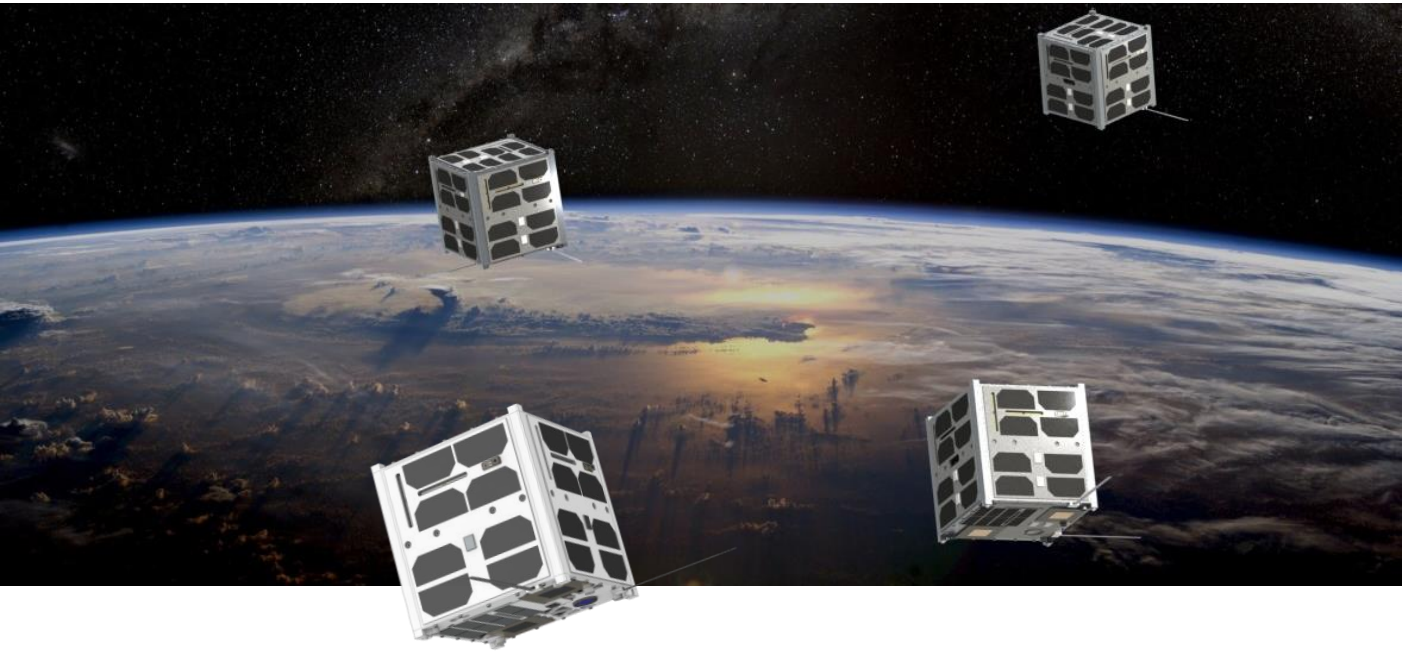


Technische Universität Berlin

Gefördert durch:

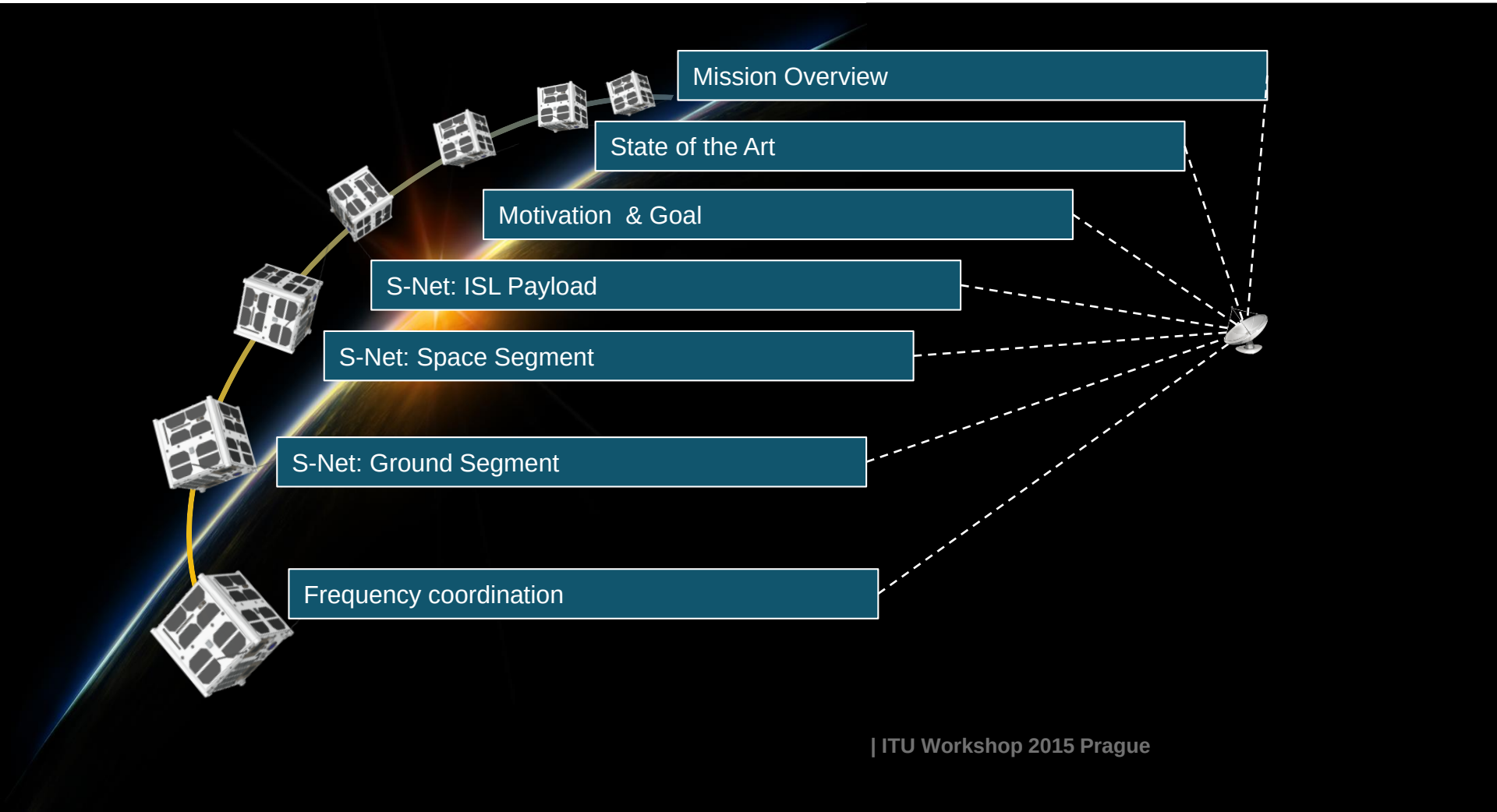
Bundesministerium für Wirtschaft und Technologie

