Cube-Sats in der Schweiz

Satelliten Grundlagen
Projekte in HB9
Demonstration eines CubeSat-Simulators

Restaurant Rössli, Rössligasse 7, 8405 Winterthur, 3. Mai 2023

Ein Vortrag für HB9W von Martin Klaper, HB9ARK

Inhalt

1. Cube-Sat Basics (Satellitenarten, Grundbegriffe, Kepler, Doppler, Bahnparameter, …)

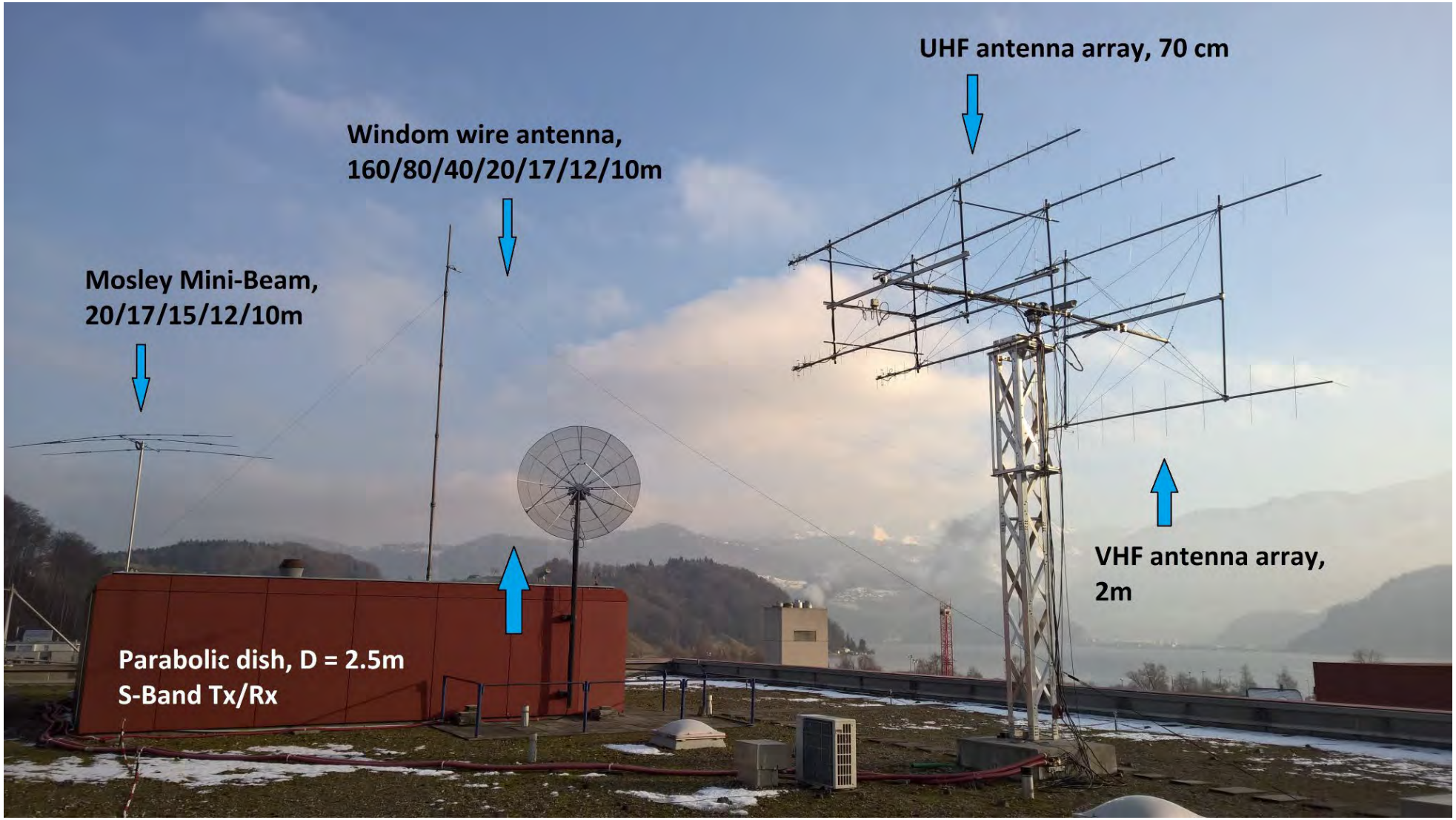
2. Cube-Sat Projekte in HB9:

SwissCube, (CHESS), Astrocast, ARIS SAGE

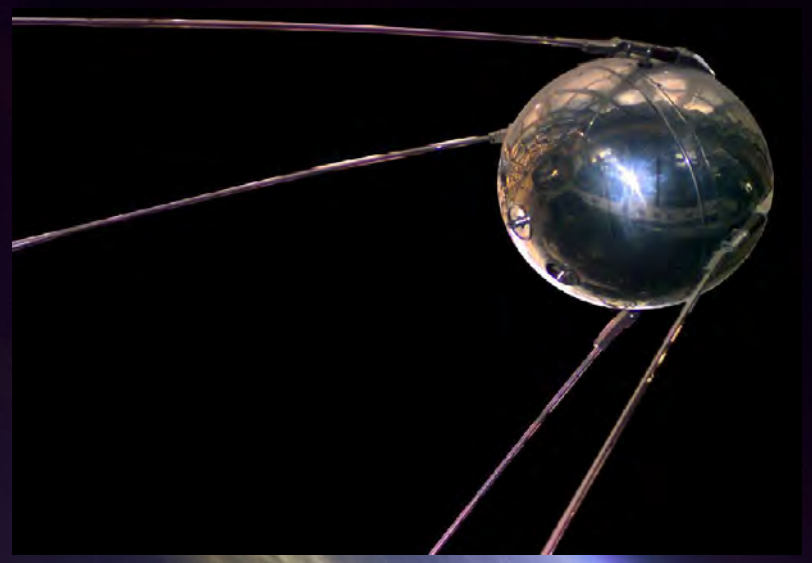
3. Demo eines CubeSat Demonstrators

Q&A

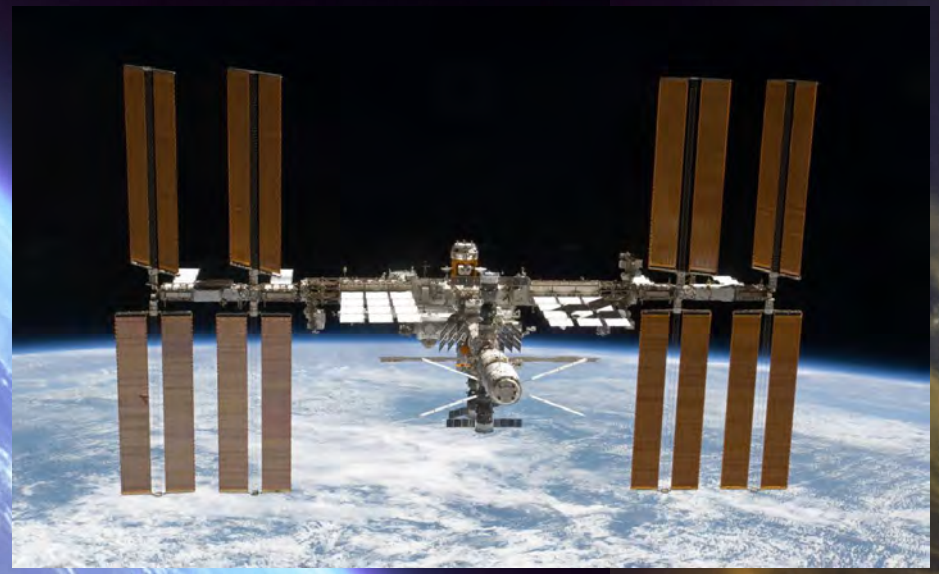
Zur Einstimmung: Mehrzweck Antennenanlage

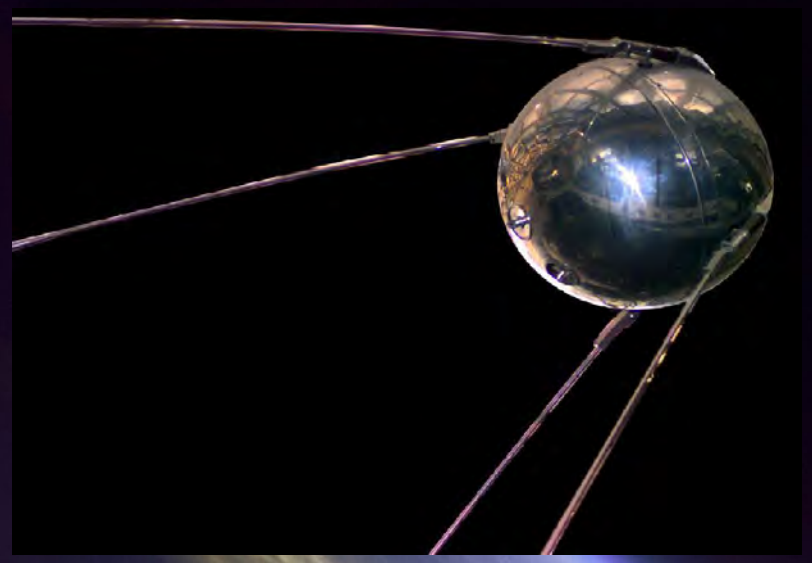


T- 00:00:17
UPCOMING
LIFTOFF
STARTUP
THE FALCON 9 FLIGHT COMPUTERS HAVE TAKEN CONTROL OF THE COUNTDOWN
SPACEFLIGHT SSO-A
STARTUP
LIFTOFF
MECO
SES-1
BOOSTBACK BURN
ENTRY BURN
LANDING BURN
LANDING
SECO-1
SPACEX



Können Sie diese Satelliten benennen?



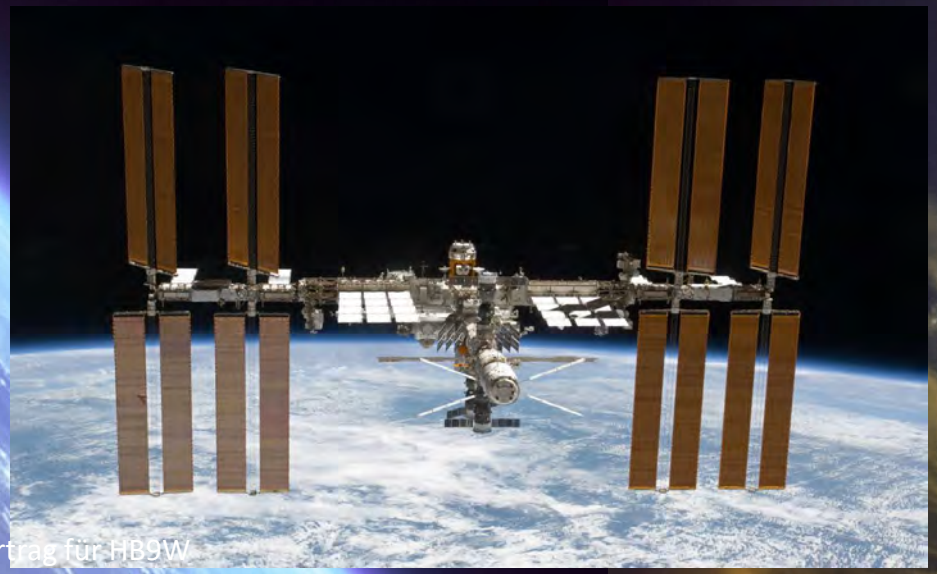


Sputnik

- Der erste von Menschen gebaute Satellit
- Wurde 1957 von der UdSSR gestartet
- Masse 84kg, Durchmesser 53cm

The Hubble Space Telescope

The International Space Station



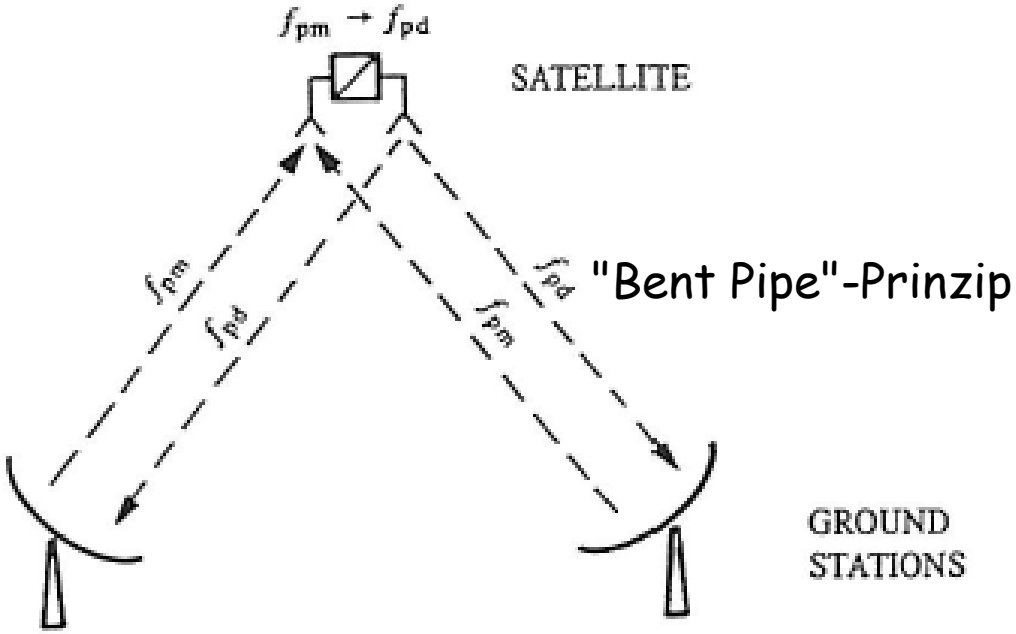
Jetzt gibt es Hunderte von Satelliten in der Umlaufbahn um die Erde während andere Satelliten das Sonnensystem erforschen.

Und einige dieser Satelliten stehen uns Funkamateuren zur Verfügung.

Satelliten Impressionen

GPS Navstar

Frdfunkstelle Raisting



"Bent Pipe"-Prinzip

Einsatzgebiete für Satelliten

- Erdbeobachtungssatelliten
  - Wettersatelliten
  - Spionagesatelliten
  - Radarsatelliten
- Nachrichtensatelliten
  - für kommerzielle Aufgaben
  - u. a. Inmarsat, Iridium, Thuraia
  - für experimentelle Aufgaben: **Amateurfunksatelliten**
- Fernsehsatelliten
  - Astra, Eutelsat
  - Es’hail-2 Sat
  - …
- Astronomiesatelliten für wissenschaftliche Zwecke
- Killersatelliten um feindliche Satelliten zu zerstören.
- **Forschungssatelliten**, z. B. für Mikrogravitationsexperimente
- Raumstationen für wissenschaftliche Zwecke
- Navigationssatelliten
  - GPS (USA, seit 1995)
  - Glonass (Russland, seit 1993)
  - Galileo (EU, ab 2014)

Basics

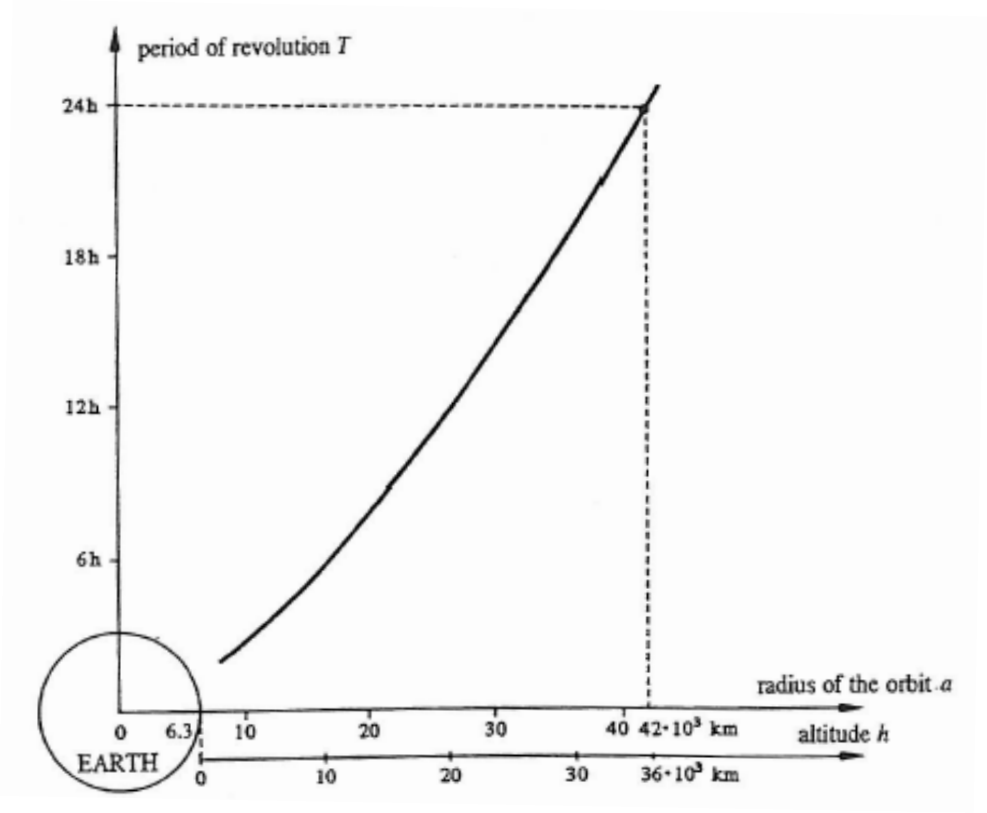
Verschiedene Satellitenbahnen

- Geostationary Earth Orbiter (**GEO**)
  - Abstand von ca. 36‘000 km von der Erde.
  - "aufgehängt" an einer festen Position über der Äquatorlinie.
  - Der Sender und Empfänger auf der Erde kann dauerhaft auf den Satelliten ausgerichtet werden.

