TESAT SPACECOM

PIONEERING WITH PASSION

Optical Inter-Satellite Communication Operational

Mark Gregory, Frank Heine, H. Kämpfner, Robert Lange (Tesat-Spacecom)

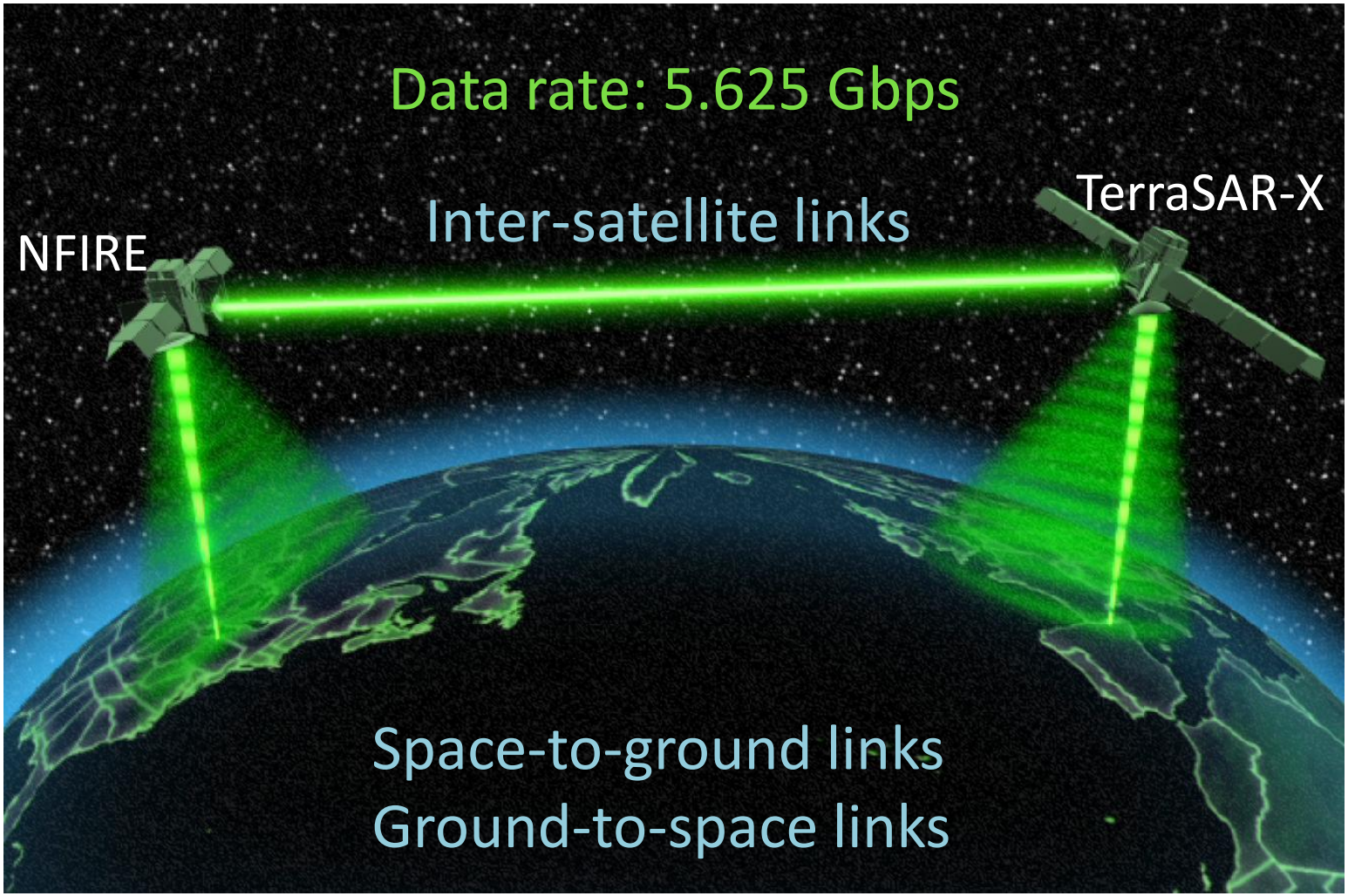
Reinhard Czichy (Synopta)

Rolf Meyer, Michael Lutzer (DLR)