aufgrund eines Beschlusses des Deutschen Bundestages

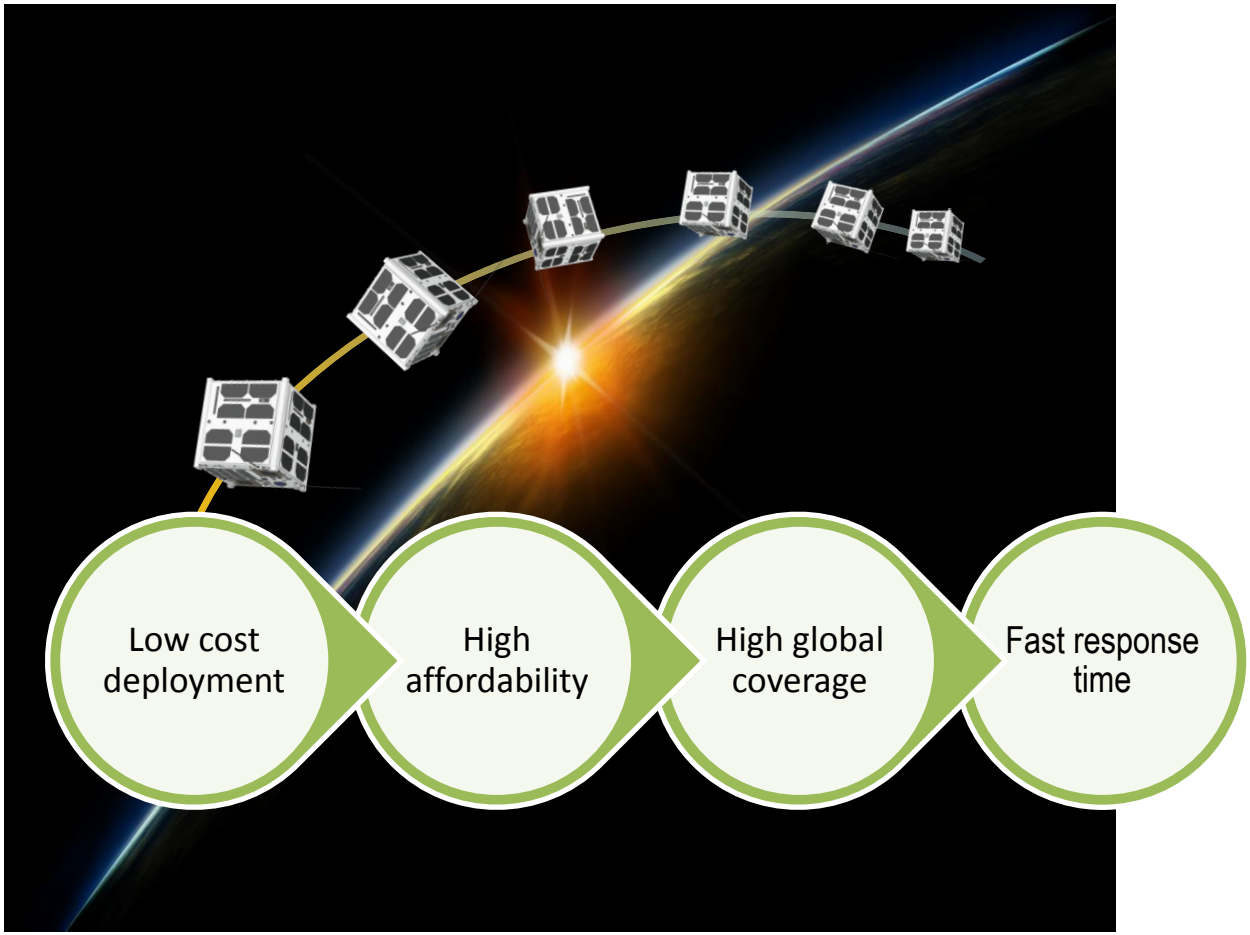
DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.
DLR FKZ: 50 YB 1225

System design of inter-satellite communication mission “S-NET”

Agenda


Mission Overview
State of the Art
Motivation & Goal
S-Net: ISL Payload
S-Net: Space Segment
S-Net: Ground Segment
Frequency coordination

Why Nanosatellite Network?