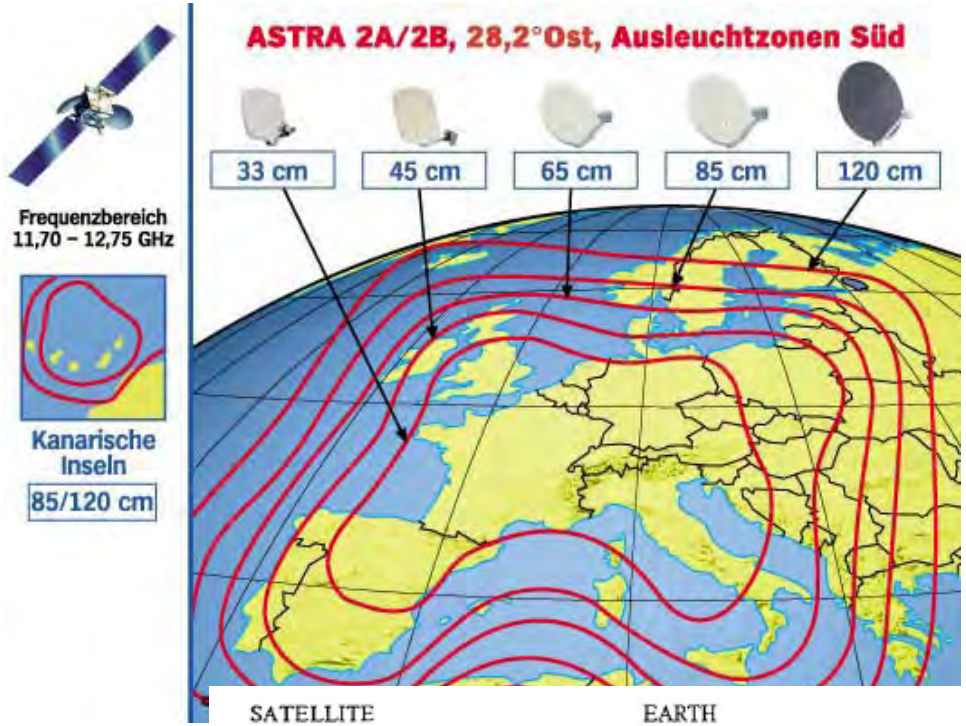
- Medium Earth Orbiter (**MEO**)
  - Erdumlaufende Systeme.
  - Flughöhe zwischen 10‘000 km und 15‘000 km.

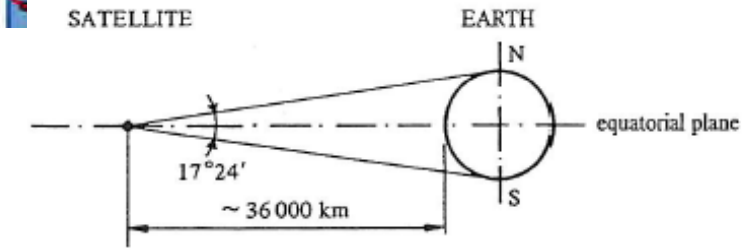
- Low Earth Orbiter (**LEO**)
  - Erdumlaufende Systeme.
  - Flughöhe zwischen 700 km und 1‘500 km

Umlaufzeiten / Geostationäre Satellitenbahn



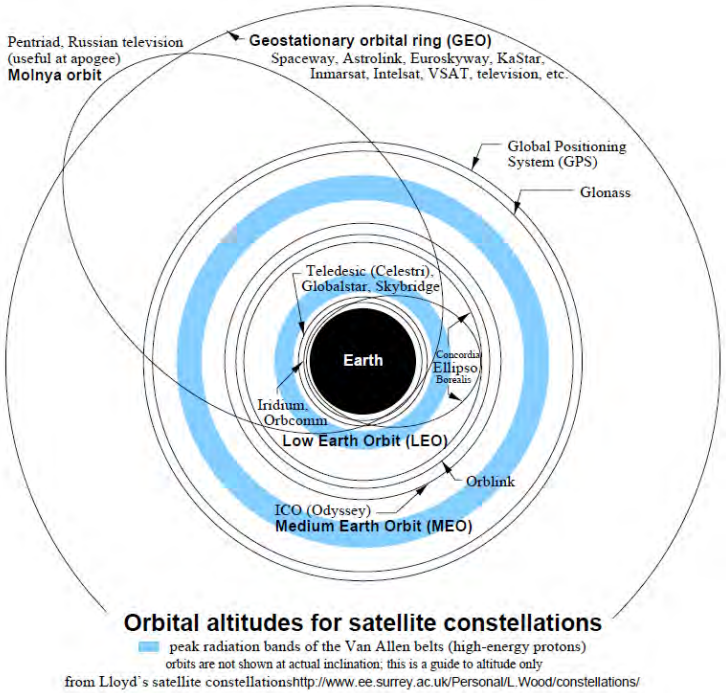
Pierre-Girard Fontolliet, Telecommunication Systems





Apparent diameter of the earth as seen from a satellite.

Berechnung von Satellitenbahnen



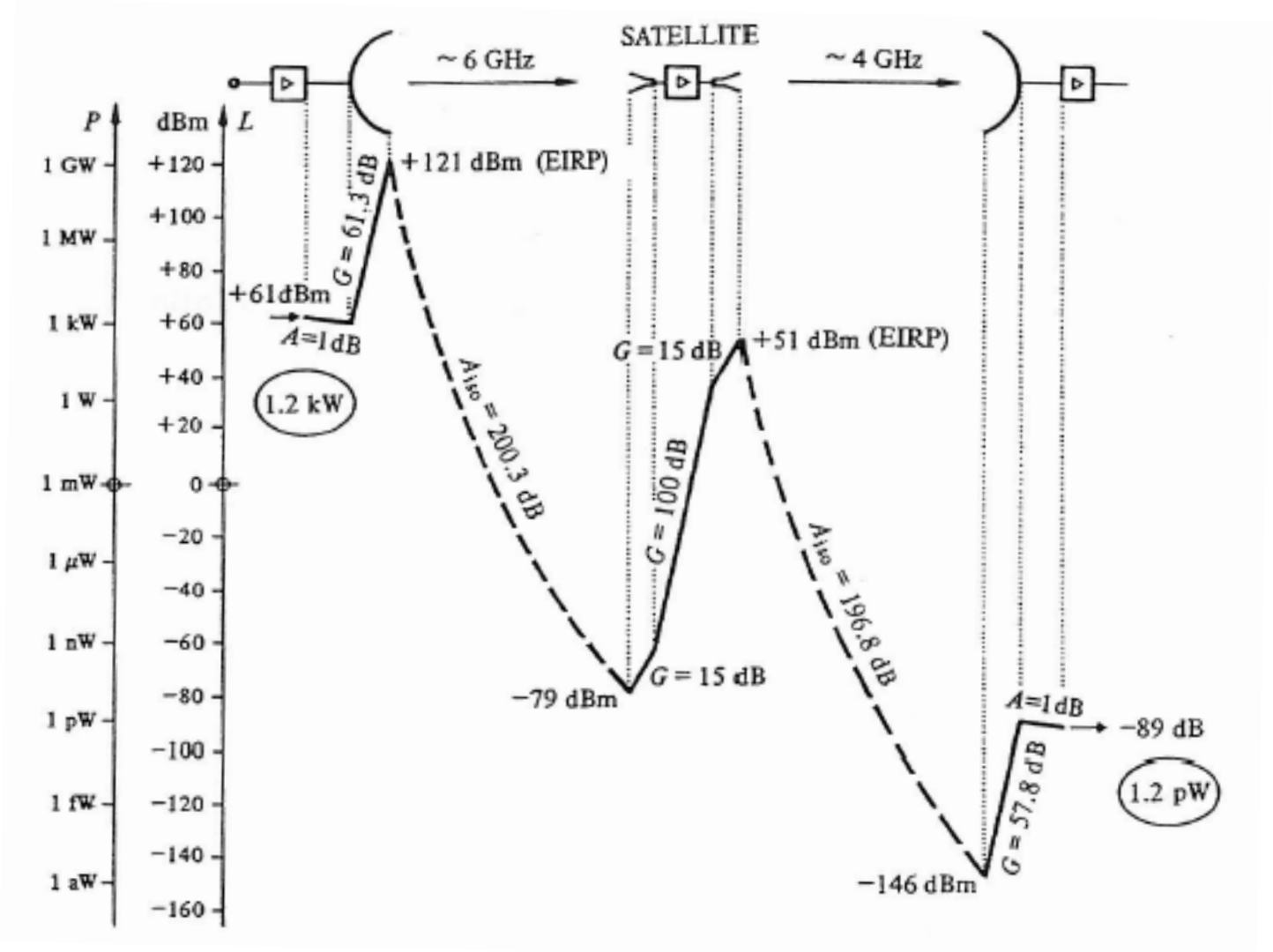
Drei **Kepler'sche Gesetze** beschreiben die Bewegung:

1. Satelliten bewegen sich auf **Ellipsen**.
   In einem Brennpunkt ist das Zentralgestirn.

2. In **gleichen Zeiten** werden **gleiche Flächen** überstrichen.

3. Die **Quadrate** der **Umlaufzeiten** zweier Trabanten sind **proportional** zu den **dritten Potenzen** der grossen **Halbachsen**.

Link Budget, Zahlenbeispiel



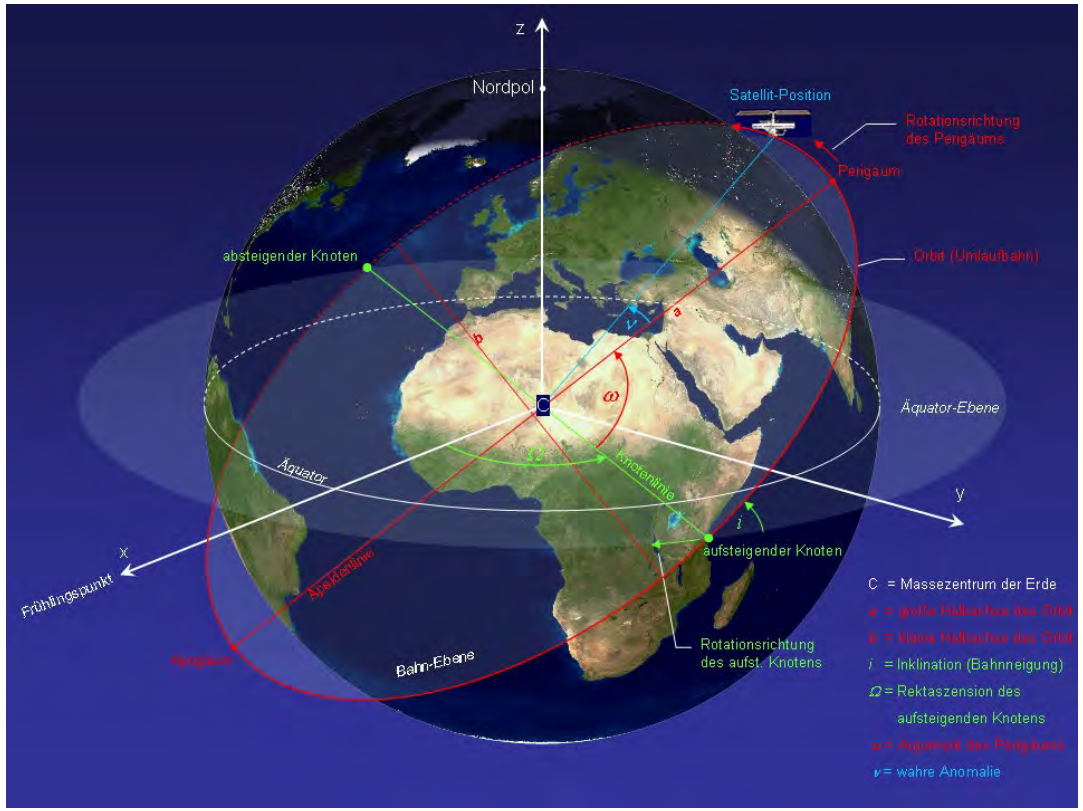
"Ideales" Downlink Budget für AFU-Sat

Downlink Budget Analysis , f = 437 MHz, data rate = 9600 bps		
Transmit Power P_{Tx}	**(1 Watt)**	+30 dBm
Connector-, Cable- and Impedance-Loss (L_{con} , L_{cab} , L_{imp})		-2.0 dB
Antenna Gain G_{Tx} (ideal Monopole)		+5.1 dBi
Friis Formula (R_S = 1815 km, h_{Orbit} = 550 km, δ = 10°)		-150.4 dB
Atmospheric & Ionospheric Losses (L_{atm} , L_{ion}) [1]		-0.2 dB
Antenna Gain G_{Rx}		+24 dBi
Polarisation Loss (L_{pol})		-3 dB
Connector-, Cable- and Impedance-Loss (L_{con} , L_{cab} , L_{imp})		-5.0 dB
Power at Receiver P_{Rx}	**(~0.15 pico Watt) S4-S5**	**-101.5 dBm**
Receiver Sensitivity (TS2000, S/N=16 dB)		-120.2 dBm
Link Margin		**+18.7 dB**

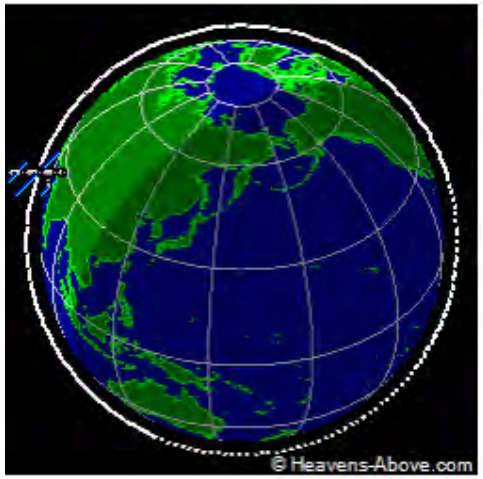
Wo steht der Satellit und wann?

https://www.heavens-above.com/ und andere Quellen

- Kepler-Gesetze -> Satellitenbahn
- Ein paar Zahlen beschreiben die Bahn
- Ein Programm erledigt die Arbeit
- Für 1 Ort zu 1 Zeit



Output von "heavens-above" (Auszug)



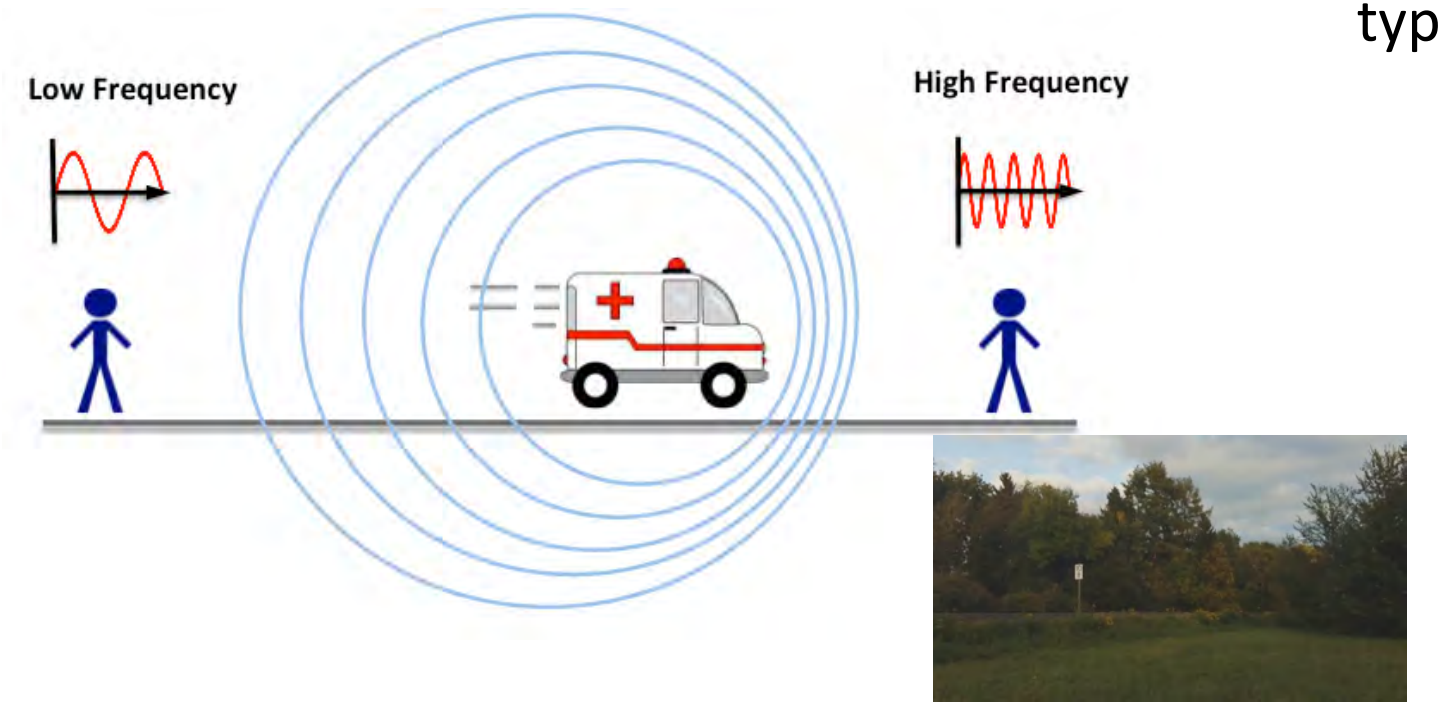
Ground track. The orbit data is extracted from the following two-line orbital elements
1 25544U 98067A 16244.94384549 .00002647 00000-0 46831-4 0 9998
2 25544 51.6449 40.0209 0002636 269.9580 224.1034 15.54358481 16773

