

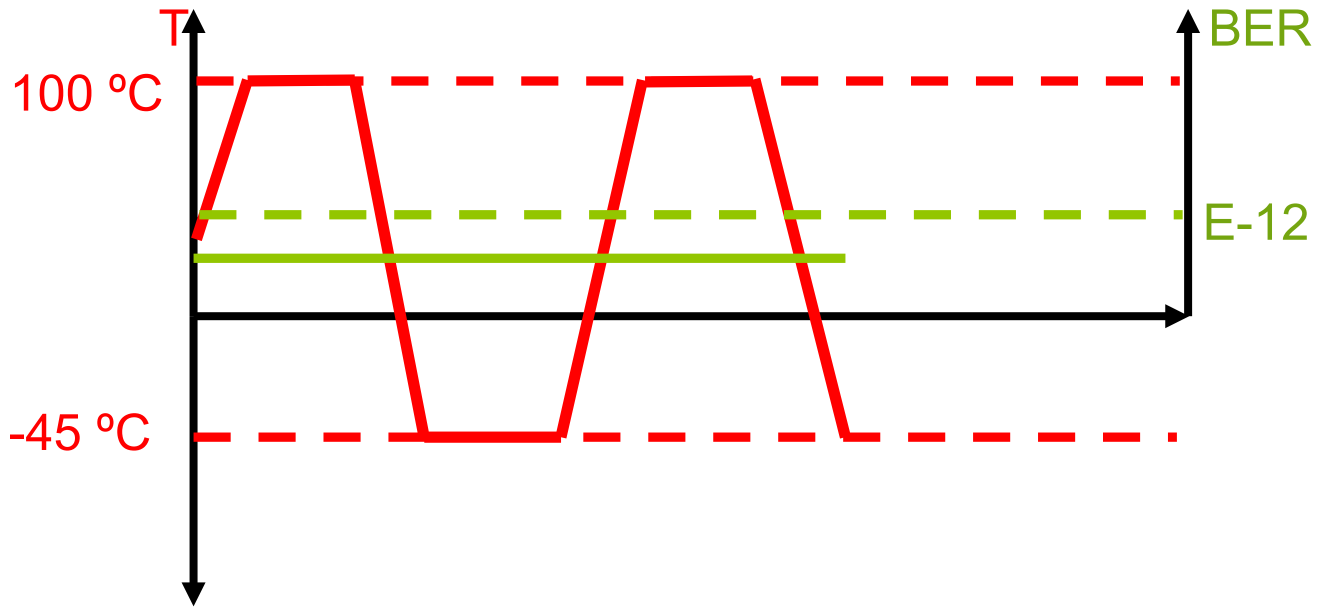
Single event phenomena can be classified into three effects (in order of permanency):
1. SEU: Single event upset (soft error); Bit flipping
2. SEL: Single event latchup (soft or hard error); High current
3. SEB: Single event burnout (hard failure); permanent physical damage

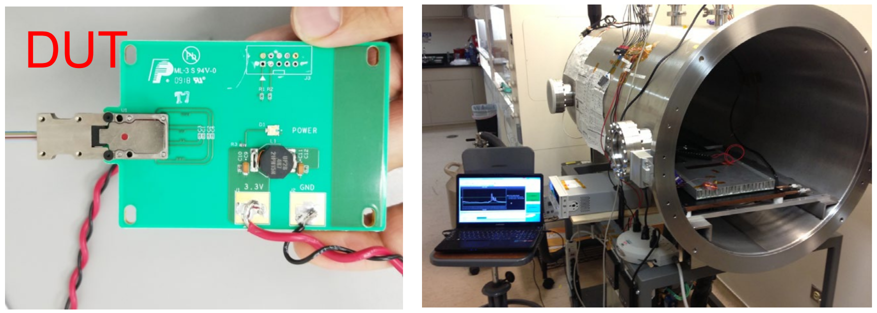
Optical transceivers
Space environment qualification tests

Thermal vacuum testing

- Simulate operation under vacuum.
- Simulate temperature cycling.
- Monitor BER during the cycles.
- Pressure: $5*10^{-5}$hPa
  (approx. $1*10^{-5}$ ounce/square inch).