Real Time

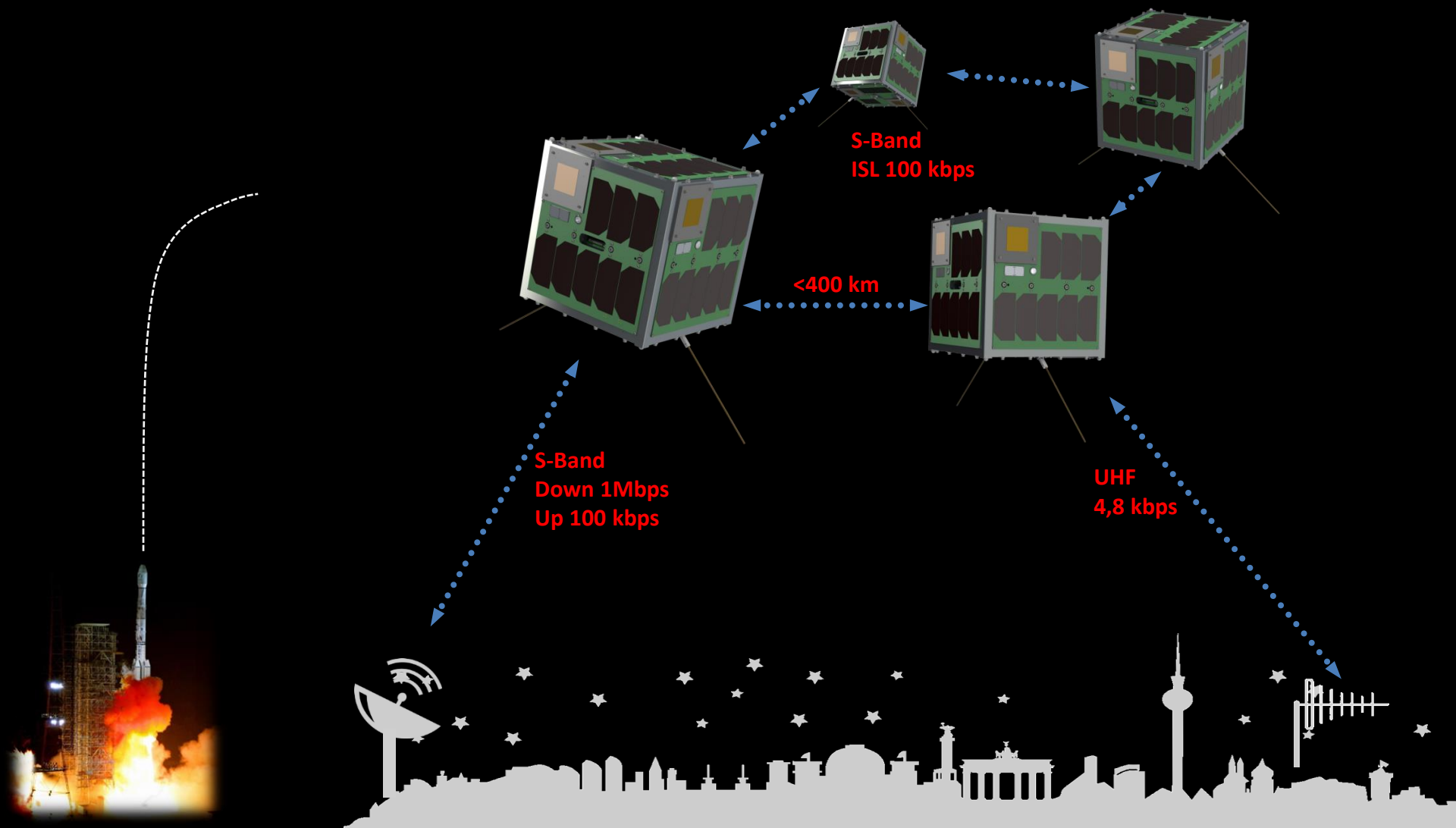
- Disaster Management
- Security Management
- Environmental Monitoring

Number of Satellites	4
Orbit height	< 650 km circular
Launch Date	Q3 2016 (TBC)
Design lifetime	1 year
Mass	< 8 kg (TBC)
Volume	250 x 250 x 250 mm3
TM/TC	UHF (nominal) S-band (experiment)
Payload	S-band transceiver (SLink) for ISL and up/downlink

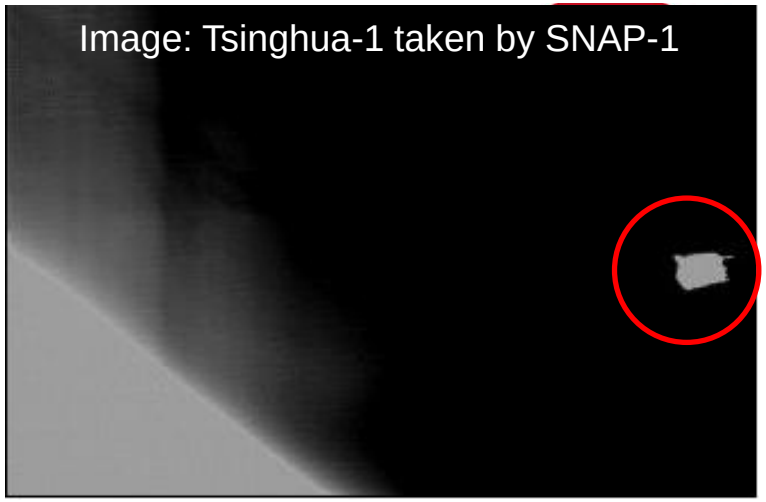
Launch <1day

Experiment in orbit > 4 month

De-orbit < 25 years



State-of-the-Art of ISL Missions



Mission	Satellites/ Mass	Architecture	Mission goal	Status
CanX 4&5	2, á 5 kg	LEO-formation	demonstration, ISL	Successful 2014
ION-F	3, á 15 kg	LEO-formation	demonstration, ISL, formation flight,	open
3CS	3, n/s	LEO-constellation	demonstration, ISL, formation flight,stereo imaging	Launch failure
FASTRAC	2, á 20 kg	n/s	demonstration, UHF-ISL	successful
SNAP-1	2, 6,5 kg & 49 kg	LEO-formation	rendezvous, remote inspection, UHF-ISL	successful

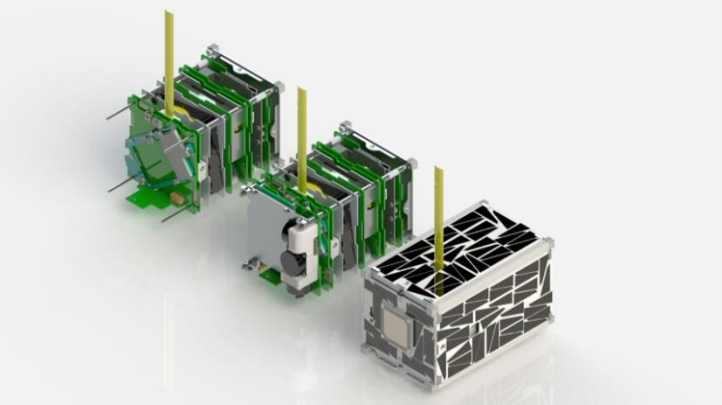
Edison Demonstration for SmallSats Networks (EDSN)