Epoch (UTC):	31 August 2016 22:39:08
Eccentricity:	0.0002636
inclination:	51.6449°
perigee height:	402 km
apogee height:	406 km
right ascension of ascending node:	40.0209°
argument of perigee:	269.9580°
revolutions per day:	15.54358481
mean anomaly at epoch:	224.1034°
orbit number at epoch:	1677

http://www.heavens-above.com/

Dopplereffekt

Scheinbare Frequenzverschiebung bei relativer Bewegung zwischen Sender und Empfänger



Grösse des Dopper Effektes

$$f = \left(1 + \frac{\Delta v}{c}\right) f_0$$

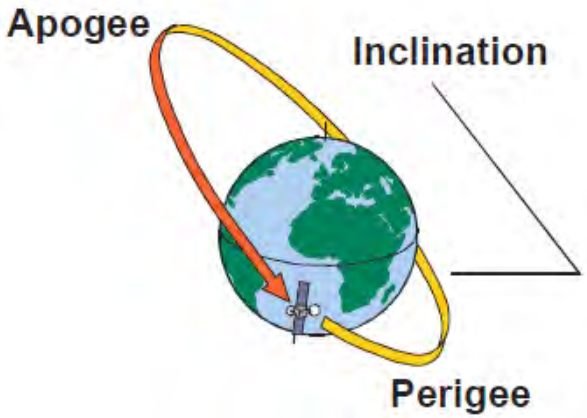
$$\Delta f = \frac{\Delta v}{c} f_0$$

typische Werte für $\Delta \mathrm{v} \approx 7\,\frac{km}{s}$:

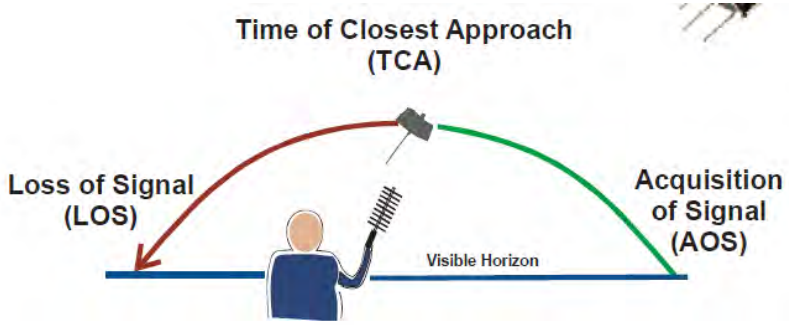
$$f_0 = 145\ MHz\ \rightarrow$$
$$\Delta f = \mathbf{3.4\ kHz}$$

$$f_0 = 435\ MHz$$
$$\rightarrow \Delta f = \mathbf{10.1\ kHz}$$

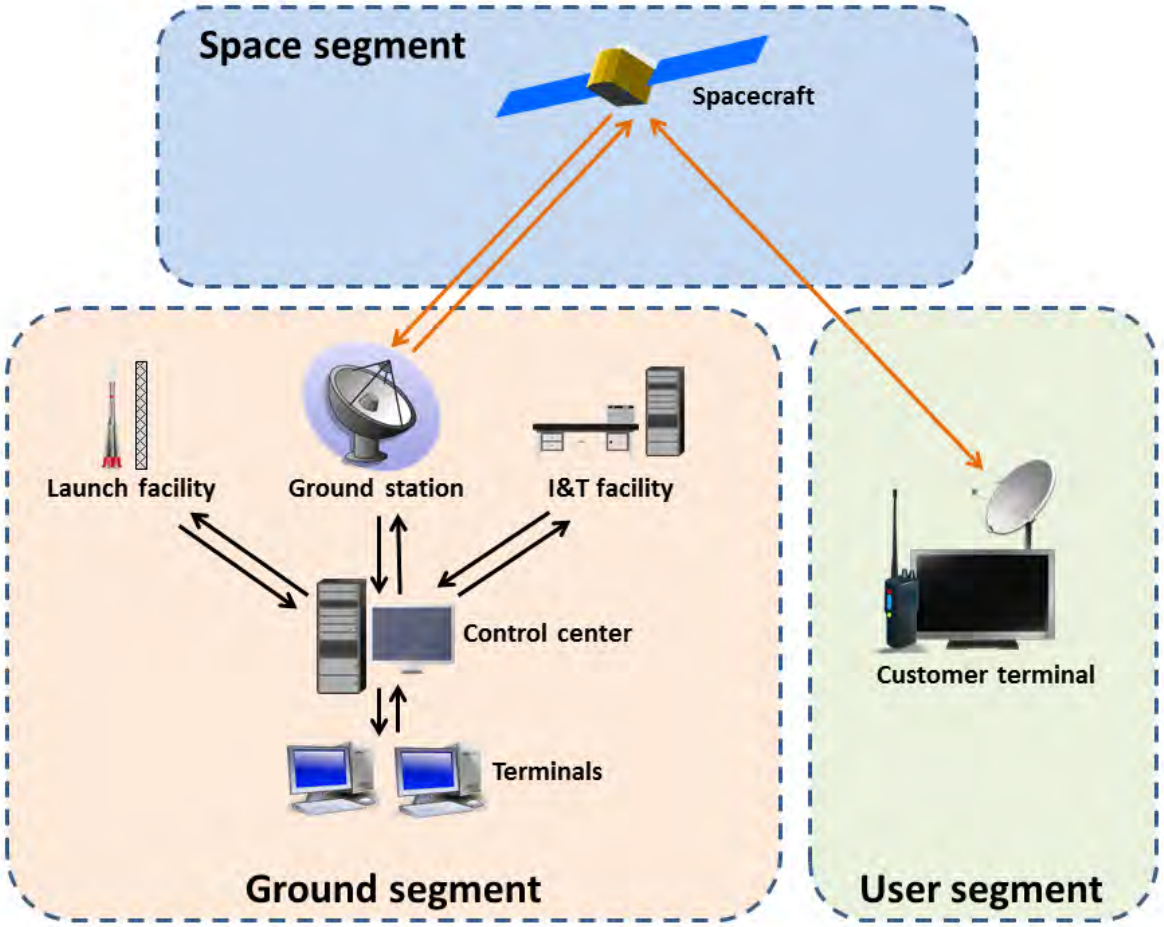
Glossary



- **Zenith**: point directly "above" a particular location
- **Nadir**: point directly *below* a particular location
- **Apogee**: point farthest away from the Earth
- **Perigee**: point nearest to the earth
- **AOS** **A**cquisition **o**f **S**ignal
- **TCA**: **T**ime of **C**losest **A**pproach
- **LOS**: **L**oss **o**f **S**ignal
- **Azimuth:** the angle of horizontal deviation (from north)
- **Elevation**: the angle of vertical deviation (from horizon)
- **UTC**: Coordinated Universal Time
- **Doppler**: An increase (decrease) in the frequency waves as the source and observer move towards (away from) each other.
- **Uplink/Downlink:** transmission from earth to space and vice versa



Space-/Ground-/User Segment



GS impressions

Source: Surrey Space Technology Limited (SSTL)

@Bletchley Park

Zwischenfragen

1. Welche Gesetze beschreiben die Bahn des Fernsehsatelliten Astra?

2. Astra ist sehr weit entfernt.
   Wie gross ist die Dopplerfrequenz?

Cube Satelliten Projekte in HB9

Swisscube

- 23. September 2009 mit einer indischen PSLV C14
- Die Nutzlast besteht aus einem Teleskop, das Bilder von den Airglow-Emissionen aufnimmt. Das Teleskop hat eine Länge von 50 mm. An einem Ende nimmt ein CMOS-Detektor Bilder mit einer Auflösung von 188 x 120 Pixeln und einer Pixelgröße von 24 µm über eine Fokussieroptik auf, die ein FOV von 25° und eine Auflösung von 0,16°/Pixel bietet. Ein bei 767 nm zentrierter Bandpassfilter mit einer Bandbreite von 20 nm wählt die gewünschte Wellenlänge des Airglow aus.

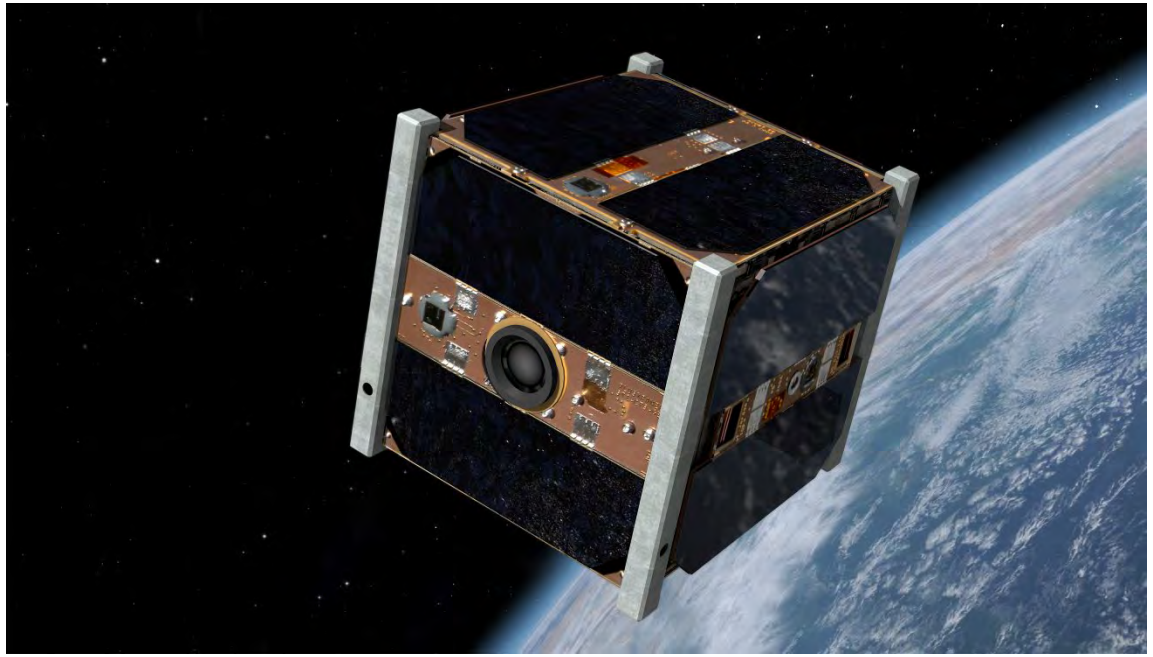
FOV = Field of View, Sehwinkel

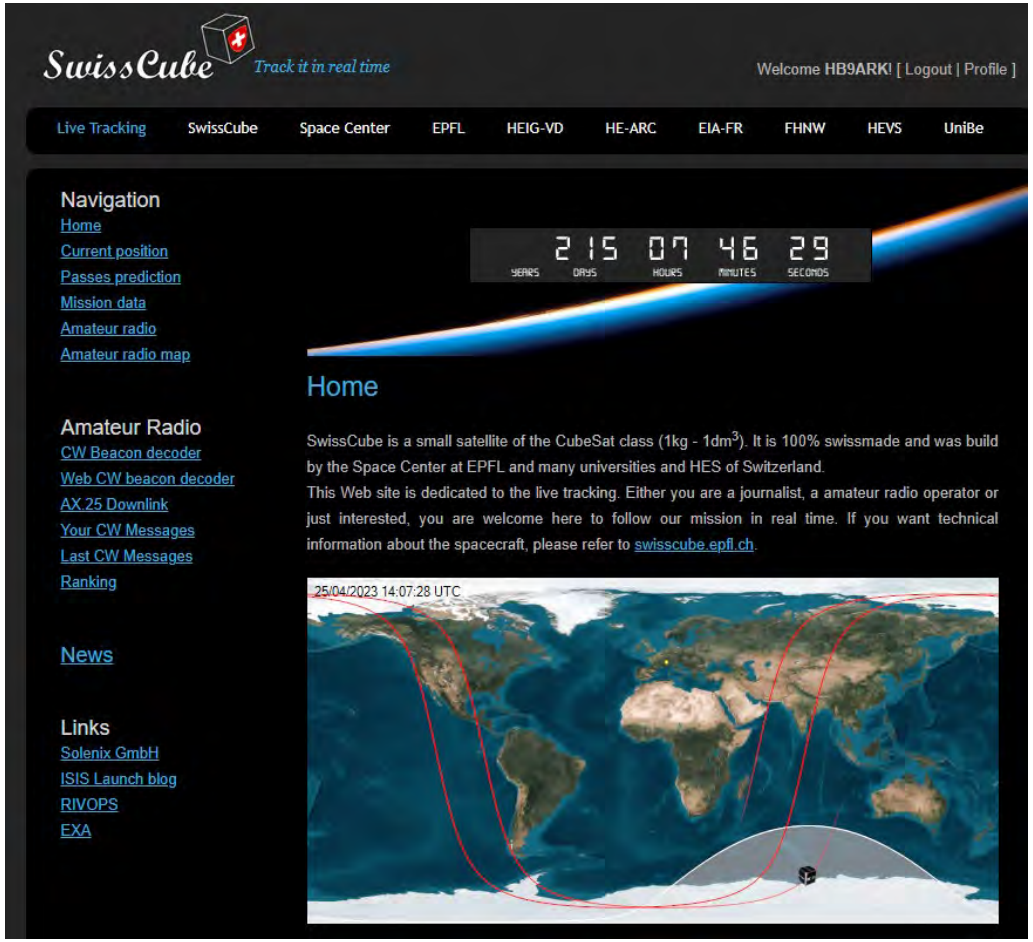
Swisscube

- Ein Bakensignal (20,8 dBm oder 120mW, 10 Bits/Sek. im Morsecode bei 437 MHz) ist ständig in Betrieb und wird durch einen Befehl vom Boden aus abgeschaltet und durch die Haupt-HF-Datenübertragung ersetzt. Dieser Hauptdatenstrom sendet die wissenschaftlichen und technischen Telemetriedaten mit 1200 Bits/Sek. bei einer Ausgangsleistung von 30 dBm (1W) und ist FSK-moduliert bei einer Frequenz von 437 MHz. Das Uplink-Signal verwendet die Trägerfrequenz 145 MHz und ist AFSK-moduliert.

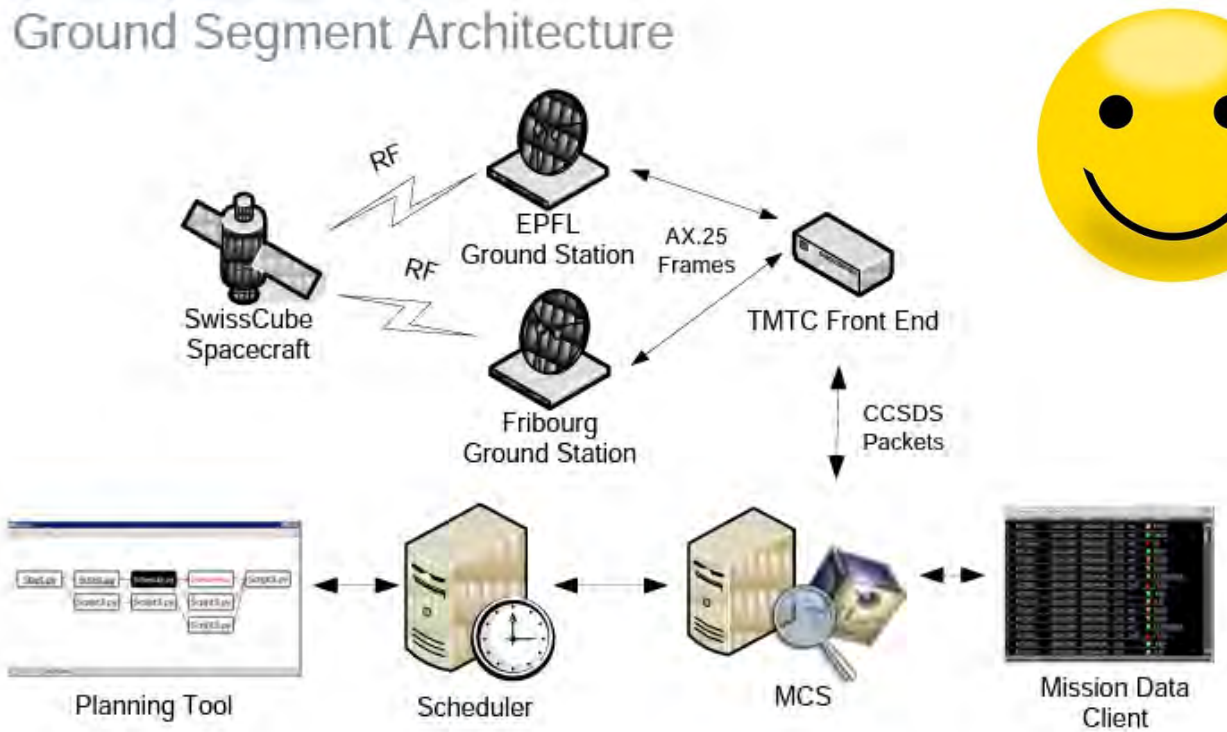
Swisscube, https://archiveweb.epfl.ch/swisscube.epfl.ch/

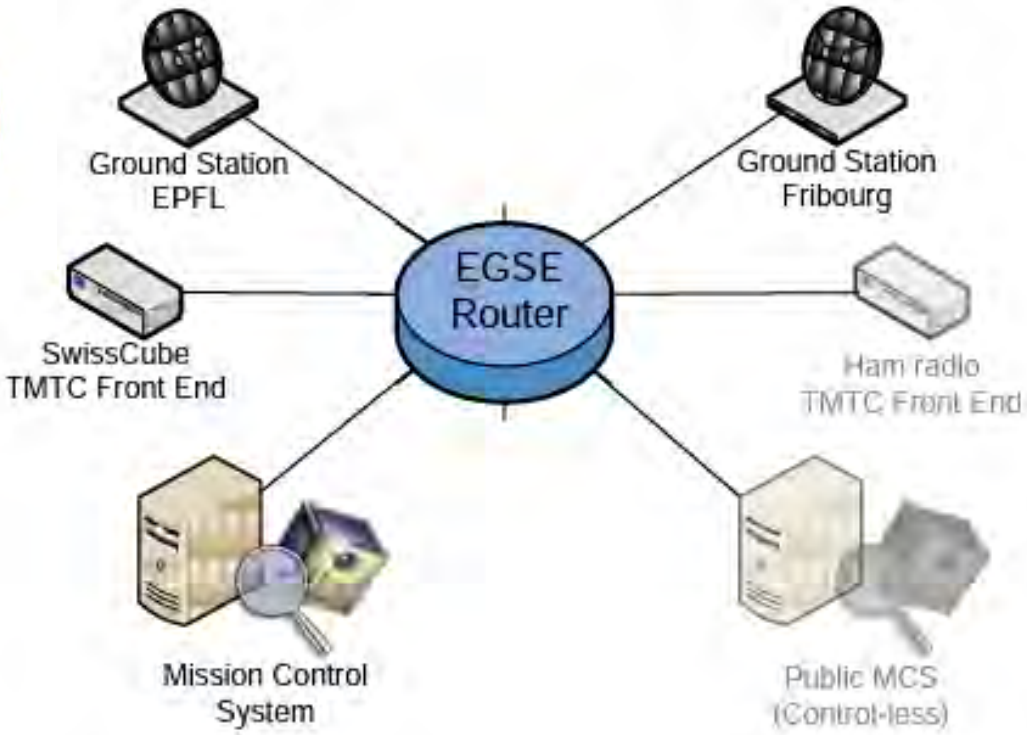
Swisscube ist immer noch aktiv (trotz gewisser Schwächen).
Armin, HB9MFL benützt ihn regelmässig.