PROPRIETARY INFORMATION

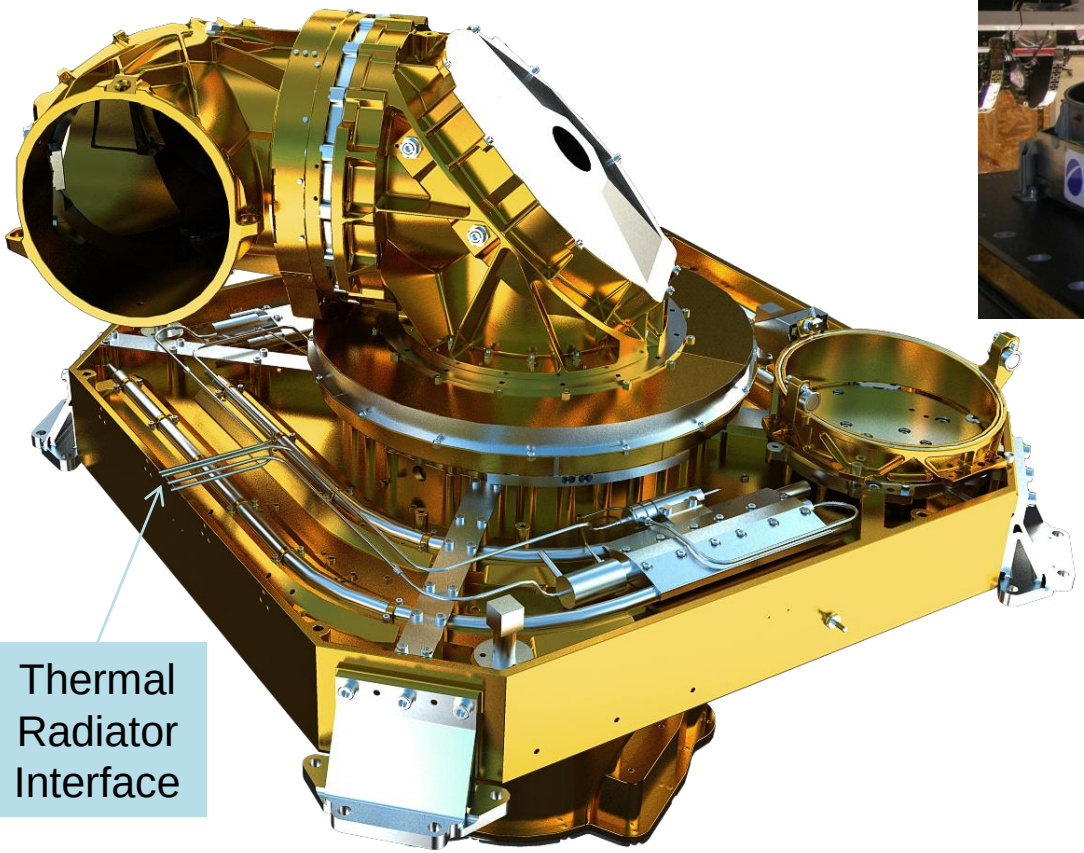
©Tesat-Spacecom GmbH & Co.KG reserves all rights including industrial property rights, and all rights of disposal such as copying and passing to third parties

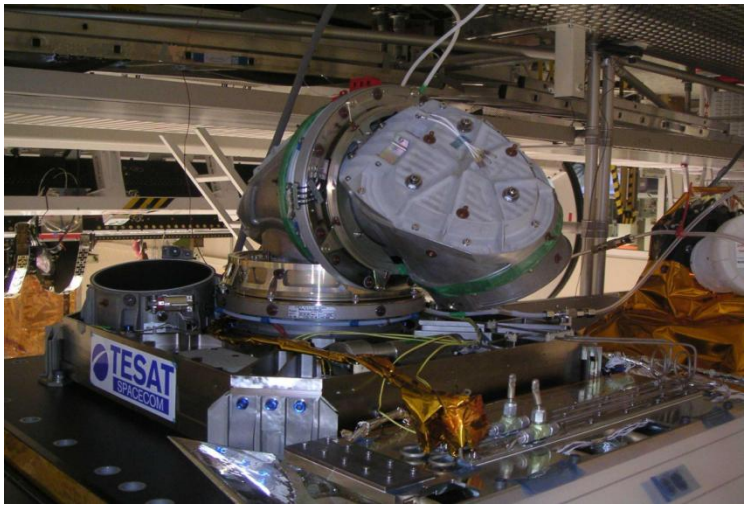
Gbps Laser Communication Operational In-Orbit !



©Tesat-Spacecom GmbH & Co.KG 2010

Laser Communication Based on Homodyne BPSK



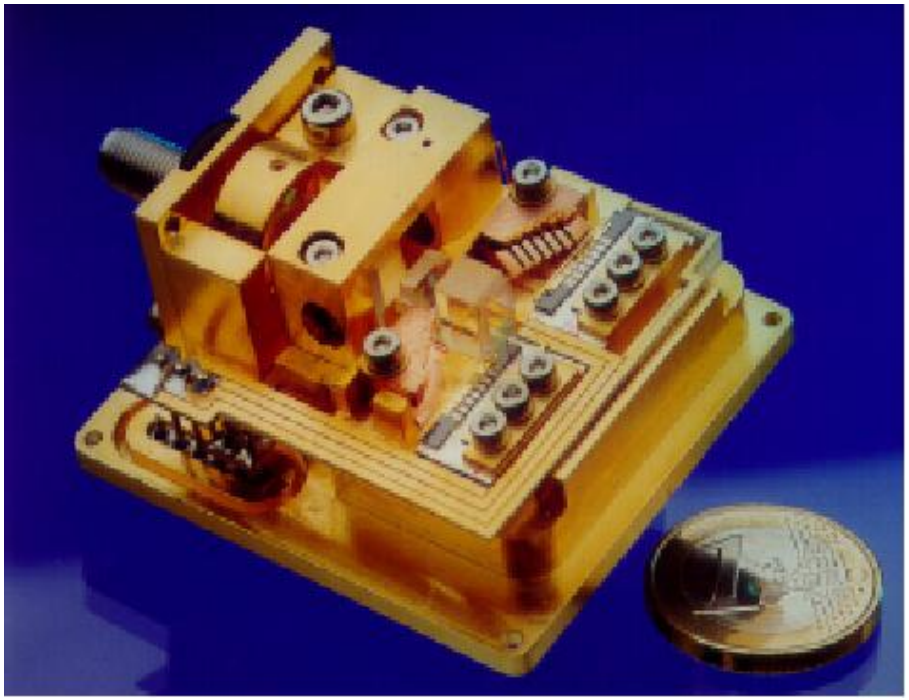


- High data rate,
  … still scalable !
- Small size and mass
- Link maintained
  with the sun
  in the field-of-view