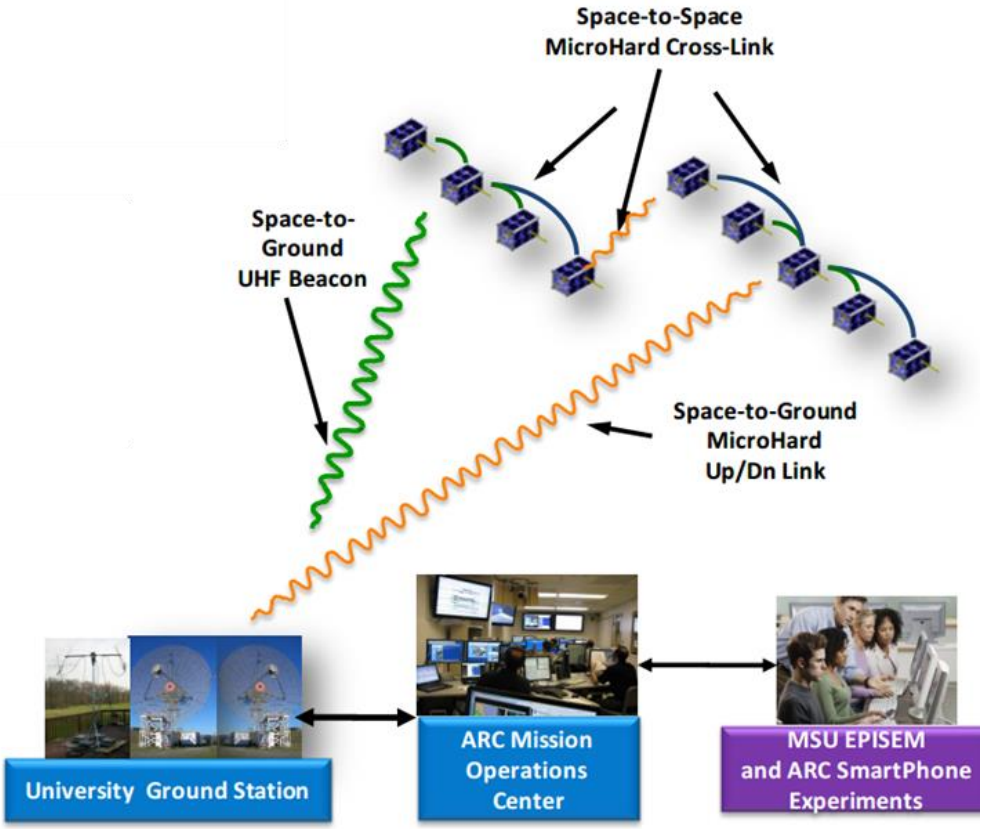
UHF link

- Swarm acquisition
- Crosslink for data consolidation

S-band link

- Distributed operation scheduling
- Downlink with designated relay satellites





MISSION S-NET

Mission S-NET

Mission Statement

- *Demonstration of inter satellite communication within a nanosatellite network*

Objectives

- demonstrate multipoint inter-satellite-link with S-band transceiver
- verify the newly developed / optimized ISL communication protocols (OSI level 3 and above)
- analyze the stability of a nanosatellite formation
- demonstrate the feasibility of nanosatellites as a base for demanding communication missions

Enabling Technology

HISPICO (2008)
highly integrated Sband transmitter for CubeSats

0,11 kg
Tx: 1 Mbps

SCOM (2010)
Sband transceiver for micro satellites

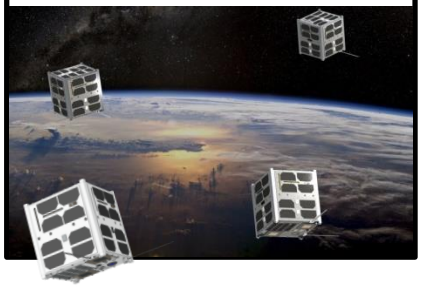
0,86 kg
Tx: 4 Mbps
Rx: 150 kbps

SLINK (2012)
Sband transceiver for ISL communication for nanosatellites

0,4 kg with enclosure
Tx: 1 Mbps
ISL: 100 kbps

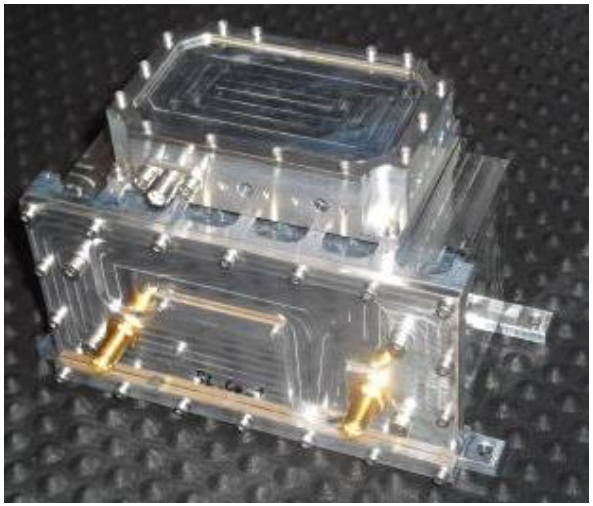
S-NET (2016)
Nanosatellite mission for ISL demonstration