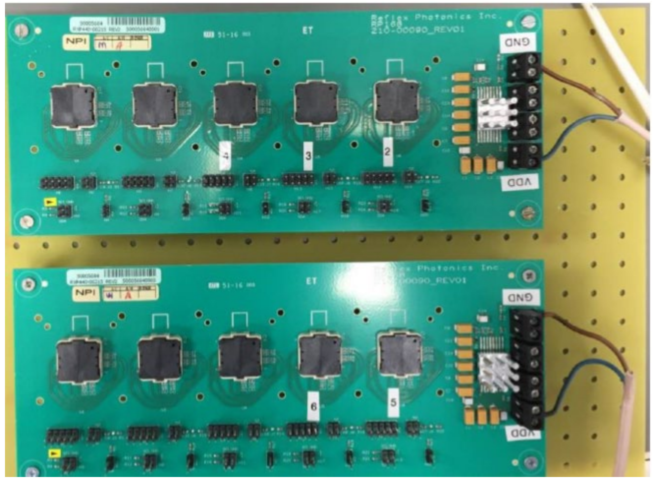






TID – Cobalt 60 tests

- The Gamma-ray dosing rate is set at roughly 100 rad/h.
- The cumulative doses must aim for 100 krad.
- There was a post-radiation annealing step of 24 h at 22 ºC.
- There was a further annealing of 168 h at 100 ºC.

