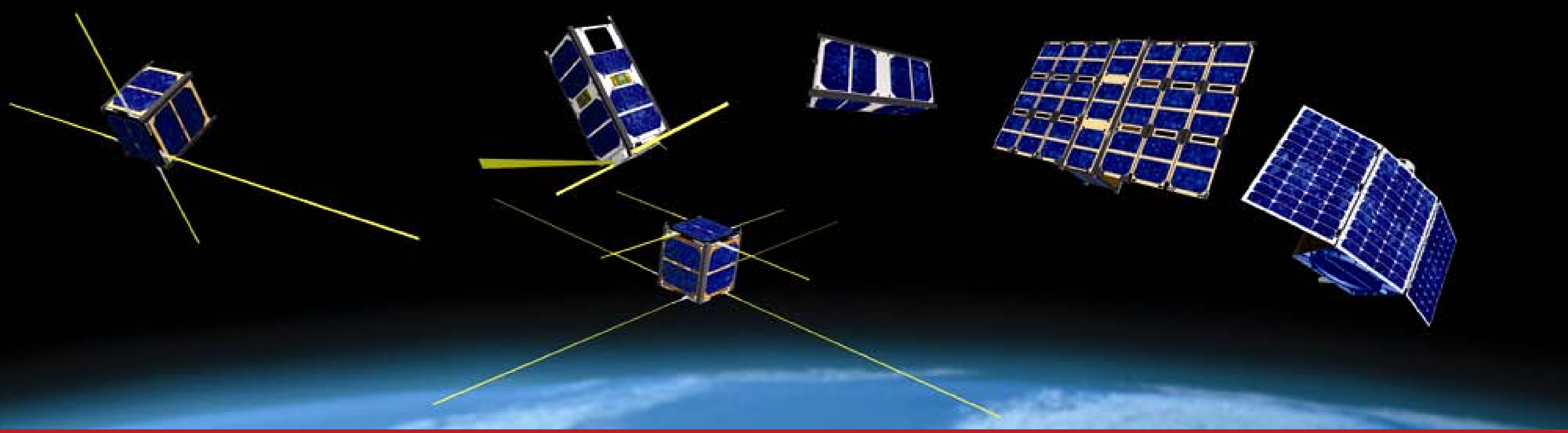
ISIS – Innovative Solutions In Space

Closing the Link

Communication System Technology Developments

Joost Elstak



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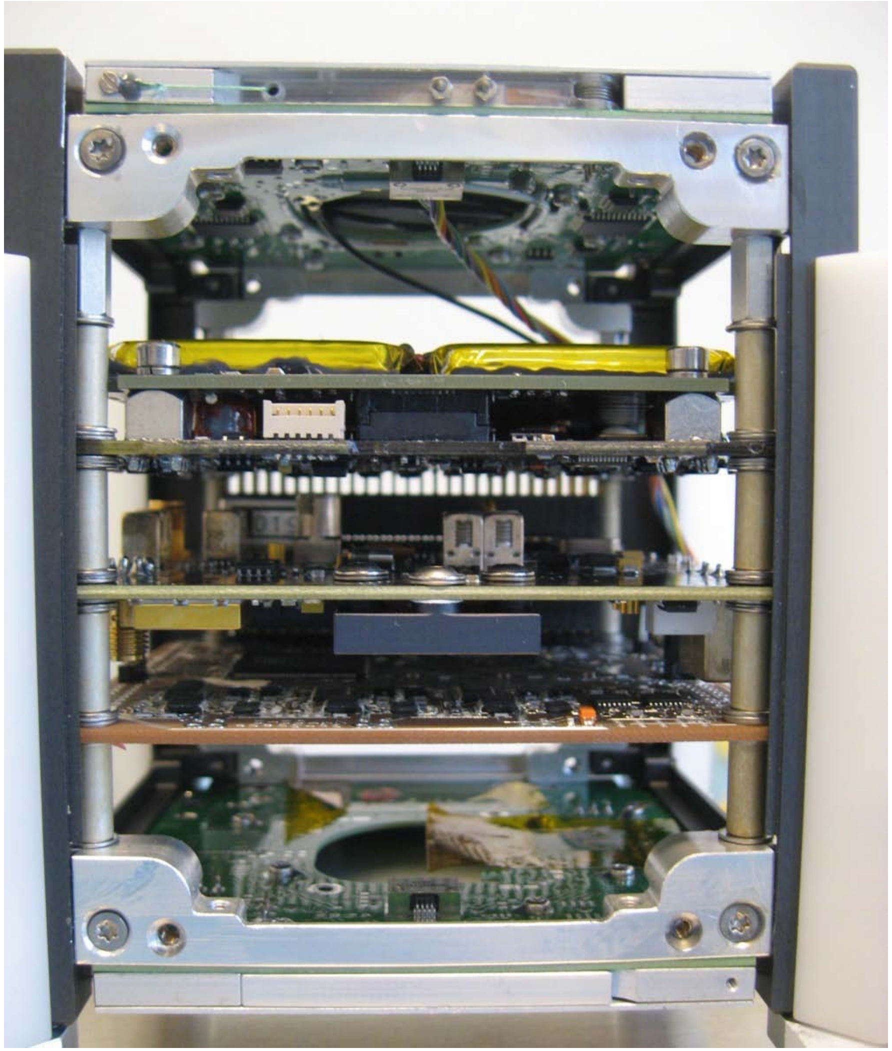
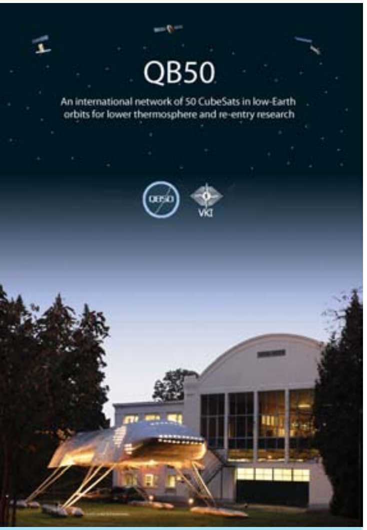
Challenges