4 nanosatellites in LEO

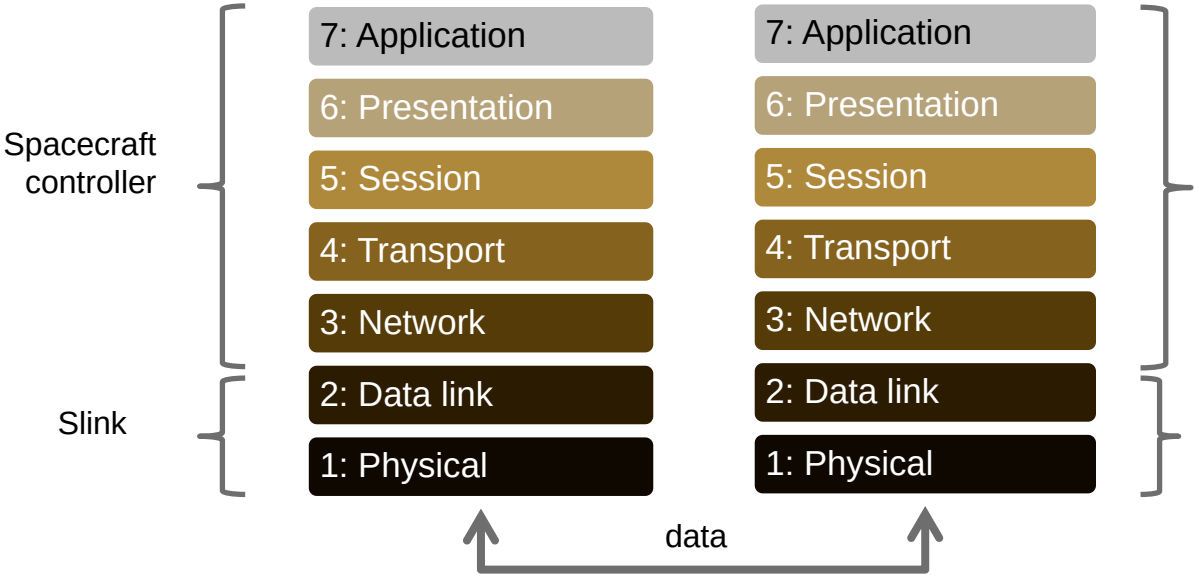


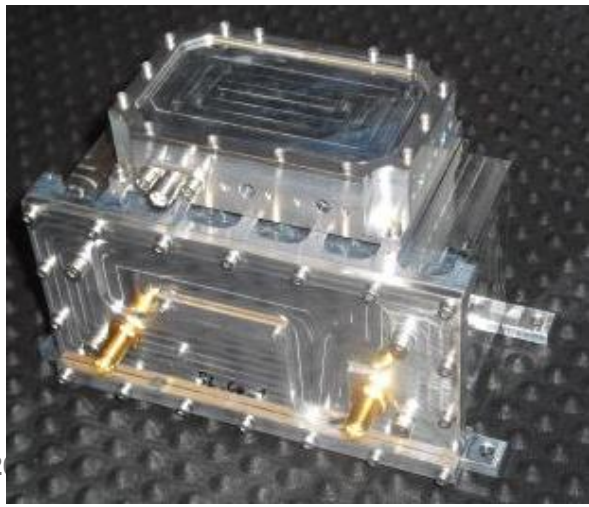
ISL Payload

Frequency	
ISL	2210.2 … 2269.8 MHz
DL	2212.0 … 2268.0 MHz
UL	2024.2 … 2109.8 MHz
Range	
UL / DL	≤ 2500 km
ISL	≤ 400 km
Data Rate	
Downlink	0.67 … 3.39 Mbps
Uplink	30 … 270 kbps
ISL	27.5 ... 169 kbps
SNR	8 dB
Modulation	BPSK,DQPSK, ADPSK16,DPSK8
Coding	TURBO code, Convolutional code/Viterbi
RF output	≥ 0.5 W
Power	≤ 10 W
Mass	0.174 kg w.o. case 0.4 kg w. case
Interface	SPI, UART (RS-422)



ISL Payload Layer

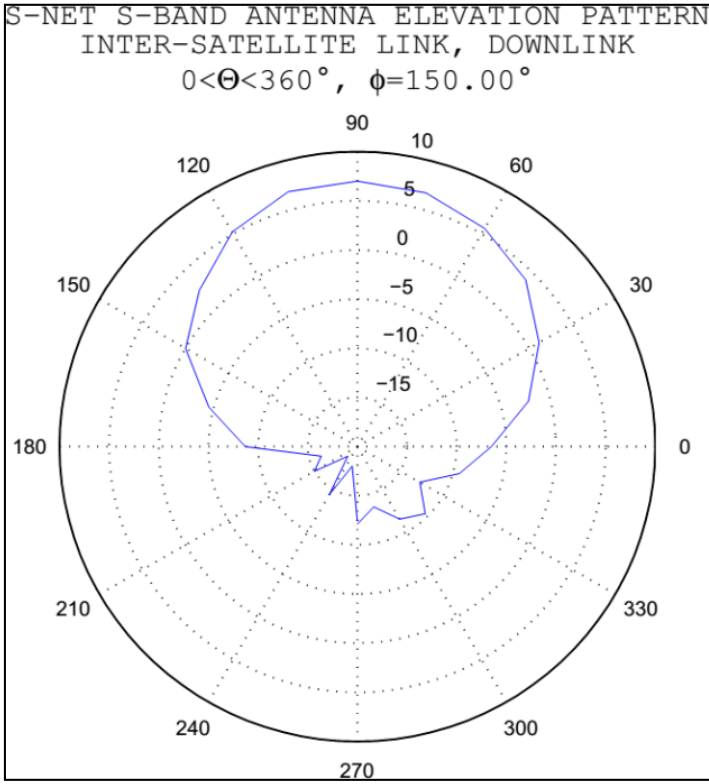




Link budget ISL (AWGN)

- Symbol rate: 80 kBaud
- Tx Power: 28,0 dBm
- Antenna gain – lost (CALLER): 4,5 dBi
- EIRP: 2,5 dBW
- Free space lost: 151,6 dB (@ 400 km)
- Additional lost: 1 dB
- Antenna gain – lost (RESPONDER): 4,5 dBi
- System Noise Figure: 3,0 dB
- C/N required (BPSK + r=0,5): 4 dB
- C/N required (QPSK + r=0,5): 6 dB