©Tesat-Spacecom GmbH & Co.KG 2010

Homodyne BPSK: Reliable

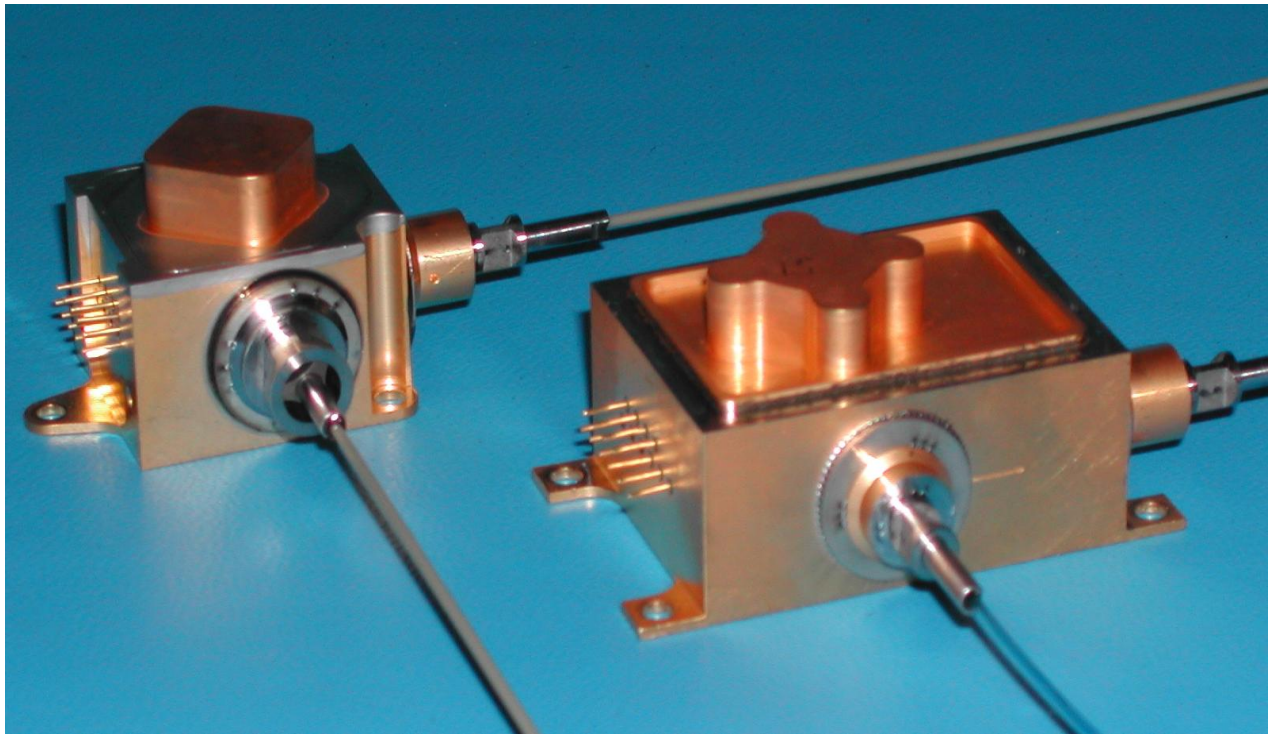
- Designed for lowest fit rate by laser diode redundancy
  - Hot: Laser diode bench
  - Cold: Redundant benches
- Pump Module Reliability > 0.999 in 15 years