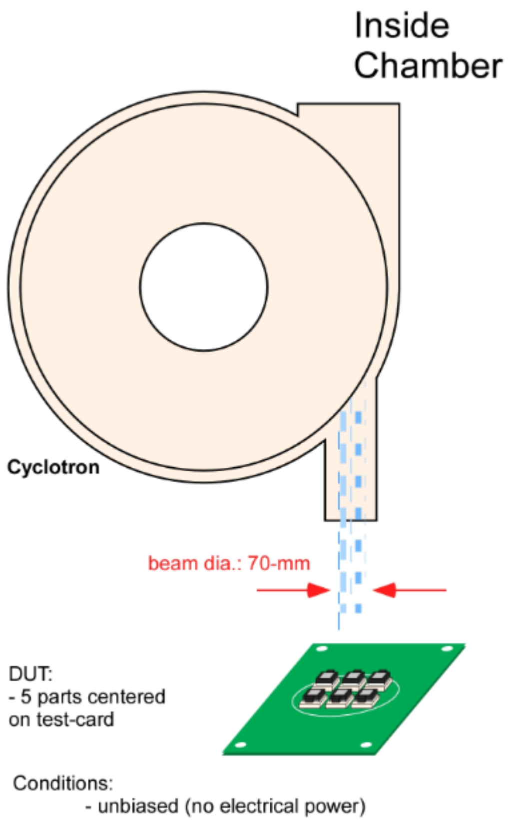


PCB to support the powered optical transceivers

University of Saskatchewan

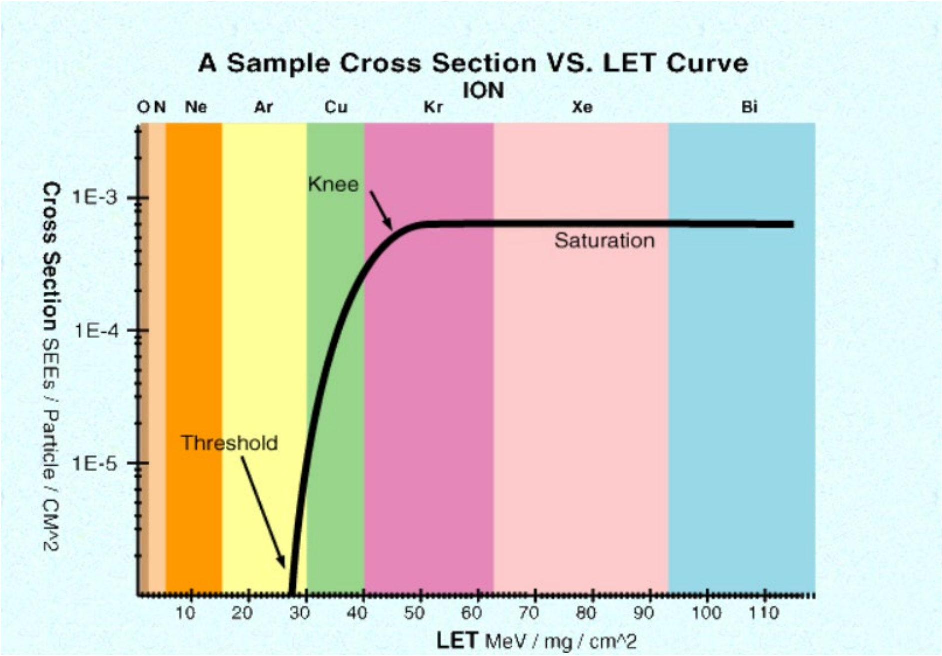
TNID – Proton tests

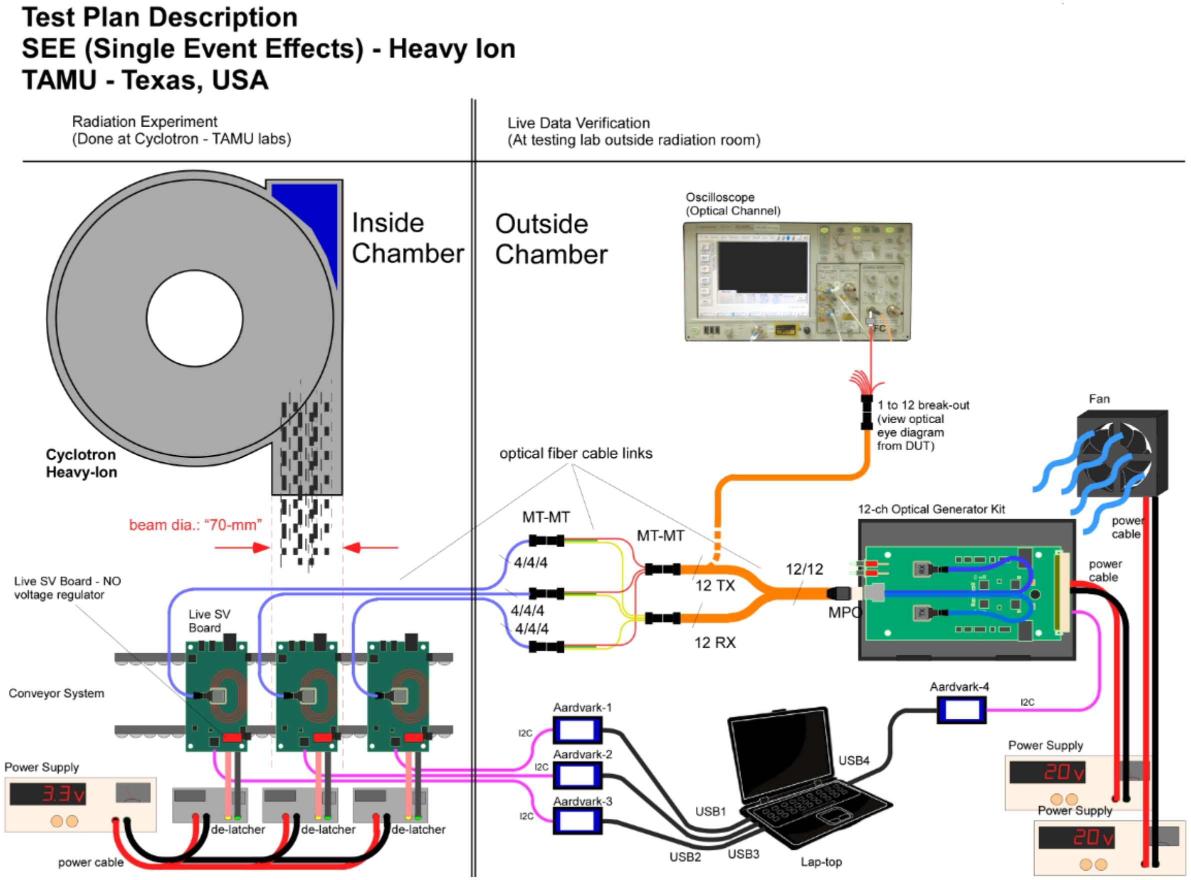
- Functional tests: BER.
- 100 MeV proton energy beam in 70-mm diameter.
- 168 h at 100 ºC post annealing step.