SwissCube Ground Segment Architecture

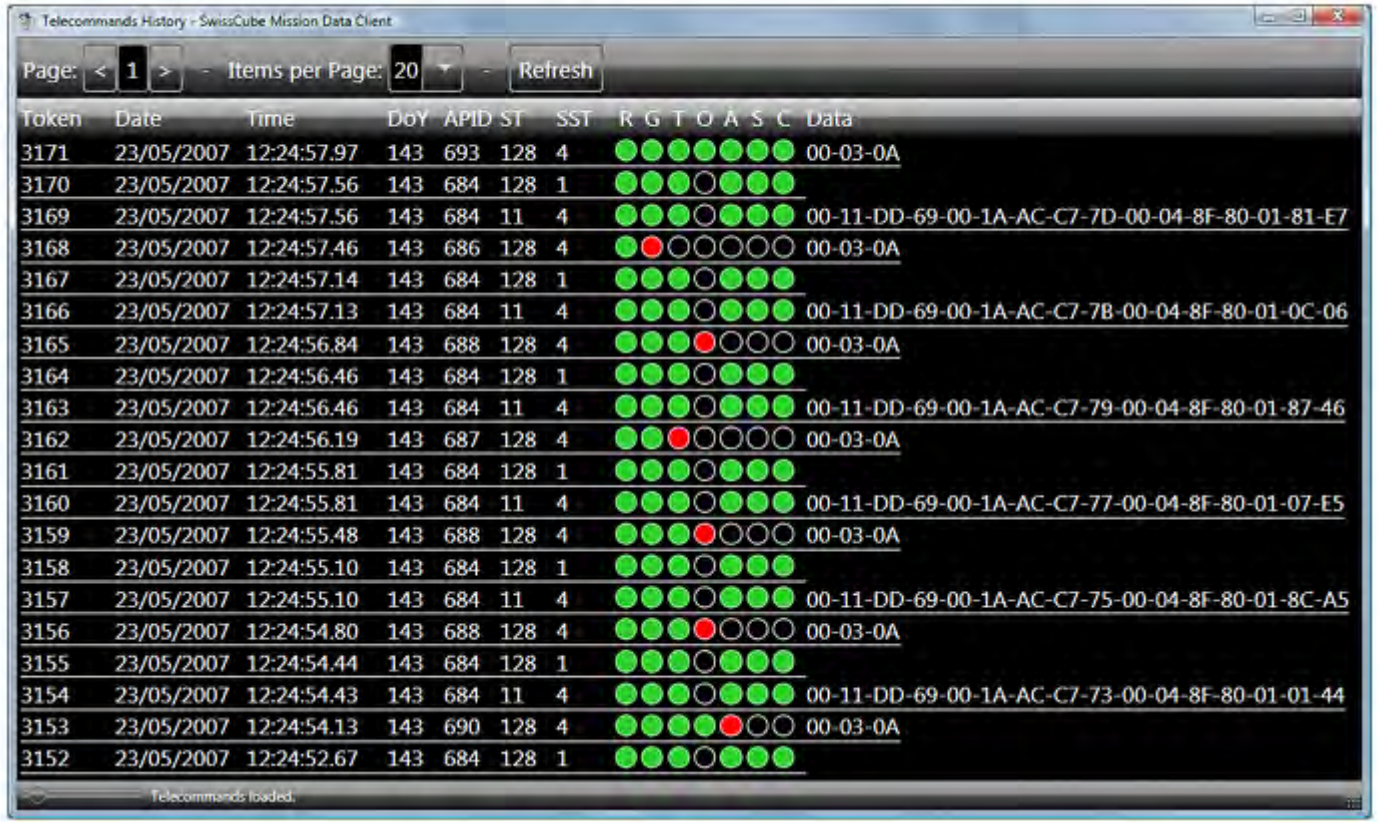




Florian George, Yann Voumard, EPFL

Mission Data Client

Mission Data Client – Telecommand view

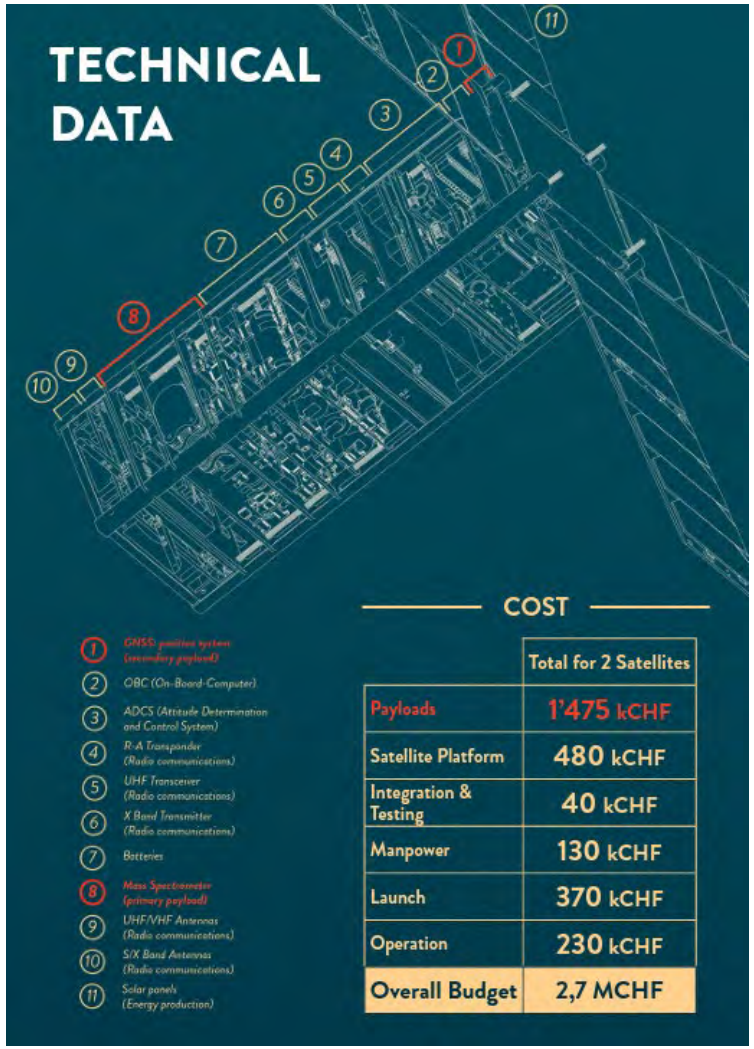


Token	Date	Time	DoY	APID	ST	SST	R	G	T	O	A	S	C	Data
3171	23/05/2007	12:24:57.97	143	693	128	4								00-03-0A
3170	23/05/2007	12:24:57.56	143	684	128	1								
3169	23/05/2007	12:24:57.56	143	684	11	4								00-11-DD-69-00-1A-AC-C7-7D-00-04-8F-80-01-81-E7
3168	23/05/2007	12:24:57.46	143	686	128	4								00-03-0A
3167	23/05/2007	12:24:57.14	143	684	128	1								
3166	23/05/2007	12:24:57.13	143	684	11	4								00-11-DD-69-00-1A-AC-C7-7B-00-04-8F-80-01-0C-06
3165	23/05/2007	12:24:56.84	143	688	128	4								00-03-0A
3164	23/05/2007	12:24:56.46	143	684	128	1								
3163	23/05/2007	12:24:56.46	143	684	11	4								00-11-DD-69-00-1A-AC-C7-79-00-04-8F-80-01-87-46
3162	23/05/2007	12:24:56.19	143	687	128	4								00-03-0A
3161	23/05/2007	12:24:55.81	143	684	128	1								
3160	23/05/2007	12:24:55.81	143	684	11	4								00-11-DD-69-00-1A-AC-C7-77-00-04-8F-80-01-07-E5
3159	23/05/2007	12:24:55.48	143	688	128	4								00-03-0A
3158	23/05/2007	12:24:55.10	143	684	128	1								
3157	23/05/2007	12:24:55.10	143	684	11	4								00-11-DD-69-00-1A-AC-C7-75-00-04-8F-80-01-8C-A5
3156	23/05/2007	12:24:54.80	143	688	128	4								00-03-0A
3155	23/05/2007	12:24:54.44	143	684	128	1								
3154	23/05/2007	12:24:54.43	143	684	11	4								00-11-DD-69-00-1A-AC-C7-73-00-04-8F-80-01-01-44
3153	23/05/2007	12:24:54.13	143	690	128	4								00-03-0A
3152	23/05/2007	12:24:52.67	143	684	128	1								

Mission Data Client

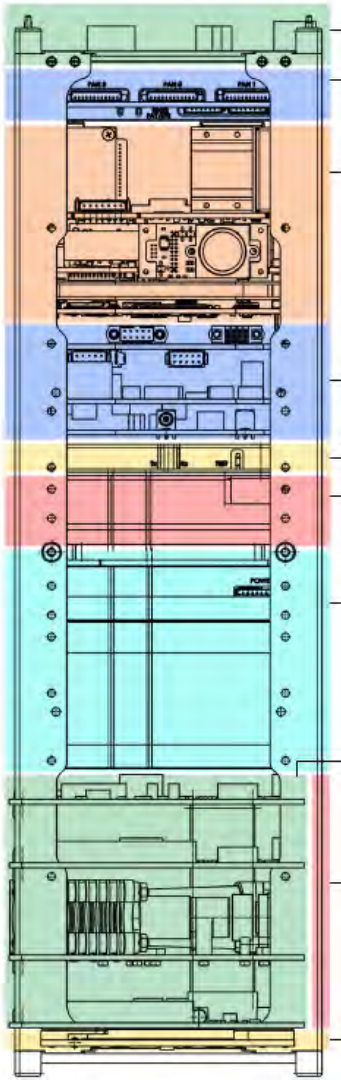
CHESS

https://chessmission.ch/?page_id=3276



	Total for 2 Satellites
Payloads	1'475 kCHF
Satellite Platform	480 kCHF
Integration & Testing	40 kCHF
Manpower	130 kCHF
Launch	370 kCHF
Operation	230 kCHF
Overall Budget	2,7 MCHF

CHESS



GNSS: Global Navigation satellite system
Function: Provides the Position, Velocity and Time (PVT) data to the satellite subsystems.
Origin: ETHZ in collaboration with U-Blox

EOBC: Endurosat On Board Computer
Function: Serves as the brain of the mission. Manages all the operations of the satellite.
Origin: Endurosat

ADCS: Attitude determination and control system
Function: Orients the satellite in space to point in a desired direction.
Origin: CubeSpace

HOBC: In House On Board Computer
Function: Interacts only with EOBC. Used as a payload to carry out tests in space.
Origin: EPFL, HES-SO

UHF Transceiver
Function: Communicates the housekeeping data to the ground station and receives uplink commands.
Origin: Endurosat

Xband Transceiver
Function: Communicates the scientific data to the ground station. Xband is needed for high data volume.
Origin: Endurosat

EPS: Electrical power system + batteries
Function: Power collection and distribution unit.
Origin: Endurosat

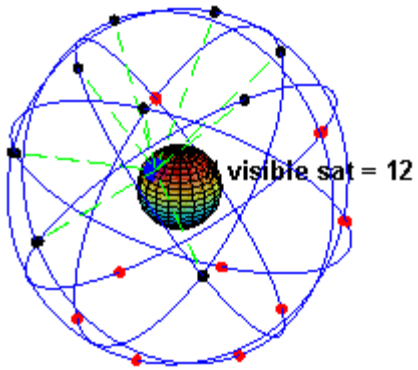
RUAG Solar Cells
Function: Serve as payload to be tested during the mission. The cells are incorporated in Endurosat solar panels.

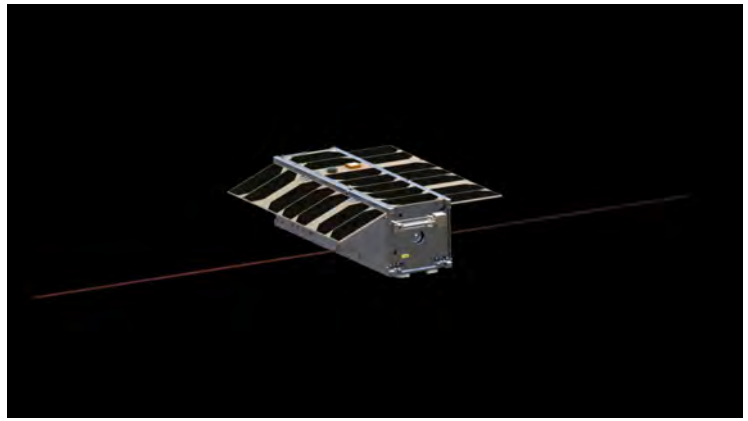
Time Of Flight spectrometer
Function: Measures neutral and ion species in the atmosphere. (Most valuable payload)
Origin: UniBe and Spacetek

Xband Antenna
Function: Serves as the Antenna for the Xband Transceiver: Patch antenna on the side of the satellite.
Origin: HSLU (Luzern)

UHF Antenna
Function: Serves as the Antenna for the UHF Transceiver.
Origin: Endurosat

Astrocast / CubETH Payload: Scientific goals





Geodesy research ETHZ, Prof. M. Rothacher

- surveying trajectories
- Precise orbit determination
- surveying attitude of satellite
- verification of orbital elements
- behaviour of the GNSS receivers

Astrocast Payload

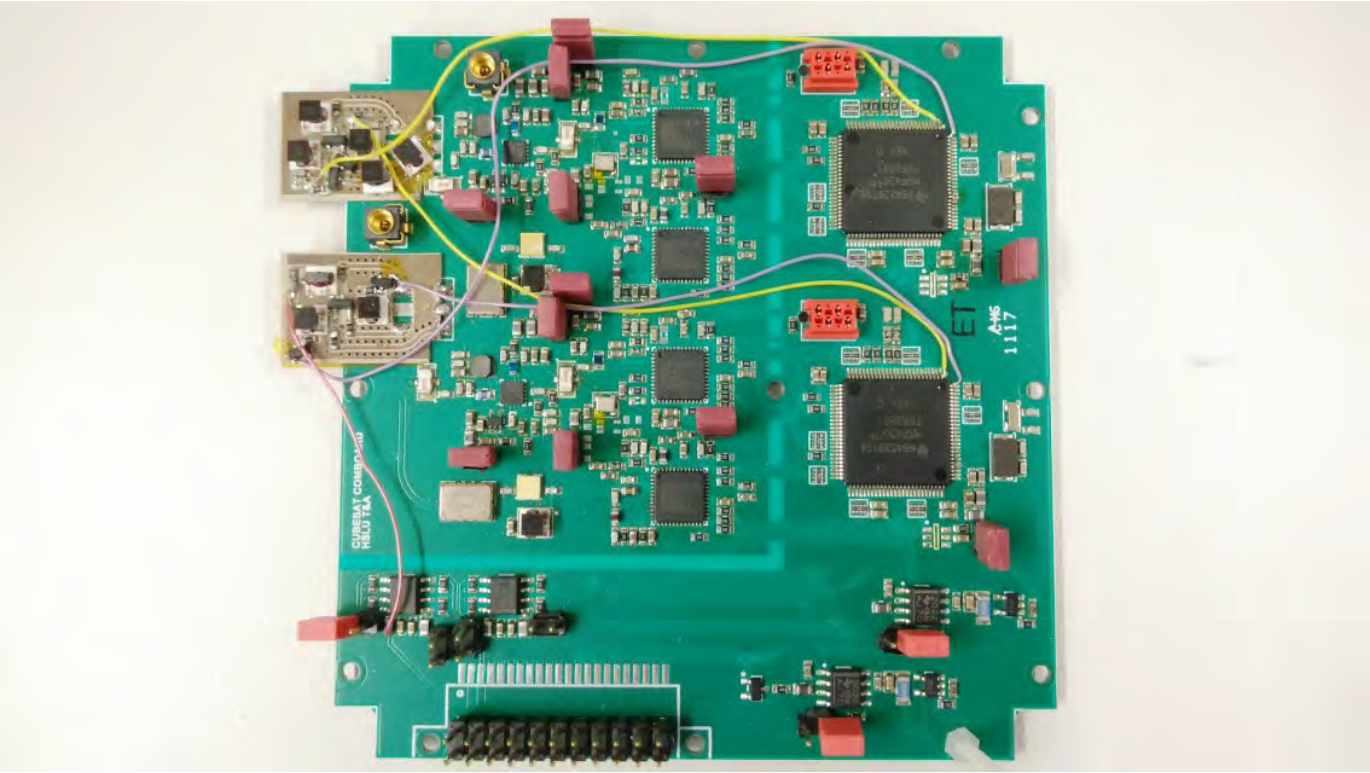
- M2M communication precursor -> SpinOff