©Tesat-Spacecom GmbH & Co.KG 2010

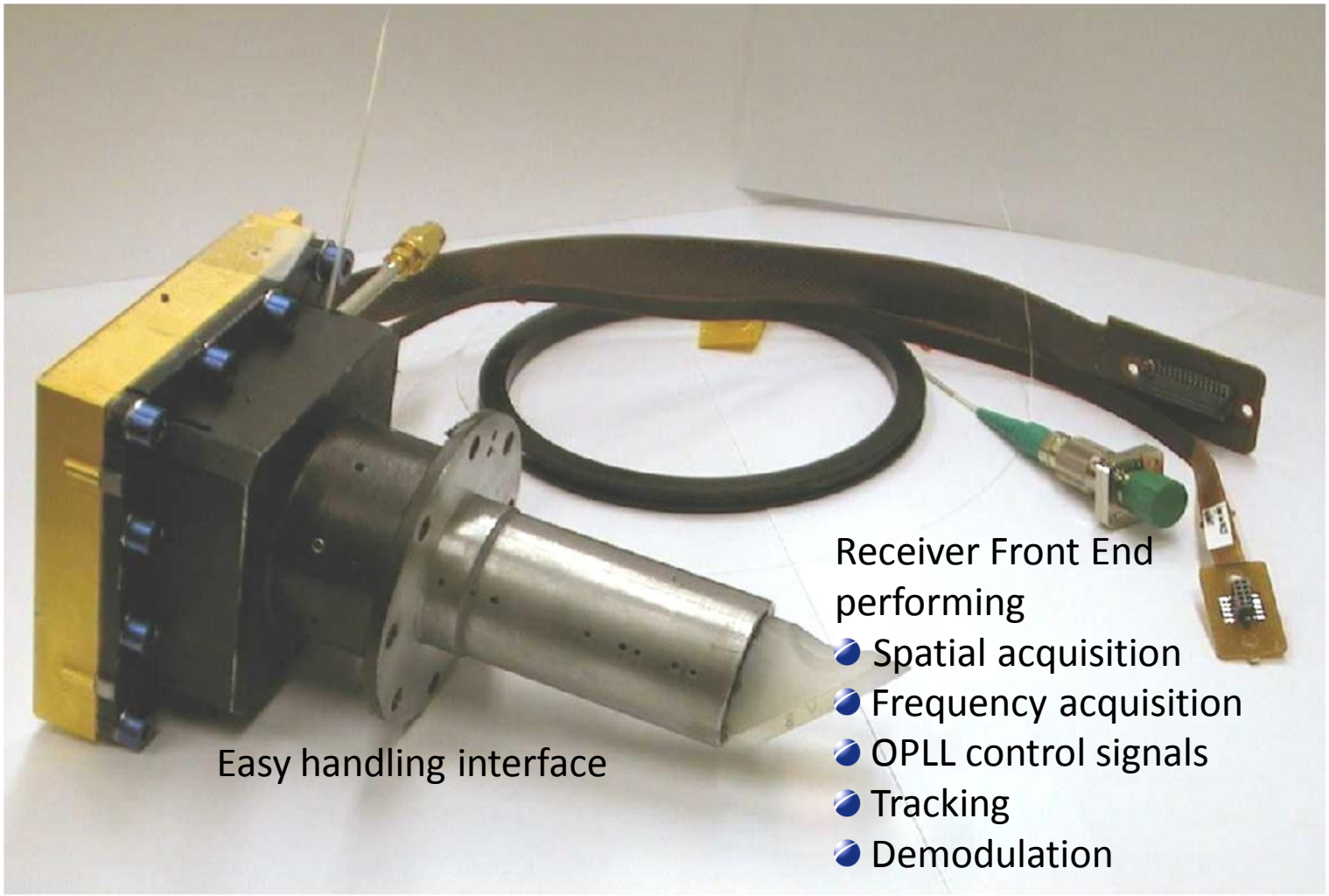
Homodyne BPSK: Robust

- Nd:YAG laser
  - Frequency stability ensured by MISER principle
  - Polarization maintaining mono-mode fiber coupled



©Tesat-Spacecom GmbH & Co.KG 2010

Homodyne BPSK: Handy



©Tesat-Spacecom GmbH & Co.KG 2010

Homodyne BPSK: Technology Readiness Level 9

- LCT operational in-orbit
- Verified as precise, reliable and robust, handy
- Extensive test and measurement campaigns
  have proven calculated link budgets to be very accurate

FM lasers delivered to ESA and U.S. customers

Heritage:

GIFTS, ALADIN, LISA, ATLID, several classified programs ...