- Margin; 400 km & DBPSK+0,5=2,4 (bit rate ca. 32 kbps)
- Margin: 400 km & DBPSK+0,75=0,4 (bit rate ca. 50 kbps)
- Margin: 100 km & 8ADPSK+0,75=3,4 (bit rate ca. 144 kbps)



Operational Scenarios

Network topology is determined by

- Orbital configuration
- Availabe ressources of the nodes
- Desired QoS
- Network operating mode

Access via competition

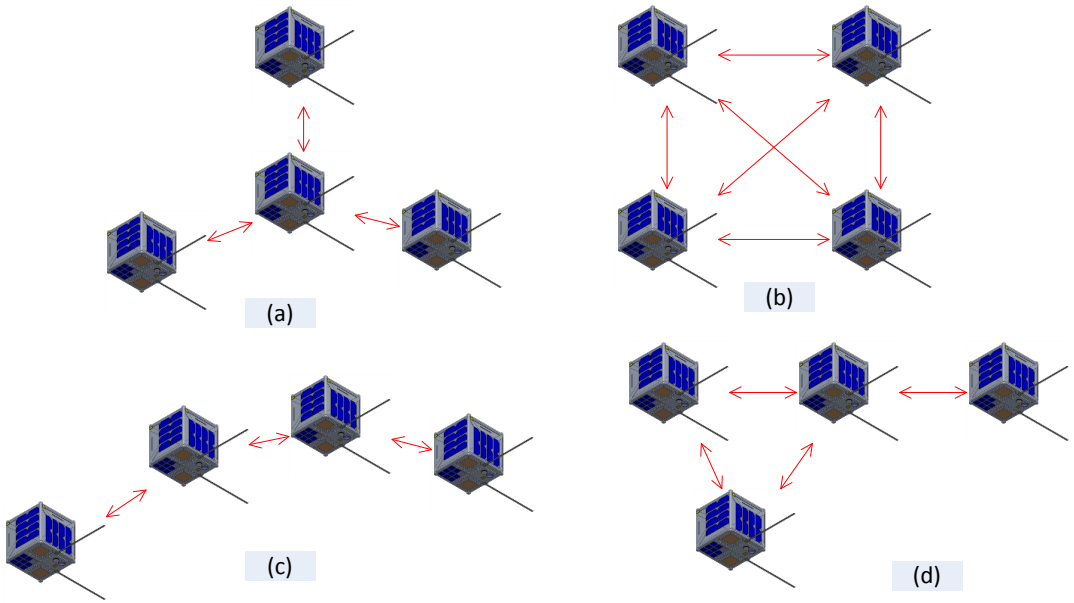
- ALOHA protocol

Access via allocation

- Token passing (decentralized)
- Polling (centralized)

Access via reservation

- TDMA

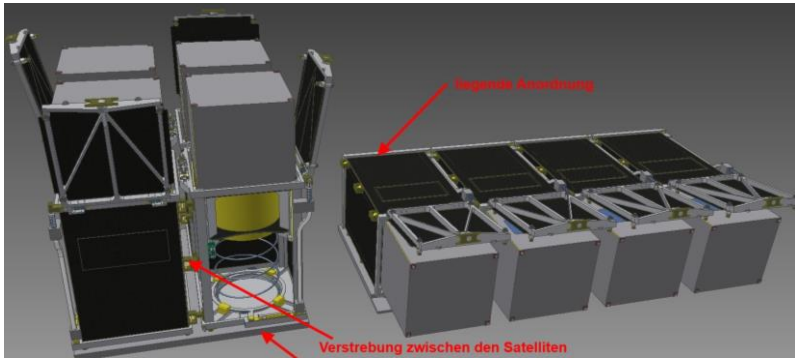


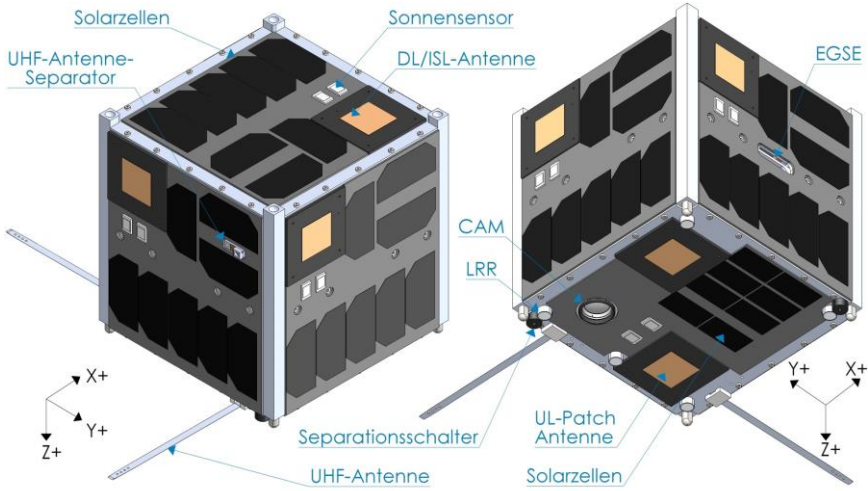
Satellite Bus TUBiX10

TUBiX10 (**TU B**erlin **i**nnovative ne**X**t generation satellite bus)

- For satellites up to 10 kg launch mass
- High level of component integration
- Separation from upper stage by a container system
- Cubic shape with 24cm edge length
- COTS hardware
- Single failure tolerance on component level

Parameter	Value
Payload capacity	<4 kg
Bus power generation	5.6 W
Payload power (average)	< 1.5 W
UHF-data rate	4.8 kbps
S-Band-data rate (optional)	1 Mbps
Attitude knowledge (coarse)	± 5 degree
Pointing accuracy (coarse)	± 10 degree
Life time	> 1 year





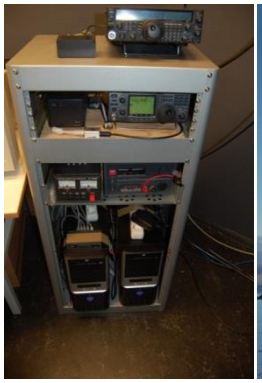
Ground Segment

UHF station

- Standard TMTC
- (432…438 MHz) – Amateuer radio freq
- Pointing antenna with approx. 14 dBi
- Datarate 4.8 kbps (tbc) brutto (UL & DL)
- Paketbased protokol, GMSK
- since 2005 (Berlin), 2006 (Spitzbergen)