HamRadio PL

- **PRBS-Ranging and TLE reconstruction**
- GNSS coordinates and speed vector
- **Packet Data Relay** (Packet repeater)
- Picture Download from on-board cameras
- Listener Mode (Echo Mode)

Astrocast / HSLU: HW & SW

GNSS board

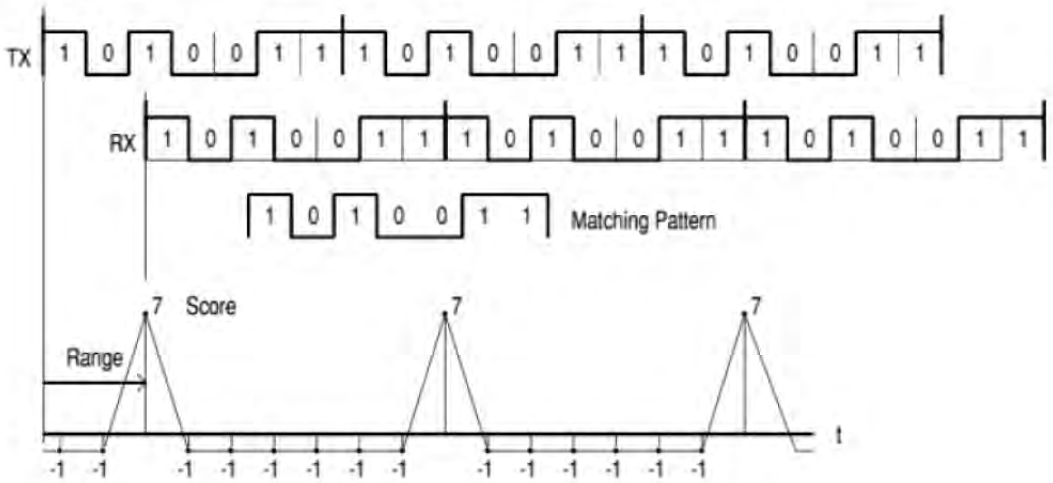


COM board VHF/UHF
also available for ham radio fct

Astrocast Ham Radio Functions

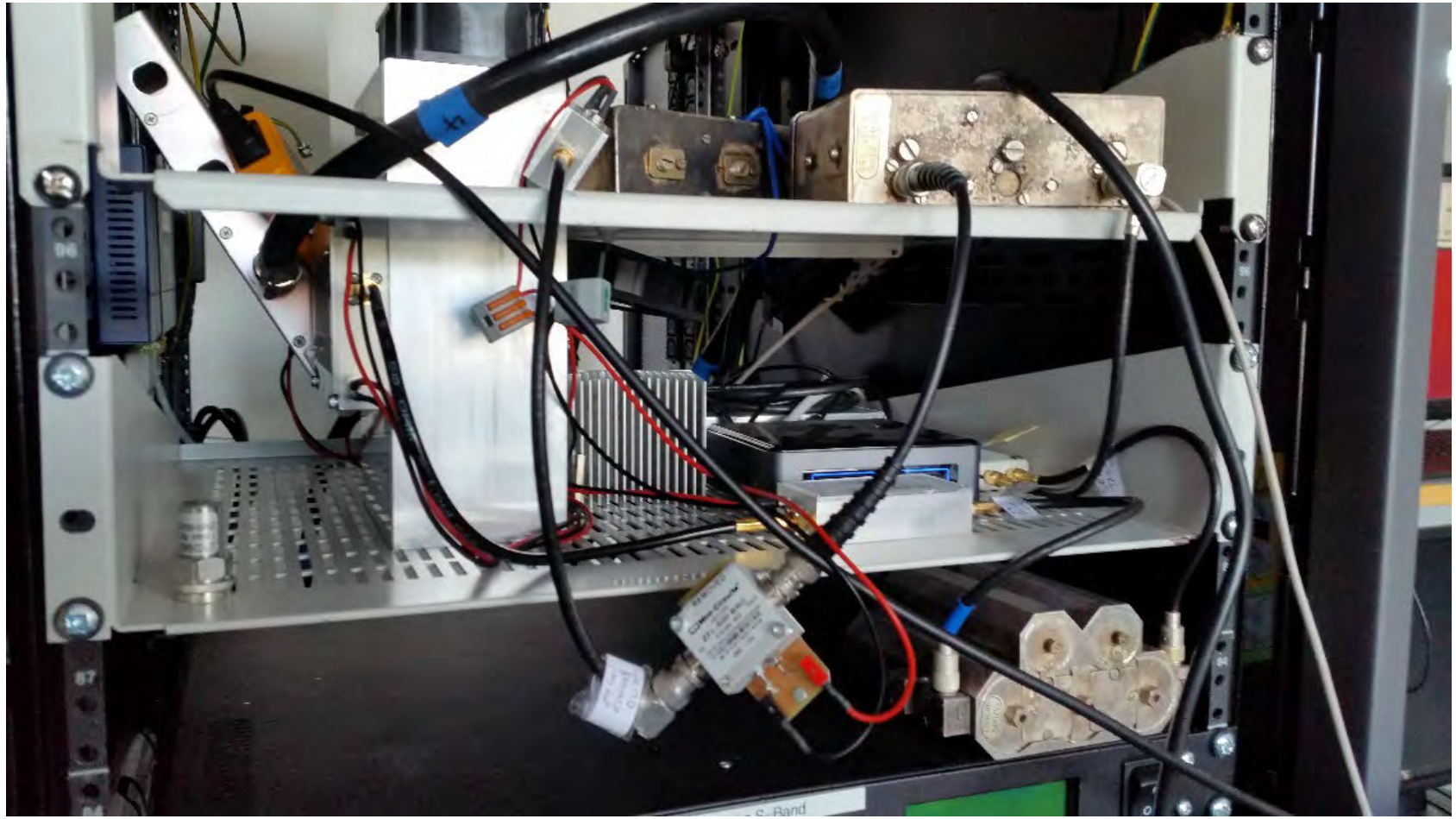
- **Ranging (Distanzmessung) -> TLE berechnen**
- Packet Repeater
- Picture Download from Startracker cameras
- Beacon transmitting GNSS (GPS) data

Pseudorange = prbs_phase *249.9 [km] + bit_clock_phase * 300 [m]



Nach einer Idee von James Miller, G3RUH

Astrocast Groundstation

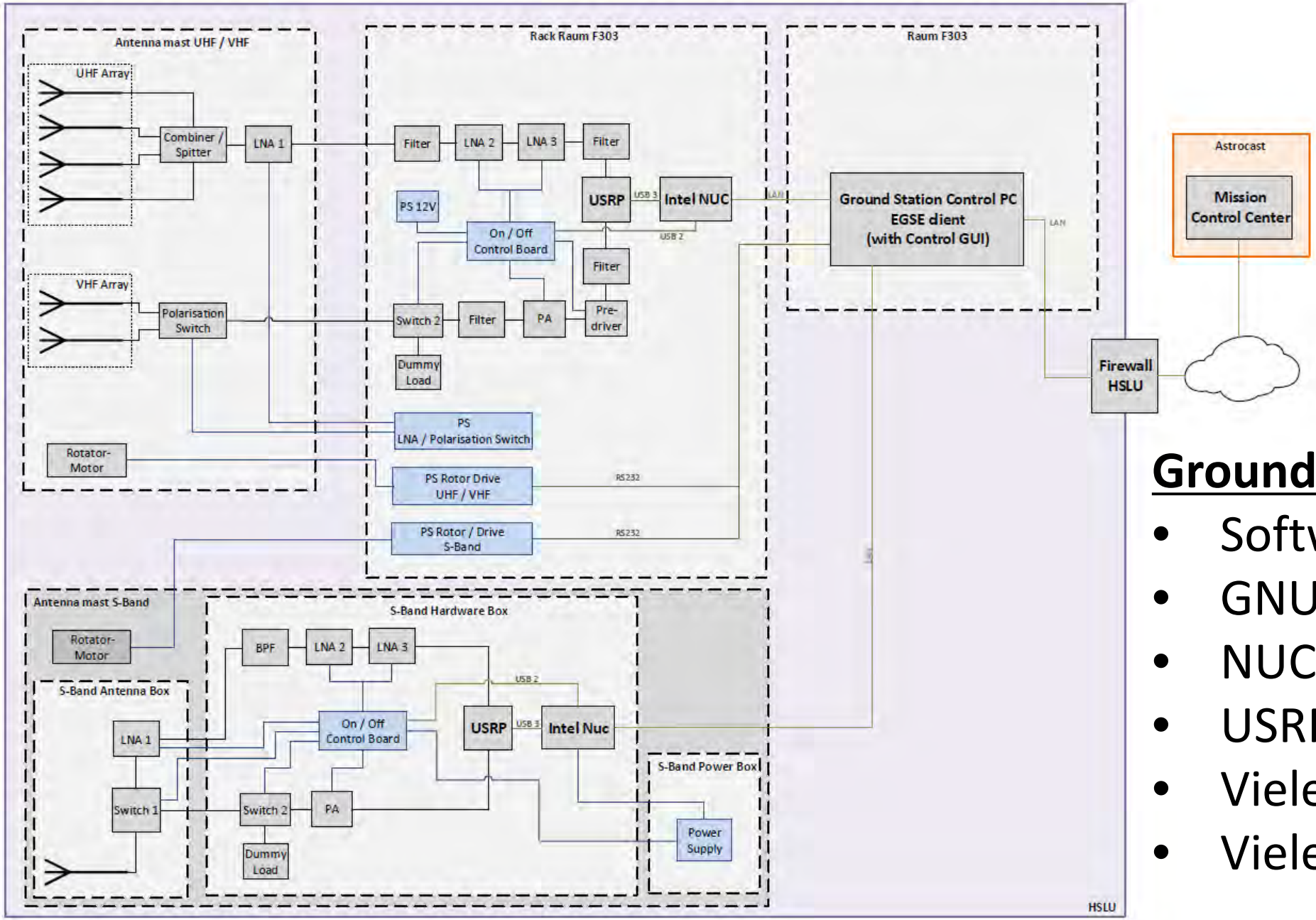


Worldwide data communication over satellite on commercial L-Band frequencies

- Ceramic patch antenna
- Supports GNSS L1 band
- L-Band:
  - 1.5GHz and 1.6GHz

Astrocast / Mouser

Astrocast Astronode S+
Satellite Communication Device



Groundstation Blockschema

- Software Defined Radio
- GNU GRC
- NUC PC
- USRP B-200
- Viele Filter
- Viele Verstärker

ARIS-SAGE

Quelle: ARIS, Annual Report 2021/2022

ARIS-SAGE

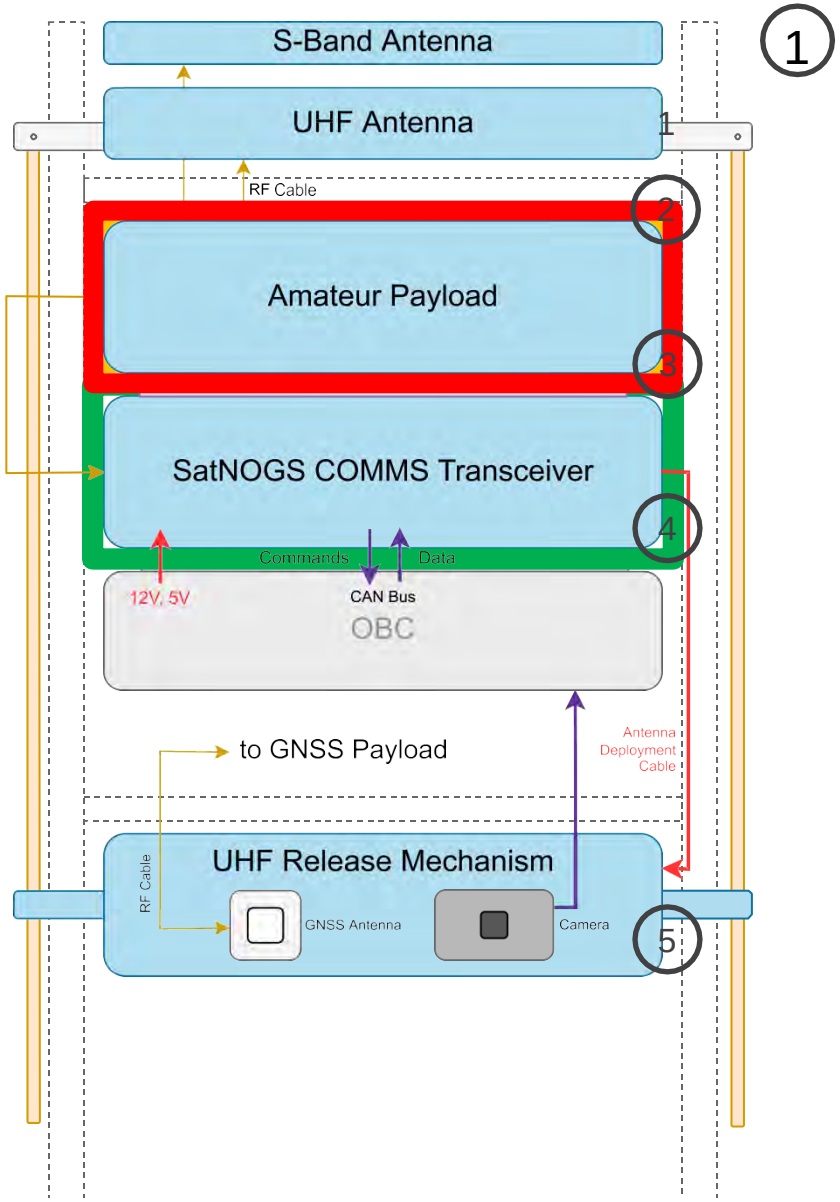
Zero G flight

Wissenschaftliches Experiment: Eukariotische Zellen in Mikrogravitation

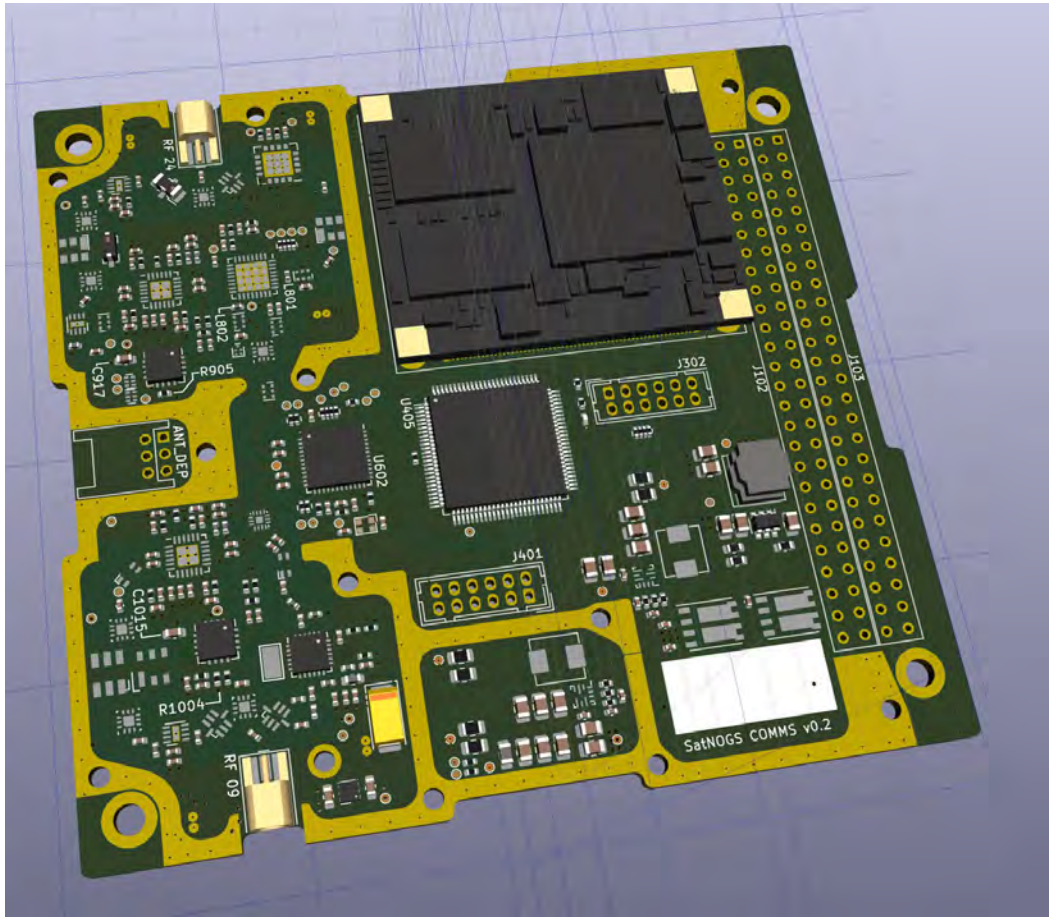
Quelle: ARIS, Annual Report 2021/2022

SAGE System Overview

1. S-Band Antenna – PCB Patch Antenna
2. UHF Antenna – Turnstile Antenna
3. Amateur Payload – S Band to UHF linear transponder
4. SatNOGS COMMS Transceiver – S Band and UHF
5. UHF Release Mechanism – Burn wire release