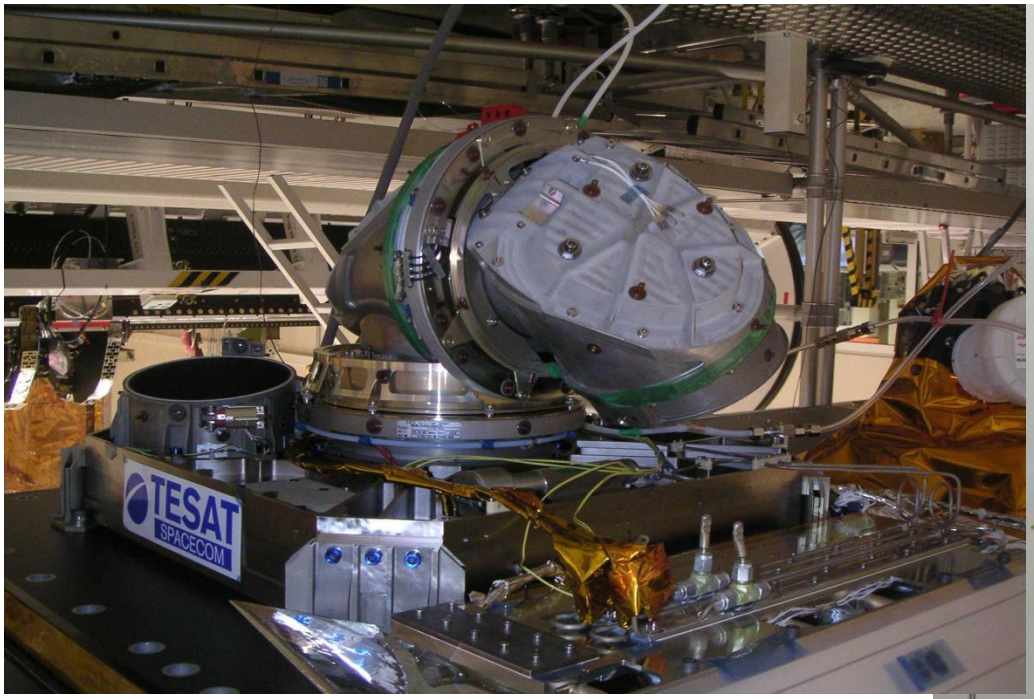
©Tesat-Spacecom GmbH & Co.KG 2010

Laser Communication Terminal: In-Orbit Verification

	LEO – LEO Links
Data Rate	5.625 Gbps
Range	Up to 5,100 km
Bit Error Rate	$< 10^{-8}$
Transmit Power	0.7 W
Telescope Diameter	125 mm
Mass	35 kg
Power Consumption	~ 120 W max.
Envelope	~ 0.5 x 0.5 x 0.6 m^3

©Tesat-Spacecom GmbH & Co.KG 2010

In-Orbit Verification: LCT Accommodated on TerraSAR



LCT integrated on TerraSAR-X (LEO satellite)
Launched June 14th 2007
Status: LCT fully operational

©Tesat-Spacecom GmbH & Co.KG 2010

In-Orbit Verification: LCT Accommodated on NFIRE

LCT integrated on NFIRE (U.S. LEO satellite)
Launched April 23rd 2007
Status: LCT fully operational

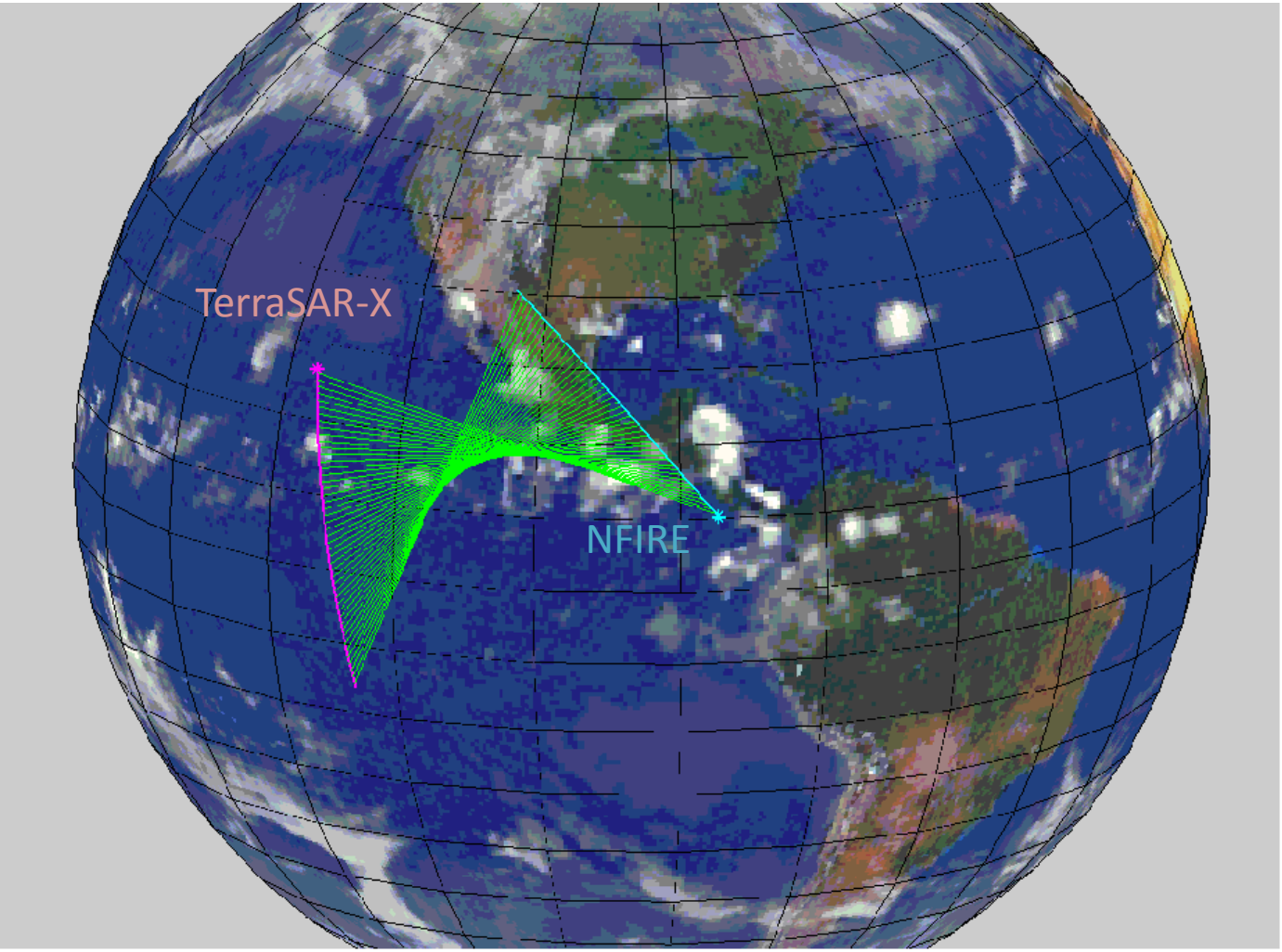
©Tesat-Spacecom GmbH & Co.KG 2010

In-Orbit Verification: Optical Ground Station (OGS)