S-Band station

- Experiment, S/W-Updates, Images
- 3 m antenna
- Developed for operation of TUBSAT series
- SGP4-based tracking
- Signal strength tracking under development



Frequency Coordination

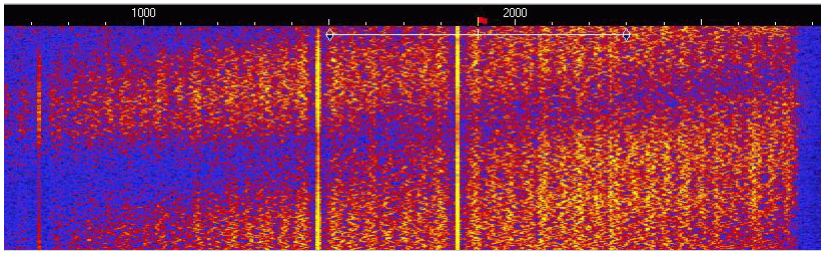
- **Coordination via DLR Space Administration**
- **Every satellite uses same frequency**

- **S-Band (+/- 20 °)**
  - **Class: ET** (Space station in the space operation service)
  - **ILS / DL:** 2262,4 - 2263,5 MHz
  - **UL:** 2081,1 - 2081,3 MHz
  - **Ground Station:** TUB, NSG

- **UHF (omni directional)**
  - **Class: EA** (Amateur satellite service)
  - **DL & UL:** 435,9 – 436 MHz
  - **Ground Station:** TUB, Svalbard, DESK

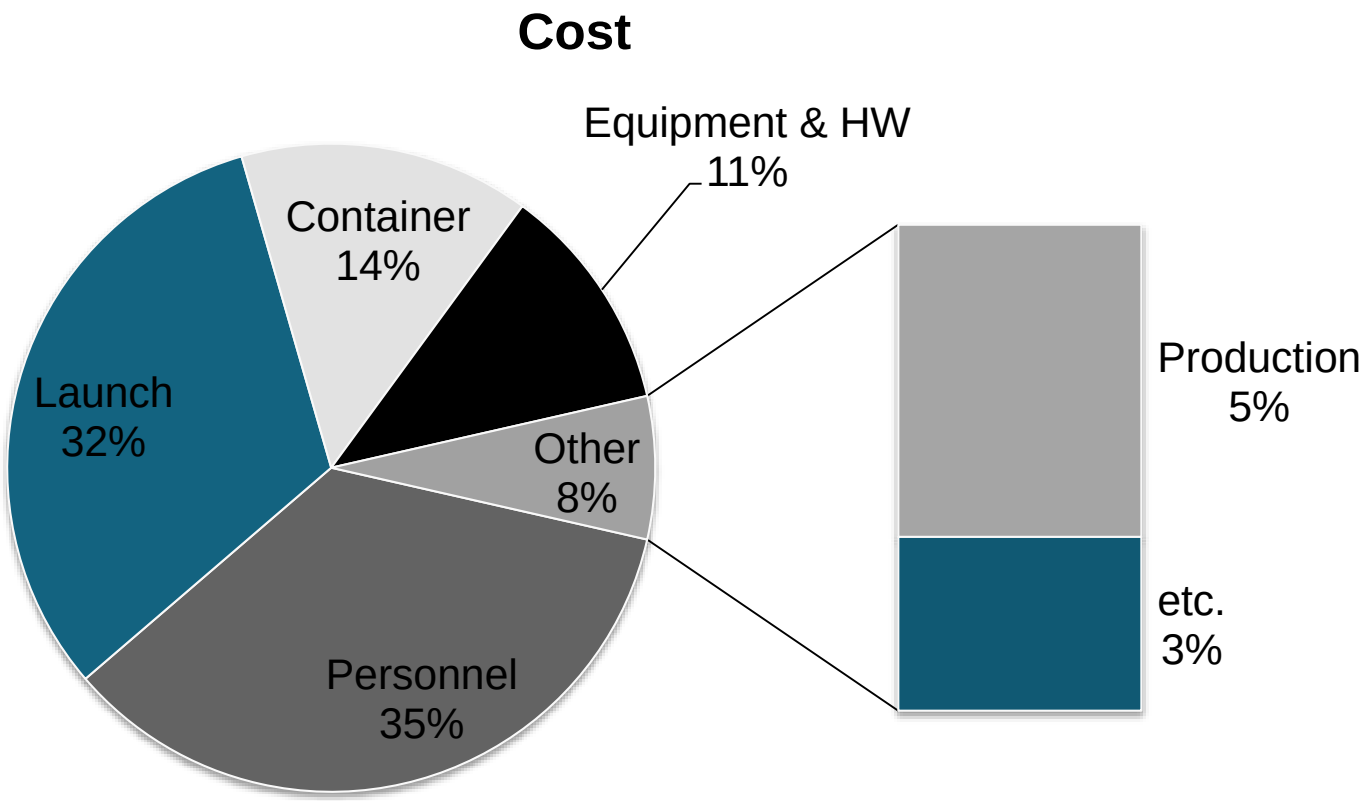
Symbol	Space Station - Class of Station
ED	Space telecommand space station
EH	Space research space station
EK	Space tracking space station
EM	Space station in the meteorological-satellite service
ER	Space telemetering space station
ES	Station in the inter-satellite service
ET	Space station in the space operation service
EU	Space station in the land mobile-satellite service
EW	Space station in the earth exploration-satellite service

Frequency Coordination



- **Issues:** Guess of orbit altitude & inclination
- **Status:** processing of API by ITU BR
- **Next:**
  - IARU
  - Expected notification 2015 Q3 (prior to launch 2016 Q3)

Budget


Cost
Equipment & HW
11%
Container
14%
Launch
32%
Other
8%
Personnel
35%
Production
5%
etc.
3%