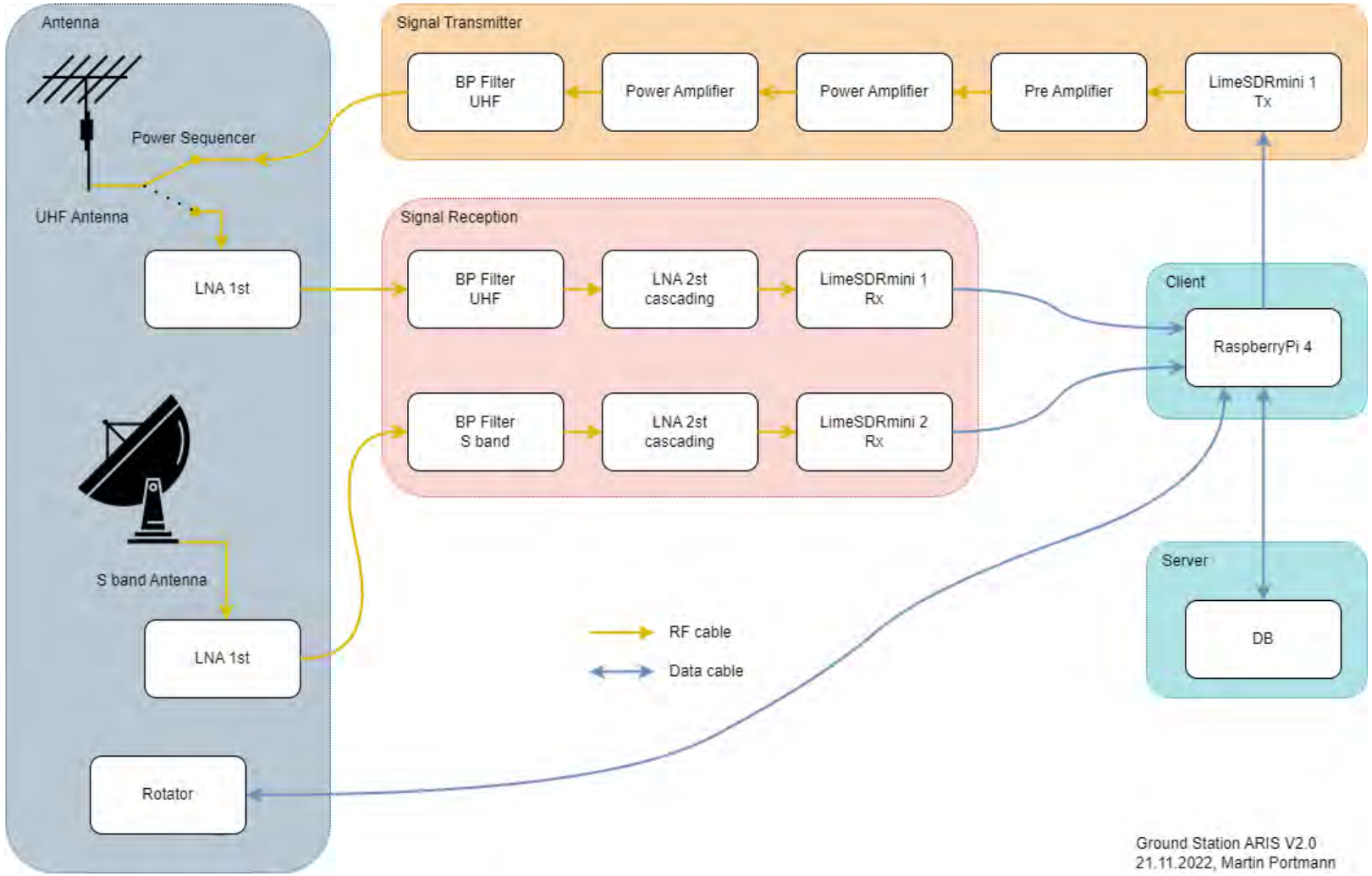
TRX Board



- Dual radio, UHF and S-Band,
  Half-duplex operation per band
- Adjustable TX power: 26 - 32dBm,
  dB step with no ALC and stability ±1.5dB
- Receiver Noise Figure: 1.5dB
- AGC dynamic range: 58dB
- Frequency step size:
  100Hz in UHF and 400Hz in S-Band
- Frequency Stability: ±0.5 ppm (uncalibrated)
- Frequency Ranges:
  - 2025-2110MHz (Rx)
  - 2200-2290MHz(Tx)
  - 2400-2450 (Rx/Tx)
  - 400-440MHz (Rx/Tx)

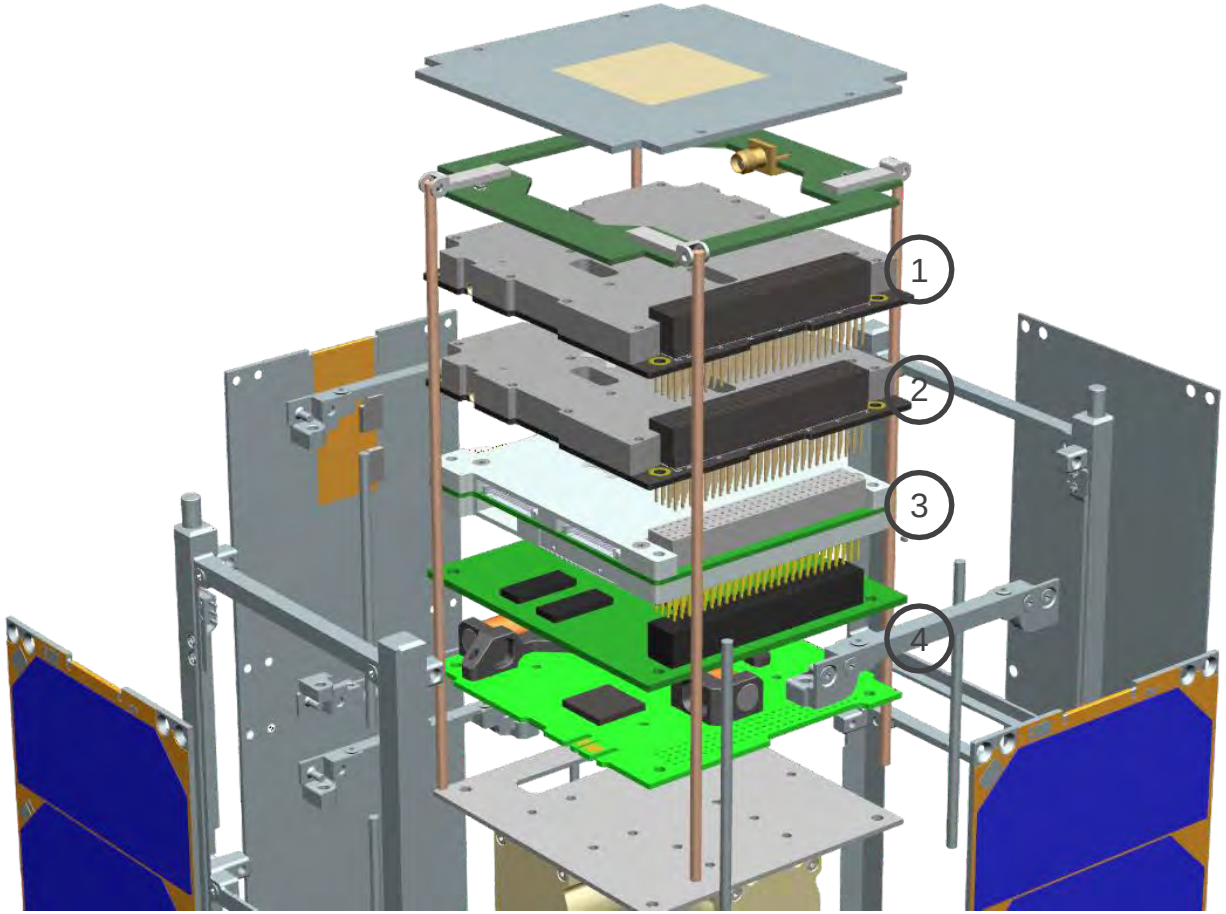
Konzept Groundstation ARIS-SAGE (work in progress)