- Mobile OGS in operation for NFIRE-TerraSAR X links
  - 6.5 cm Tx/Rx telescope
  - 500 mW Tx power
- More than 200 experiments performed by 2010
  - to verify coherent tracking and homodyne BPSK communication
- Advanced OGS with adaptive optics under development

©Tesat-Spacecom GmbH & Co.KG 2010

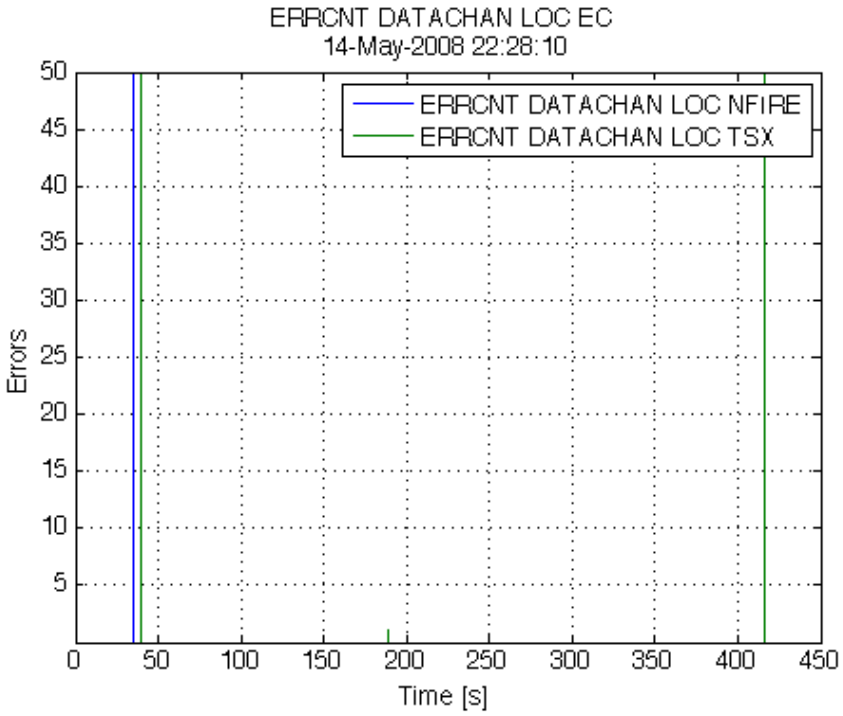
In-Orbit Verification: First Link dated Feb. 21st 2008



©Tesat-Spacecom GmbH & Co.KG 2010

In-Orbit Verification: Inter-Satellite Link

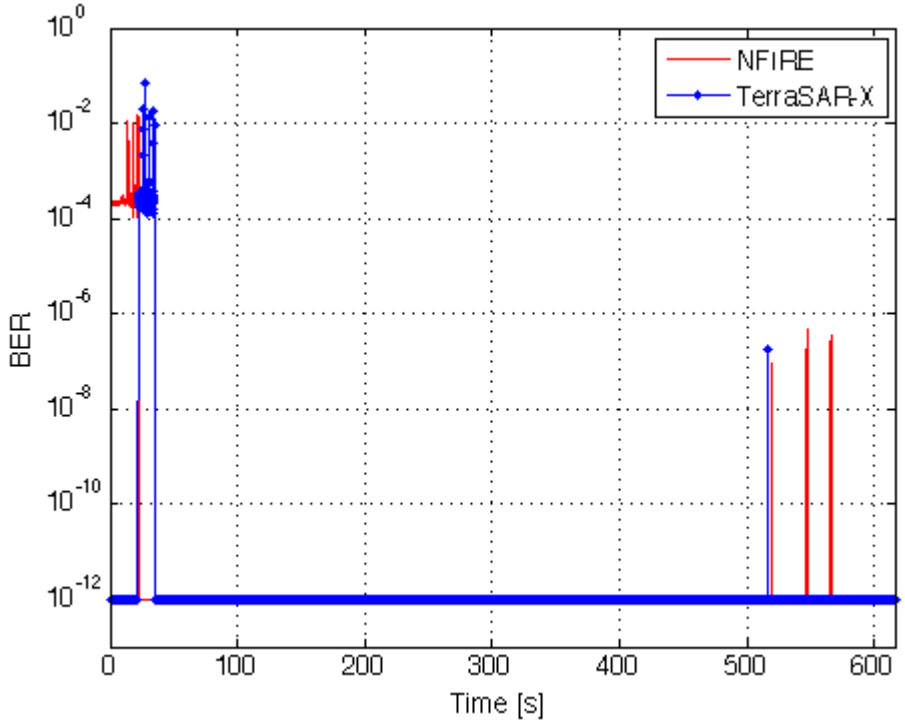
- Bit errors measured in one of the 25 data channels of 225 Mbps
- Only one bit error measured for one of the LCTs within 400 s
- Bit error rate better than 10^{-11}