Heavy-ion tests

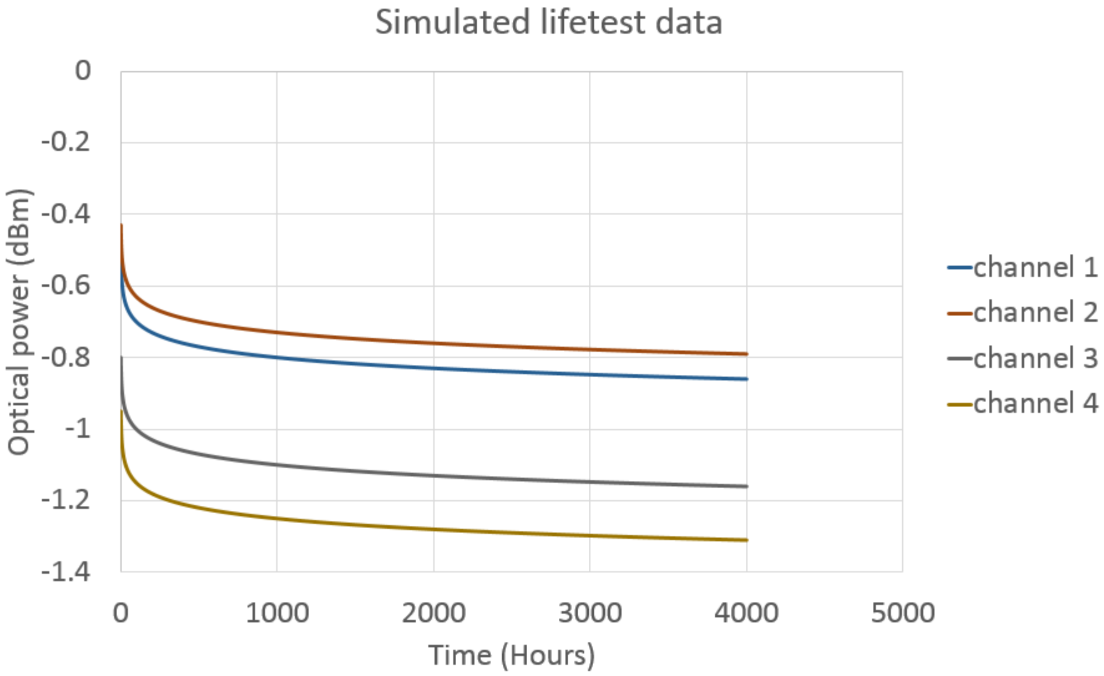
- Active DUT.
- Running BER tests and analyzing the number of events during radiation.
- Measuring the LET threshold.
- Measuring the Error saturation level.





Lifetime tests

- Goal: Validate budget link over the whole mission.
- Tests: Accelerated lifetime at 100 ºC optical transceiver case temperature and 9mA VCSELs bias.
- >15 years optical link reliability based on Eyring model prediction.



The final frontier

The insatiable human need for better and faster information will continue to drive the demand for improved communication system for many years to come.

The multibeam GEO satellites and the LEO constellations will improve all the nations connectivity and give better global coverage.

Indeed, improved processors and systems that can scale-up require interconnect solutions that are also able to scale-up.

Optical interconnect is speeding humanity technological progress toward the final frontier...

References

- *High-throughput optical inter-board interconnects for next-generation on-board digital transparent processors.* N. Venet, M. Sotom, H. Gachon, V. Foucal, M. Pez, V. Heikkinen, T. Tuominen, S. Pantoja
- *Facilities and Radiation Test Methods*, Ari Virtanen 1,1 University of Jyväskylä, Finland
- *Proton Test Guideline Development*, Stephen Buchner, Paul Marshall, Scott Kniffin and Ken LaBel NASA/Goddard Space Flight Center

Thank you!