Basierend auf SatNOGS
https://satnogs.org/



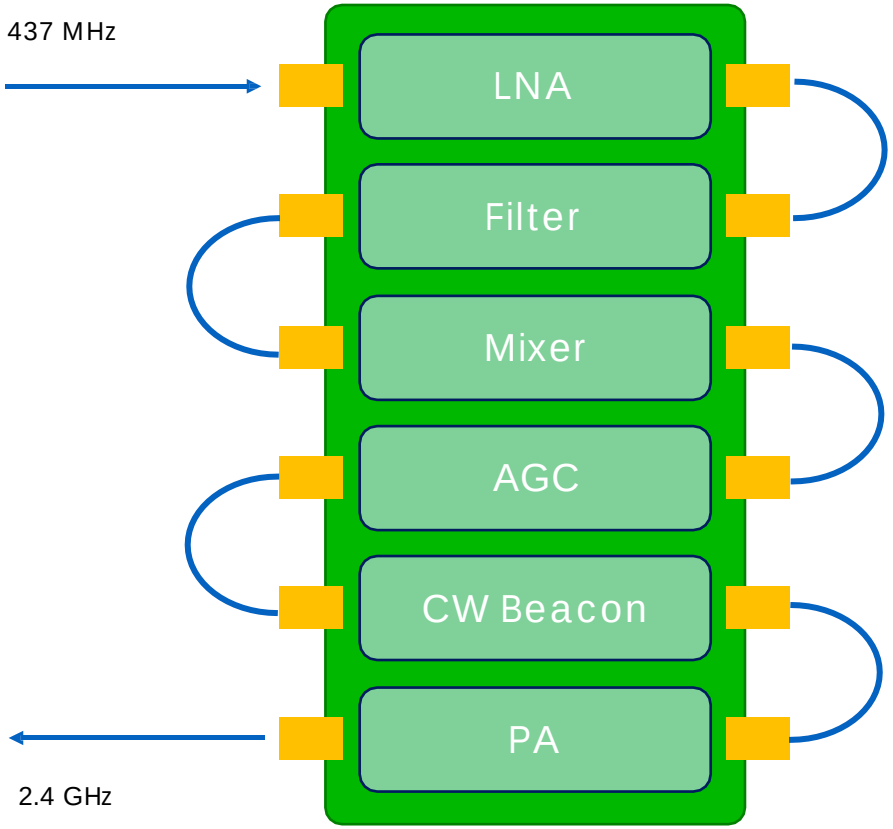
Amateur Payload

1. S-Band Antenna
2. UHF Antenna
3. Amateur Payload
4. SatNOGS COMMS Transceiver

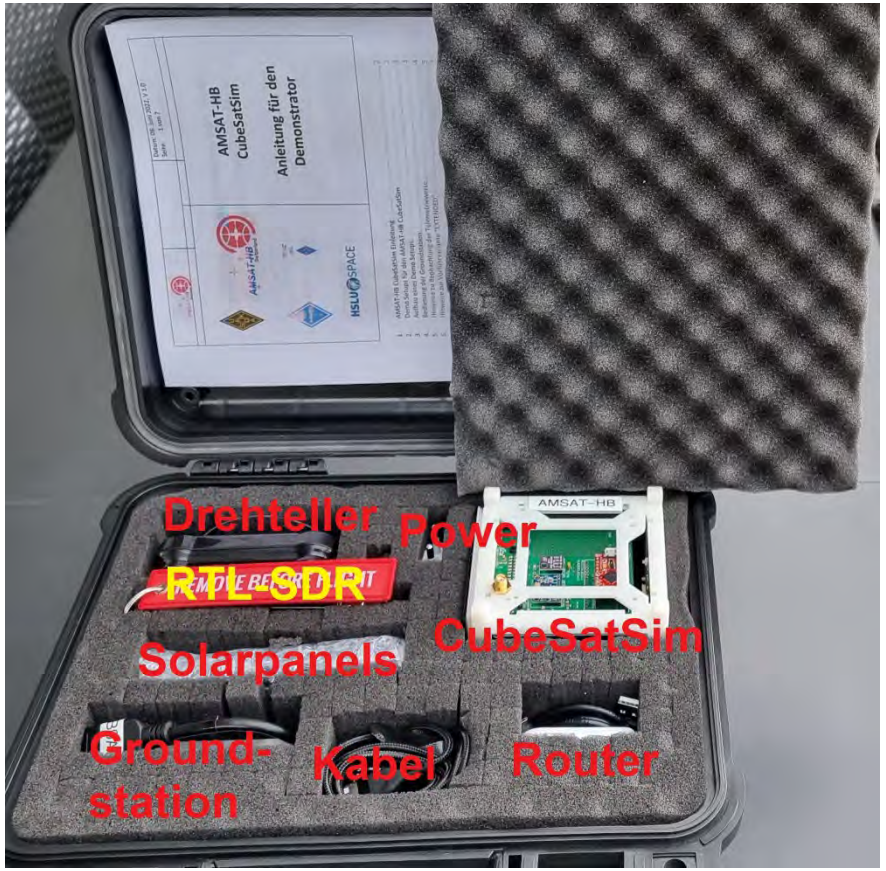


Linear Transponder U/S
Eigenentwicklung
SAGE / HB9ZZ

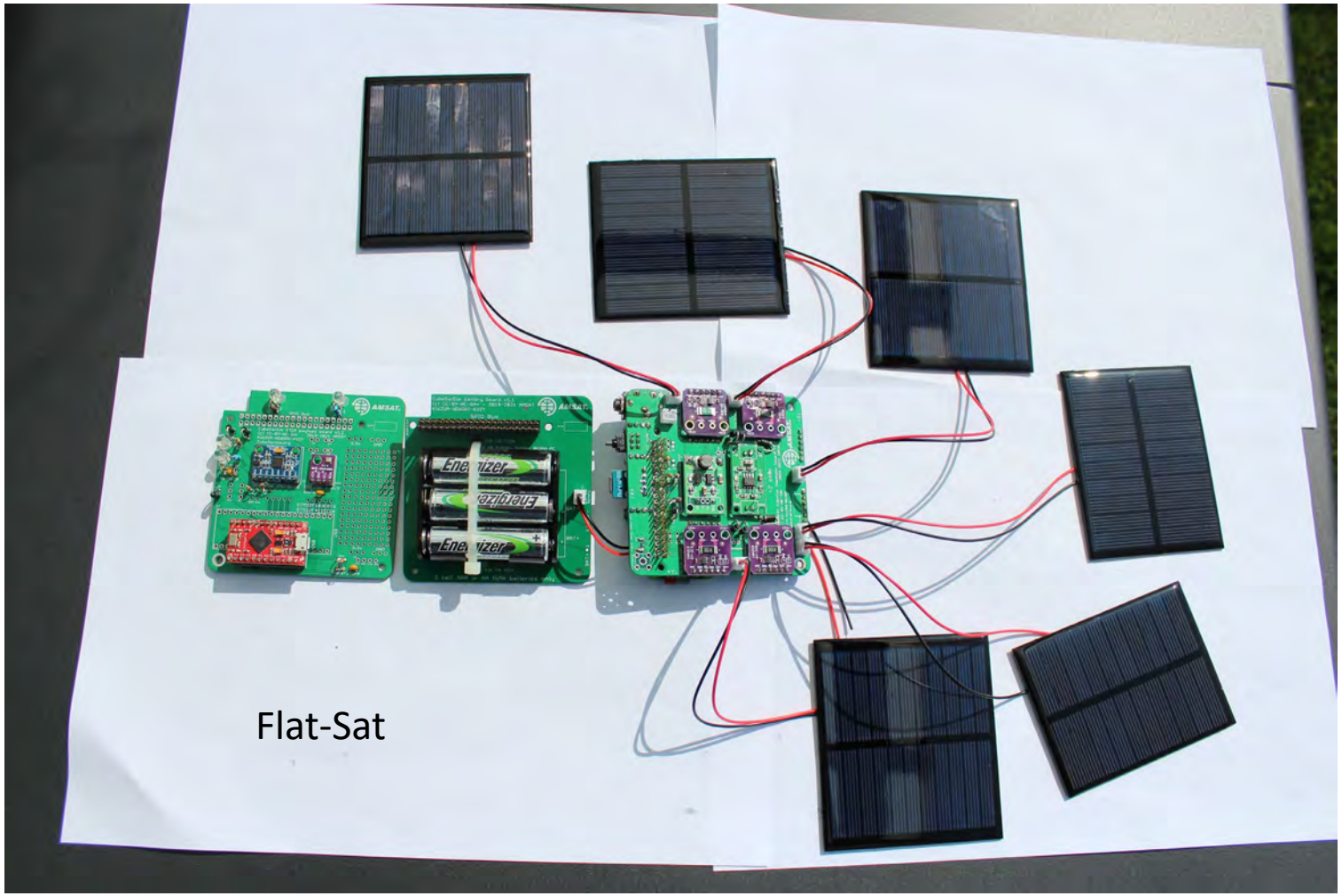
Amateur Payload: linear Transponder



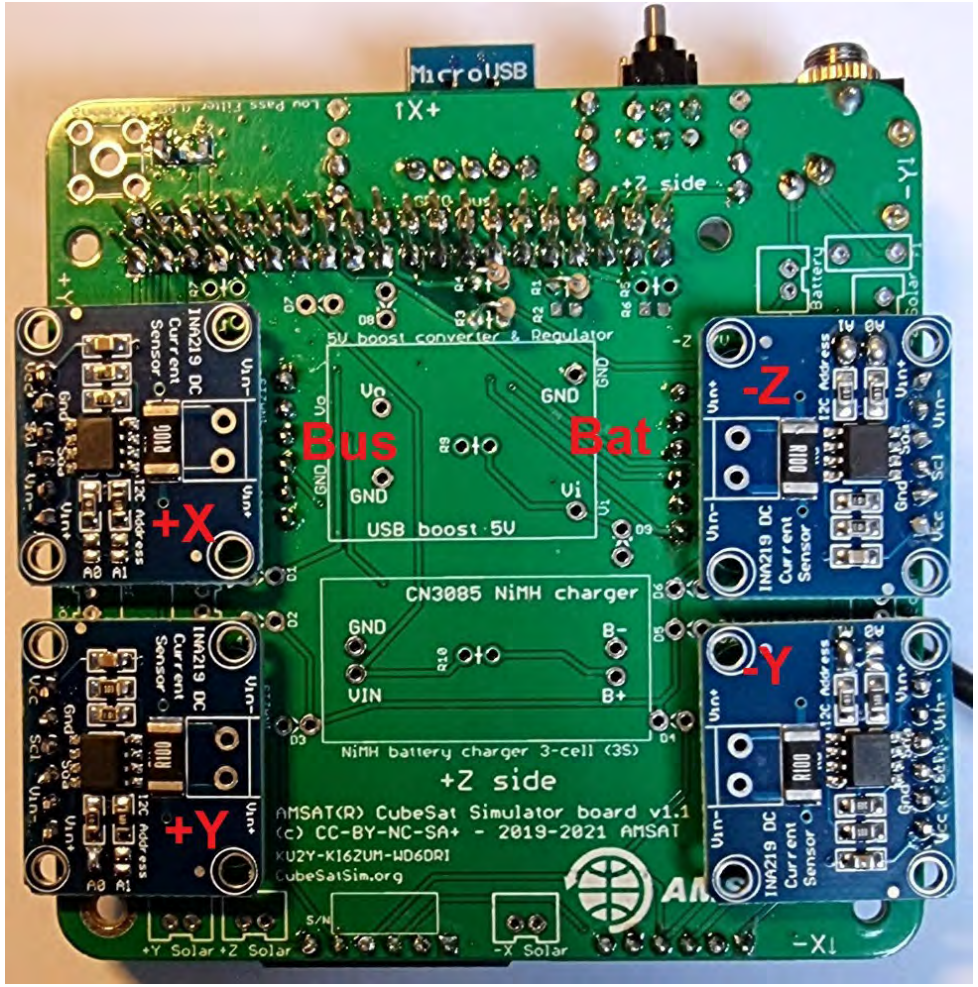
CubeSatSim Nachbau nach Alan Johnston, KU2Y

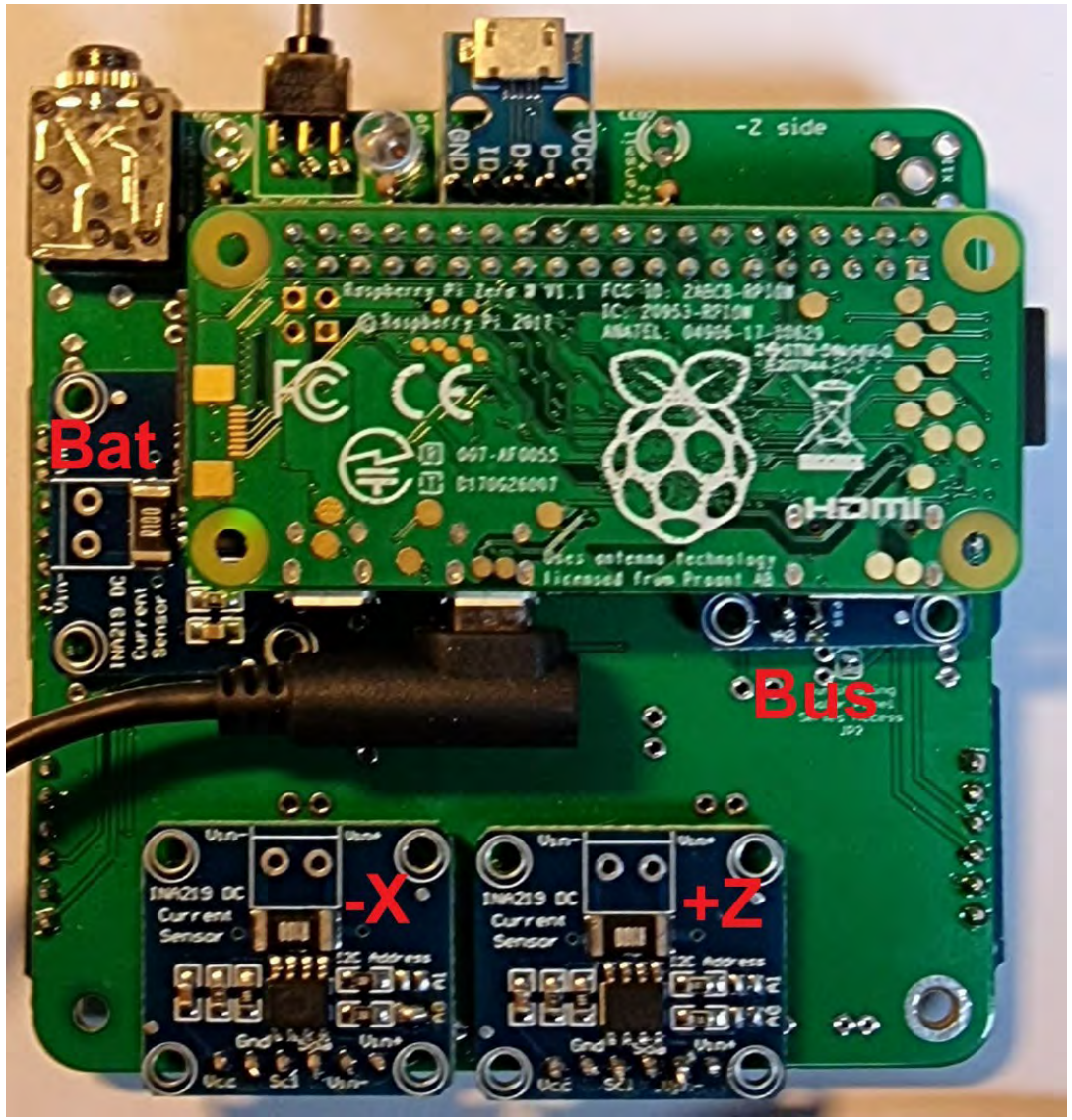


Transport-Box

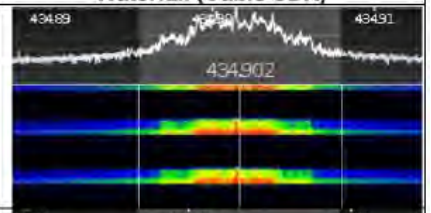
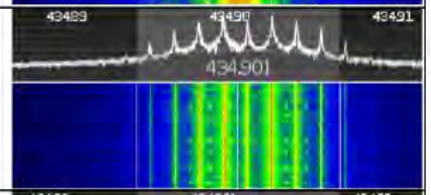
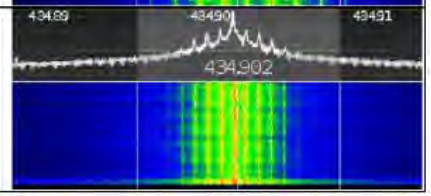


CubeSatSim


MicroUSB
+X
Bus
Bat
-Z
+Y
-Y
5V boost converter & Regulator
USB boost 5V
CN3085 NiMH charger
NiMH battery charger 3-cell (3S)
+Z side
AMSAT(R) CubeSat Simulator board v1.1
(c) CC-BY-NC-SA+ - 2019-2021 AMSAT
KU2Y-K16ZUM-WD6DRI
CubeSatSim.org
+Y Solar +Z Solar
-X Solar

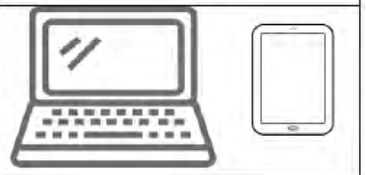

-Z side
Bat
Bus
-X
+Z

CubeSatSim - Funktionsumfang

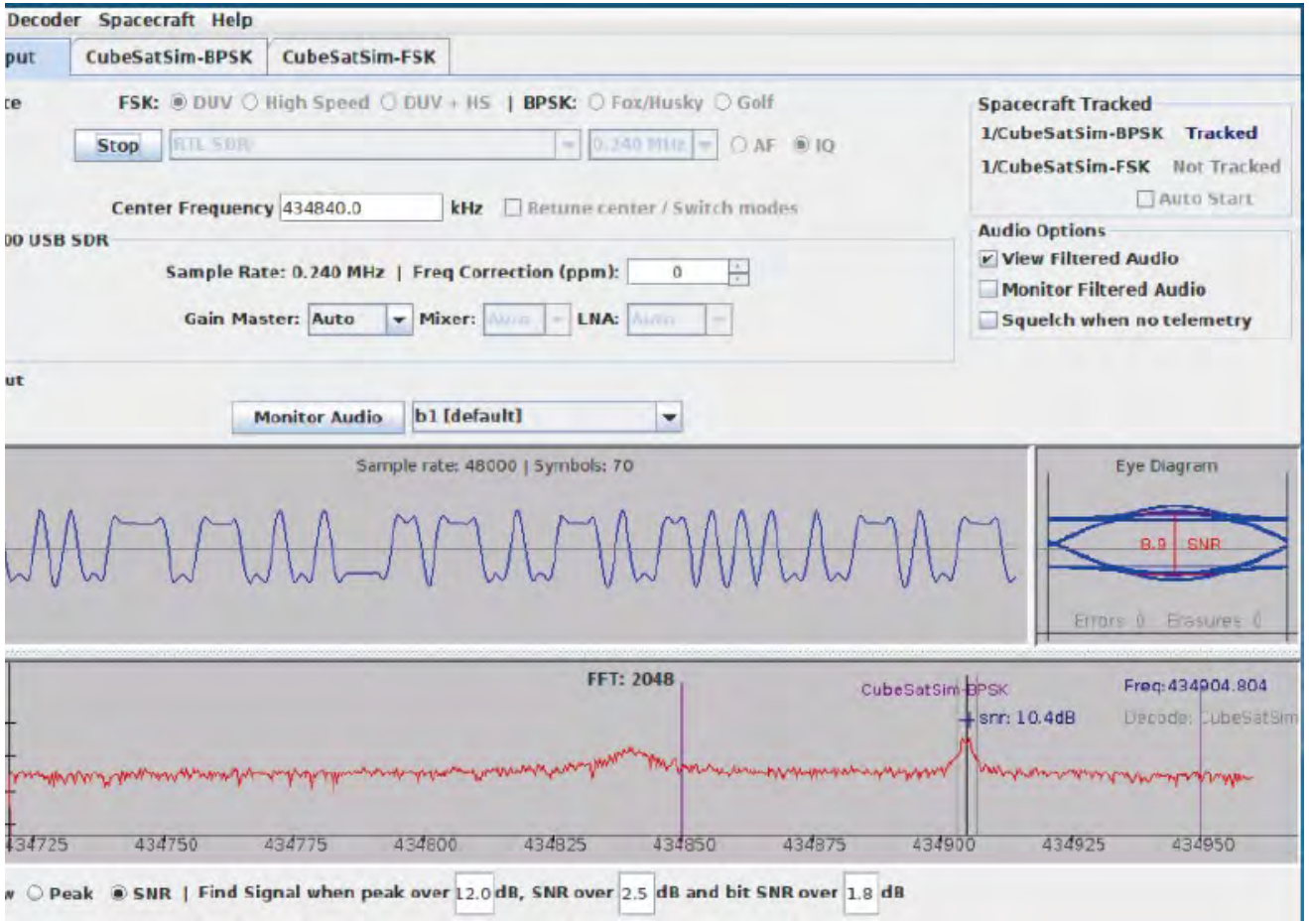
Blinks	Mode	Description	Decoding	Command	Audio	Waterfall (Cubic SDR)
1	APRS	Automatic Packet Reporting System. This digital mode sends a packet of data with AFSK or Audio Frequency Shift Keying modulation.	Windows: SoundModem or Direwolf Raspberry Pi/Linux: OpenWebRX or Direwolf with spreadsheet http://cubesatsim.org/telem	`config -a`	CubeSatSim.org/a	
2	FSK	Frequency Shift Keying. This mode transmits a continuous signal that makes a rumbling sound that emulates the AMSAT Fox CubeSats such as Fox-1C or AO-95. Also known as DUV or Data Under Voice.	Windows/Raspberry Pi/Linux: FoxTelem	`config -f`	CubeSatSim.org/f	
3	BPSK	Binary Phase Shift Keying. This mode transmits a continuous signal that sounds like noise that emulates the AMSAT Fox-1E or HuskSat-1 CubeSats. You need to demodulate using USB.	Windows/Raspberry Pi/Linux: FoxTelem	`config -b`	CubeSatSim.org/b	
4	SSTV	Slow Scan TeleVision. This mode transmits stored images in Scottie 2 format which sounds like a series of tones.	Windows: MMSSTV Raspberry Pi/Linux: QSSTV	`config -s`	CubeSatSim.org/s	
5	CW	Continuous Wave or Morse Code. This mode transmits a FM modulated tone at 20 words per minute Morse Code telemetry.	Windows/Raspberry Pi/Linux: fldigi with spreadsheet http://cubesatsim.org/telem	`config -m`	CubeSatSim.org/m	

- Housekeeping Telemetry
- Basic status of the spacecraft
- Temperatur
- Spannungen
- Ströme
- Spin und Beschleunigung

CubeSatSim Demo

Groundstation "Fox in a Box" **192.168.0.101** MAC: ...-28-C9 **pi** **VNC** oder **Tastatur & Maus**	 Netz **AMSAT-HB** !!	**CubeSatSim** 192.168.0.102 MAC: ...-EB-D8 **pi** **putty**
	Router "AMSAT-HB" **192.168.0.254** MAC: ...-C9-FA **Webbrowser**	

Martin Klaper, HB9ARK	Ref.: Anleitung für CubeSatSim Demonstrationen V-1.1.docx



AMSAT-HB Switzerland

Ausbildung, Webinare, Vorträge

- Erste Schritte
- Webinare / HamAcademy
- Coaches
- Externe Ausbildung

Verein

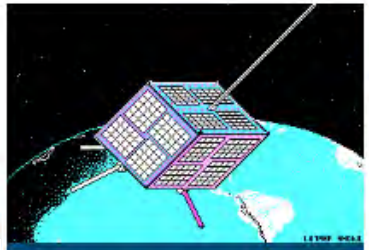
- Vorstand
- Geschichte
- Mitglied werden
  - Antragsformular
- Aktivitäten unserer Mitglieder
- Termine
- HB9RG
- Statuten

Satelliteninfo

- Einführung
- Operating
- Telemetrie
- Frequenzen
- QO-100
- Artikel

ARISS / QO-100 Schulkontakte

- ARISS
  - ARISS Einführung
  - Informationen für Lehrer
  - Informationen für Schüler
  - Für Funkamateure



OSCAR - News April 2023
26.04.2023 , Thomas HB9SKA

Das erste deutschsprachige, unabhängige Bulletin über AMSAT und HAM-Space Neu in Ausgabe A...

ARIS-Team besuchte SwissCube
14.04.2023 , Thomas HB9SKA

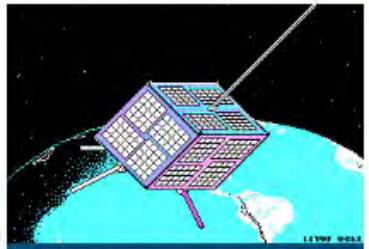
Am 12.4.2023 besuchte ein Teil des ARIS-Teams HB9MFL, welches einen neuen CubeSat baut, um zu se...

Drei Funkamateure fliegen zu...
03.04.2023 , Lipp Michael

Die NASA hat heute die Crew bekannt gegeben, welche voraussichtlich 2024 zum Mond fliegen werden...

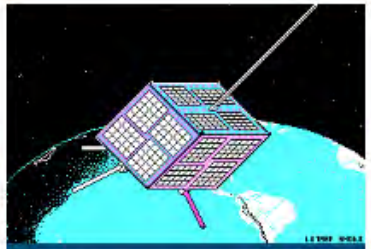
DXpedition Malediven (8Q)
30.03.2023 , Thomas HB9SKA

Michael Zwingl, OE3MZC, kündigt eine DX-Aktivität mit vier Funkamateuren aus Österreich an. Der ...



OSCAR - News März 2023
22.03.2023 , Thomas HB9SKA

Das erste deutschsprachige, unabhängige Bulletin über AMSAT und HAM-Space Neu in Ausgabe M...