 ©Tesat-Spacecom GmbH & Co.KG 2010

In-Orbit Verification: Inter-Satellite Link

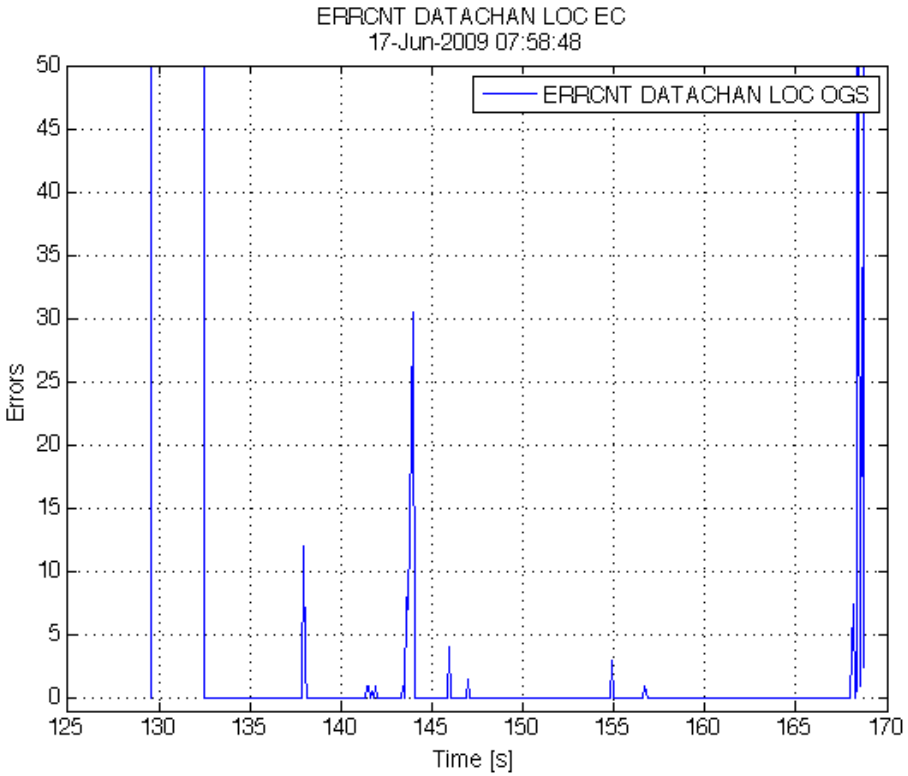
- After ~ 5 min the counter LCT vanishes below the horizon
- BER increases due atmospheric disturbance



©Tesat-Spacecom GmbH & Co.KG 2010

In-Orbit Verification: Space-to-Ground Link

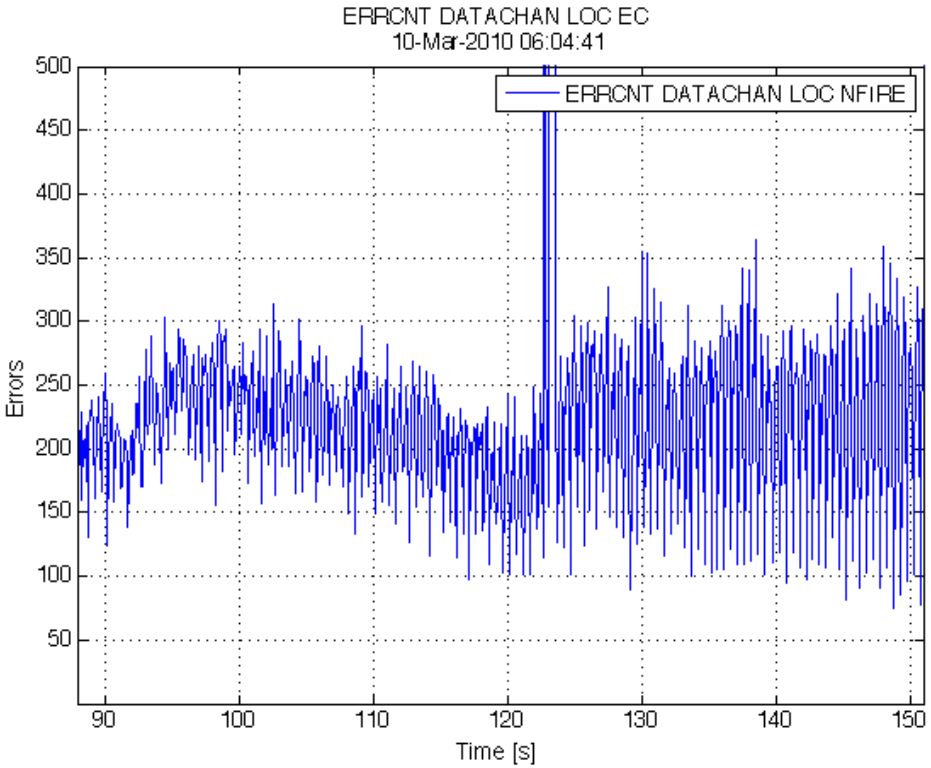
- Bit error rate still low, but increased due to atmospheric distortion
- Measurement campaign running to optimize OGS