Summary and Outlook

Communication technology is the key to push the potential of nano satellites

S-Net is first nano satellite mission to demonstrate

- Multi point to multi point protocol
- High data rates in S-Band up to 100 kbps
- Communication range up to 400 km

Challenges

- Difficulty in launch coordination of multiple piggy back satellites with strict separation requirements

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in der Helmholtz-Gemeinschaft

DLR Fkz: 50 YB 1225

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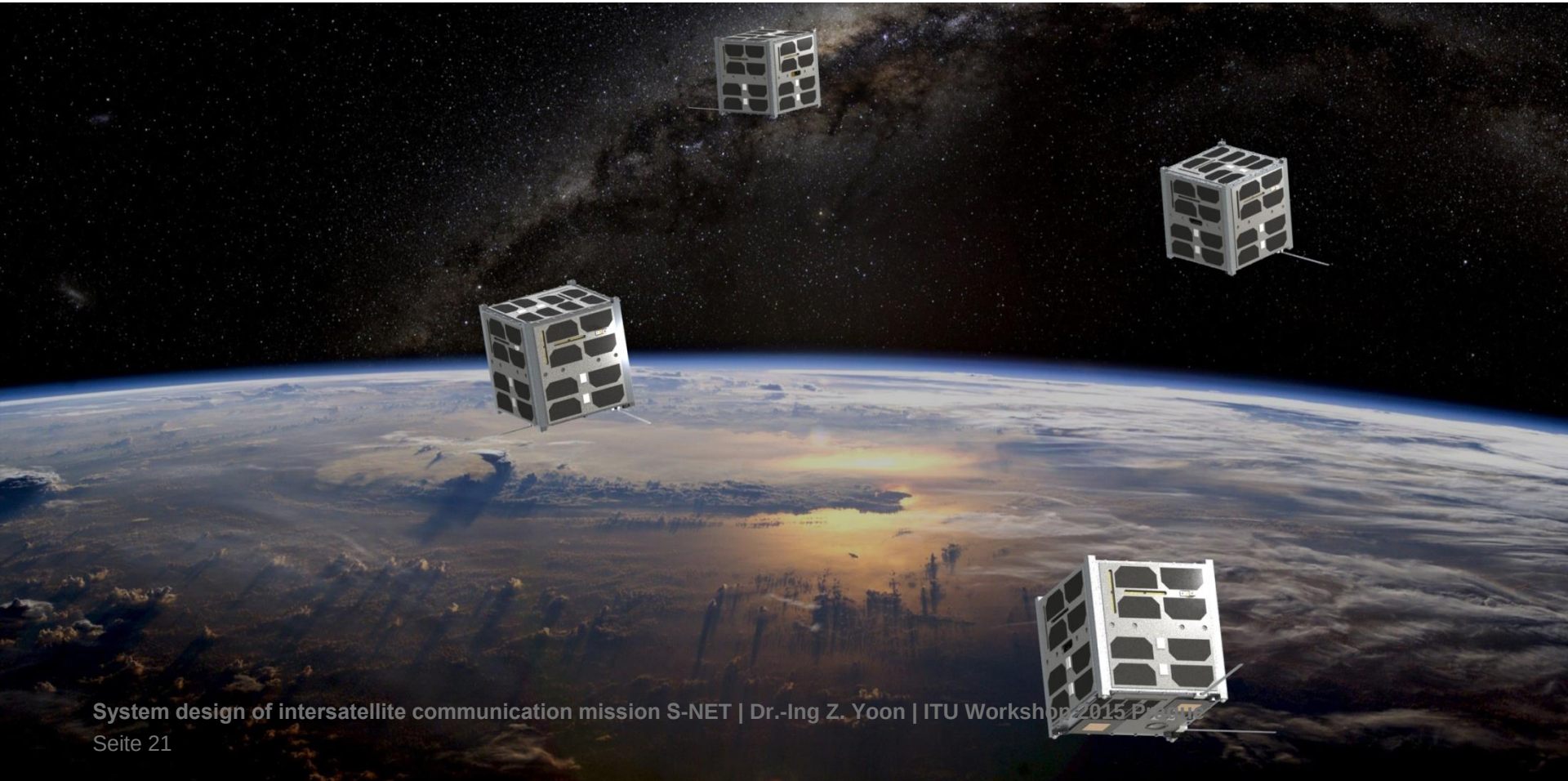

Technische Parameter des Funksystems: ISL

Funktion / Parameter	Wert	Einheit	Kommentar
Frequenzband Empfänger	2210.2...2269.8	MHz	Zenterfrequenz
Datenrate Empfänger	100	kbps	
Frequenzband Sender	2210.2...2269.8	MHz	Zenterfrequenz
Datenrate Sender	100	kbps	
Benötigte HF-Bandbreite	120	kHz	
Frequenzraster Sender	100	kHz	
Bandbreite des	120	kHz	-3 dB
ausgestrahlten Signals	tbd	kHz	-20 dB
	tbd	kHz	-50 dB
HF-Leistung	-3.00	dBW	
Modulation	BPSK, QPSK	–	
	DPSK8 ADPSK16		
Frequenzstabilität Sender	±3	ppm	ohne Crystal-Alterung, ohne Dopplerverschiebung
Empfängertyp	Heterodyne		

ISL Payload Parameter

Frequenzraster Empfänger	100	kHz	
Sensitivitätsschwelle	-100	dBm	tbc
SNR	8	dB	tbc
Interferenztyp	AWGN	–	
Bandbreite Empfänger	60	MHz	-3 dB tbc
	160	MHz	-30 dB tbc
Frequenzprozessierung	PLL	–	
Zwischenfrequenz (IF)	70	MHz	
Bandbreite IF	1.75	MHz	-3 dB tbc
	2.90	MHz	-40 dB tbc
Frequenzstabilität Empfänger	±3	ppm	ohne Crystal-Alterung, ohne Dopplerverschiebung
Coderate	0.50 , 0.75	-	
Symbolrate	80.00	ksps	
Datenrate hin	27.50 . . . 169.00	kbps	Caller-Responder
Datenrate zurück	4.90 . . . 33.40	kbps	Responder-Caller