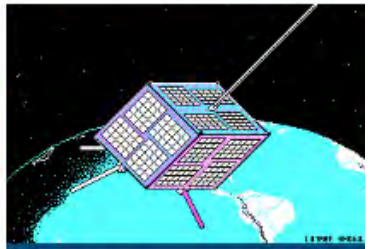


OSCAR - News Februar 2023
22.02.2023 , Thomas HB9SKA

Das erste deutschsprachige, unabhängige Bulletin über AMSAT und HAM-Space Neu in Ausg...

SWISS STUDENTS' SATELLITE PR...
29.01.2023 , Frey Thomas

NEIL/ANCHOR: An educational satellite built by Swiss students is being prepared for an important...



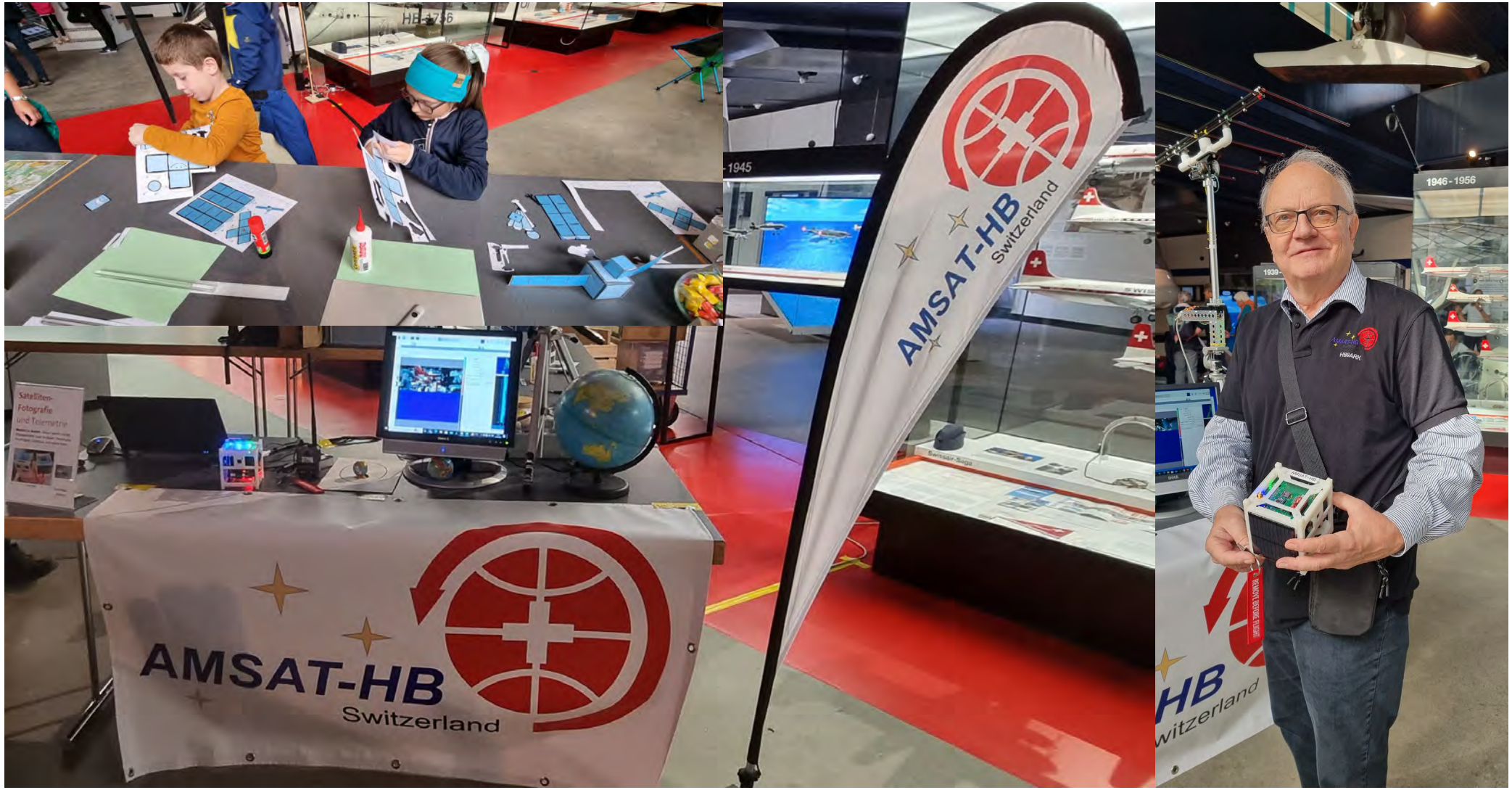
OSCAR - News Januar 2023
24.01.2023 , Frey Thomas

Das erste deutschsprachige, unabhängige Bulletin über AMSAT und HAM-Space Neu in Ausgabe J...

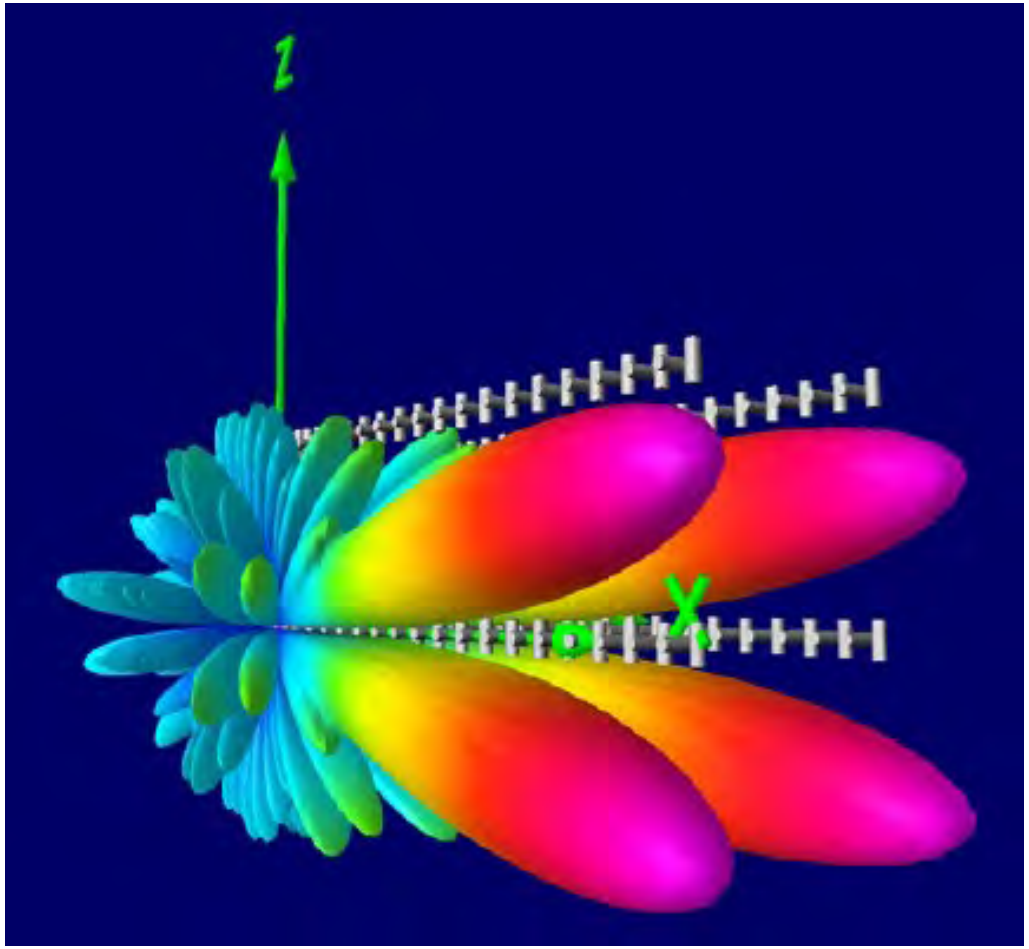
https://www.amsat-hb.org

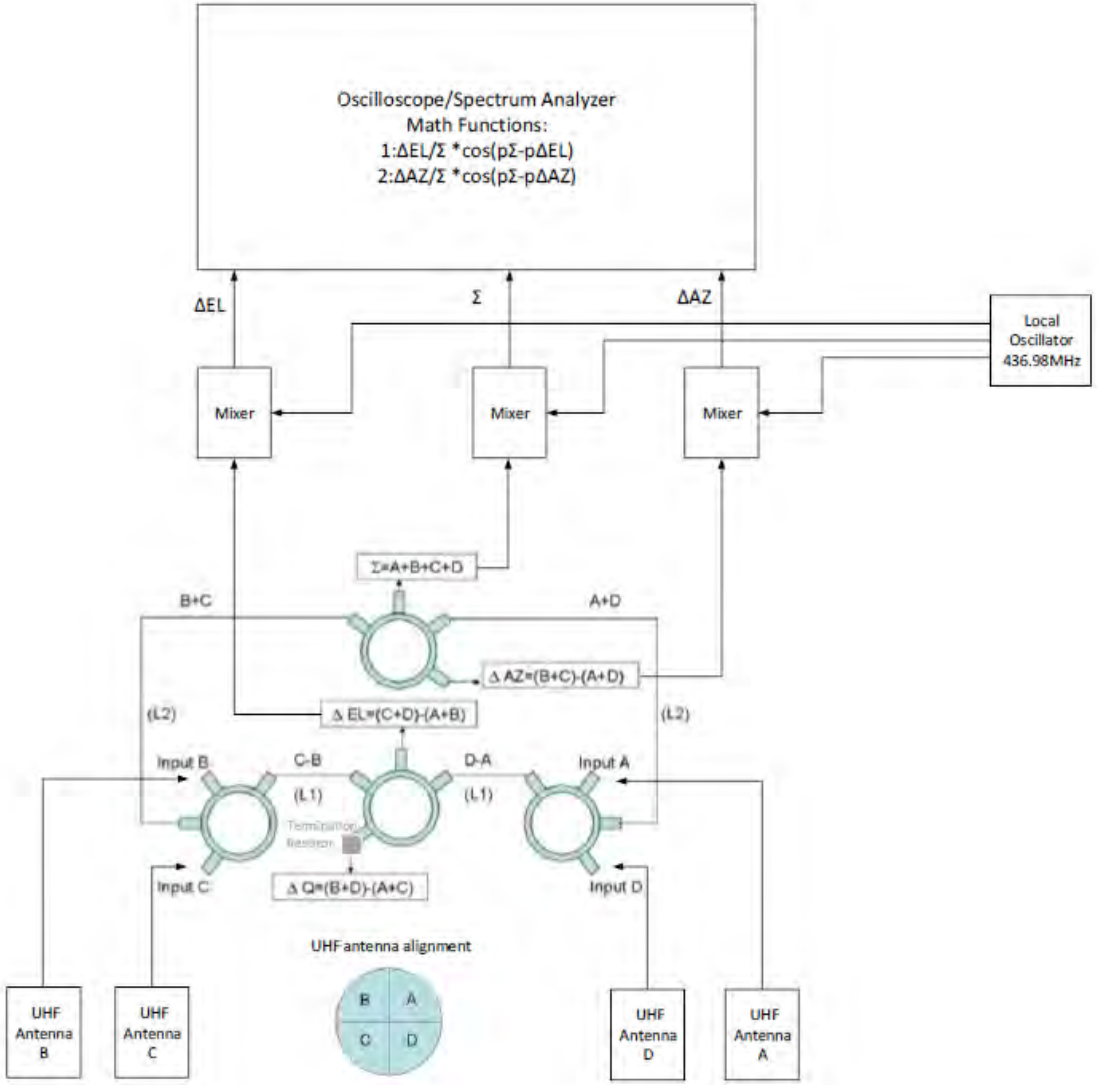
Air and Space Days im Verkehrshaus der Schweiz

6. bis 8. Oktober 2023



Zugabe

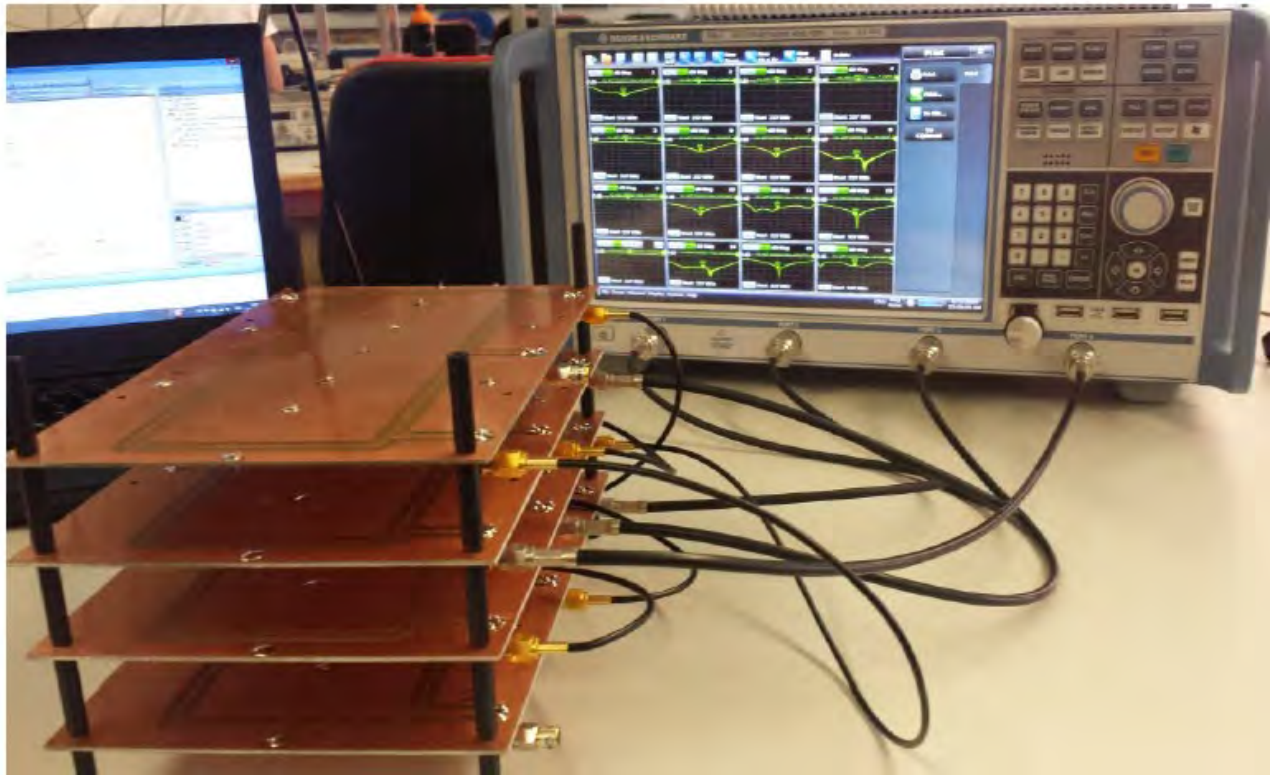


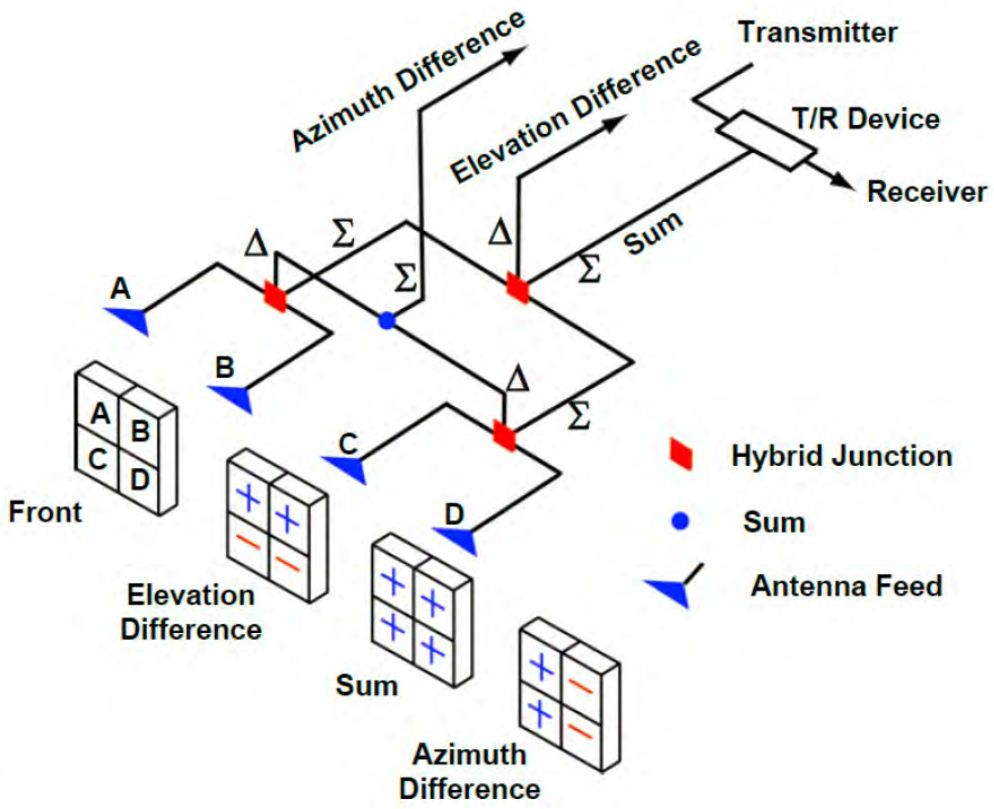


Thesis Siro Kaufmann

"Rat Race"

Test of the Microwave Combining Network





Danke für die Aufmerksamkeit

Fragen und Diskussion