©Tesat-Spacecom GmbH & Co.KG 2010

In-Orbit Verification: Ground-to-Space Link

- First link verified feasibility of high-data rate uplink (not yet optimized !)
- Communication at low bit error rates: better 10^{-5}
- Bit error rate increase due to atmospheric disturbance



©Tesat-Spacecom GmbH & Co.KG 2010

In-Orbit Verification: Results

- Spatial acquisition within seconds, depending on uncertainty cone
  - Spatial acquisition within 2 s !
- Frequency acquisition within less than 10 s
- Error-free communication in case of inter-satellite links without coding

- Homodyne BPSK well suited for ground links
  - Space-to-ground links demonstrated
  - Ground-to-space links demonstrated

- Reliable operation for more than 2 years in orbit

- **Link budget verified also optical GEO relay link performance**

©Tesat-Spacecom GmbH & Co.KG 2010

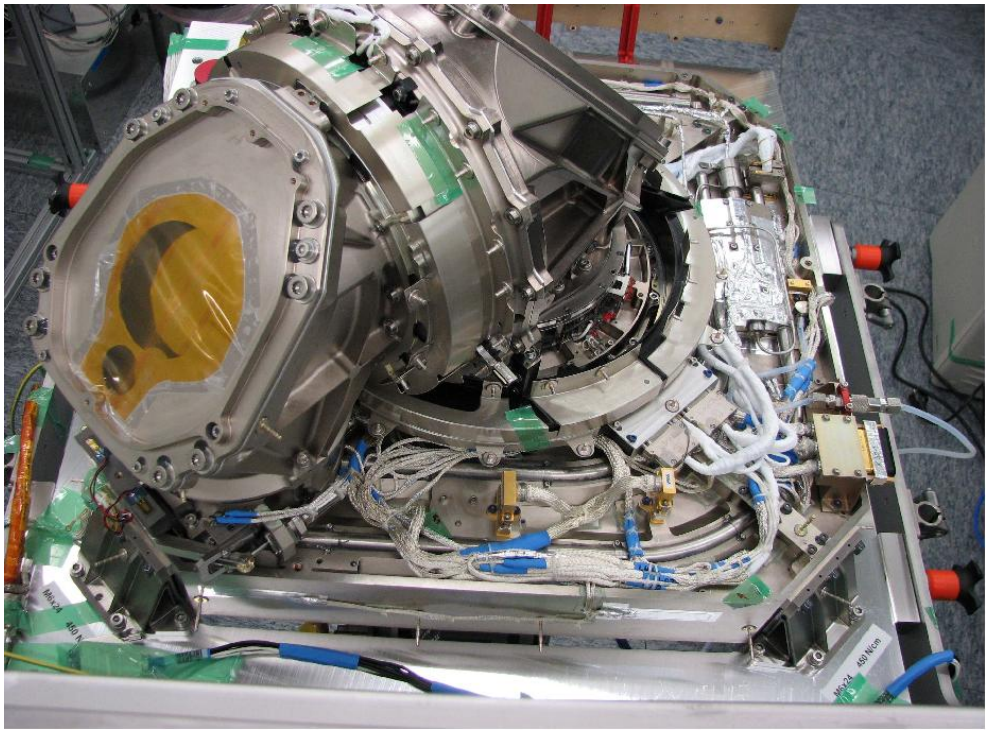
Laser Communication Terminal: Optical GEO Relay

	LEO – GEO – GEO Links
Data Rate	1.8 Gbps
Range	Up to 45,000 km
Bit Error Rate	$< 10^{-8}$
Transmit Power	2.2 W
Telescope Diameter	135 mm
Mass	50 kg
Power Consumption	~ 160 W max.
Envelope	~ 0.6 x 0.6 x 0.7 m^3

©Tesat-Spacecom GmbH & Co.KG 2010

Optical GEO-Relay: Running Programs

- LCTs on LEO satellites
  - Sentinel 1
  - Sentinel 2
- LCTs on GEO satellites
  - Alphasat
  - EDRS
- Ground station with adaptive optics



©Tesat-Spacecom GmbH & Co.KG 2010

Optical GEO-Relay: Optical Ground Stations (OGS)

- Advanced OGS (AOGS) with adaptive optics (AO)
  - AO concept successfully verified in ESA 1m-OGS at Tenerife
  - High speed InGaAs Hartmann-Shack Wavefront Sensor
  - Miniaturized 144 element deformable mirror based on MEMS technology
  - AO control loop bandwidth several kilohertz
- Compact transportable AOGS with 25 cm Telescope under development

OGS Tenerife: 1m telescope with adaptive optics

©Tesat-Spacecom GmbH & Co.KG 2010

Summary

- Performance
  - Acquisition time
  - Bit error rate

  well suited for commercial applications

- Homodyne BPSK verified as reliable and robust
- Laser communication terminals achieved TRL 9 by reliable operation for 3 years

Ready for GEO Relays

©Tesat-Spacecom GmbH & Co.KG 2010

Thank you very much for your attention !

For further information please contact:

Dr. Robert Lange

Tesat-Spacecom
Gerberstraße 49
71522 Backnang

robert.lange@tesat.de
+49 7191 930 1267

The LCT development and the in-orbit verification is supported by the German Space Agency DLR/BMWi under 50YH0202 and 50YH063

 ©Tesat-Spacecom GmbH & Co.KG 2010