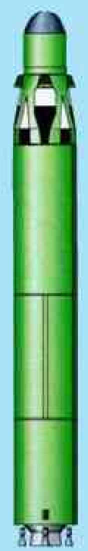


Current Comms Challenges

- Increase data transfer
  - Increase data rate
  - Increase contact time
- Operate in constellations/clusters
  - Inter-satellite interference
  - Communication with multiple satellites
- Finding a solution within CubeSat constraints is very challenging
  - Form, Fit, Function
  - Programmatics (time & money available)
- **Do better in a more challenging environment**

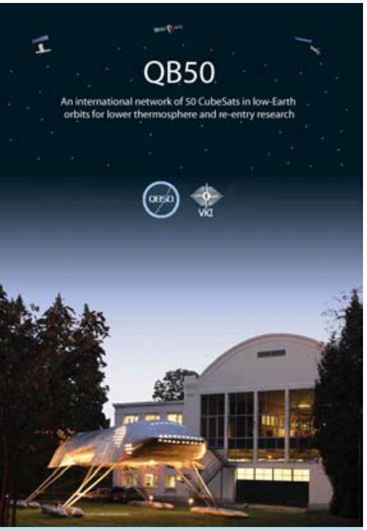
The QB50 example





- Initiative lead by von Karman Institute
- Constellation of 50 2U Cubesats
- Single launch deployment
  - 300 km, 80° inclination
  - 3 - 12 weeks lifetime
- In-situ measurement of the lower thermosphere
  - Standard sensors suite
  - Measurement during orbit decay
- Expected KO Q4 2011
- Expected launch 2013-2014

ISIS in QB50

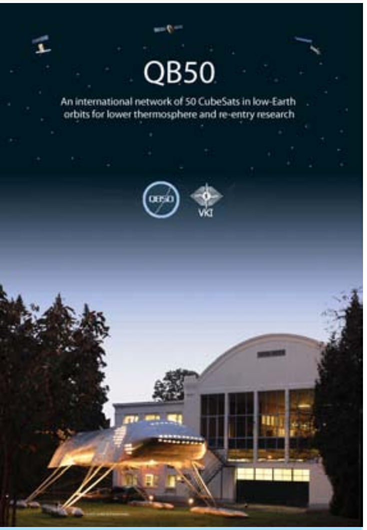


- Launch service providers
- Communication WP

Main interface between:

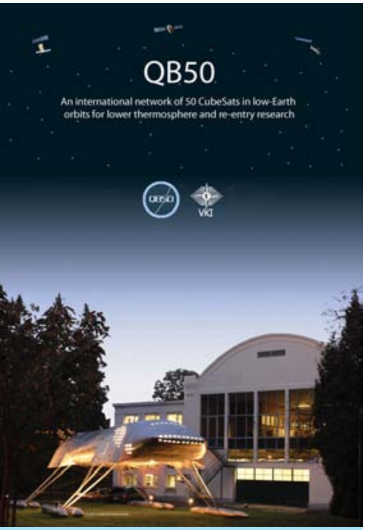
- Launcher
- Cubesat teams
- Ground stations

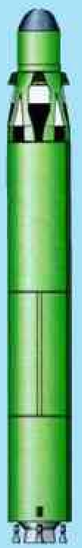
Challenges in QB50



- Launch
- Operations
- Communications

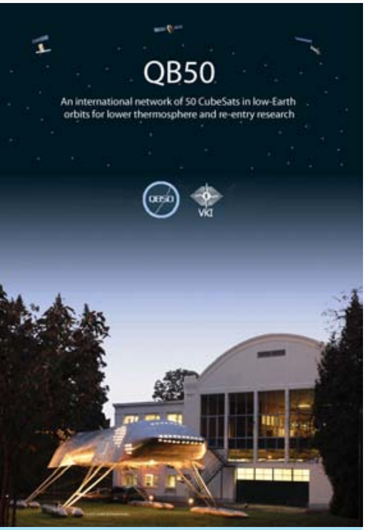
Challenges in QB50





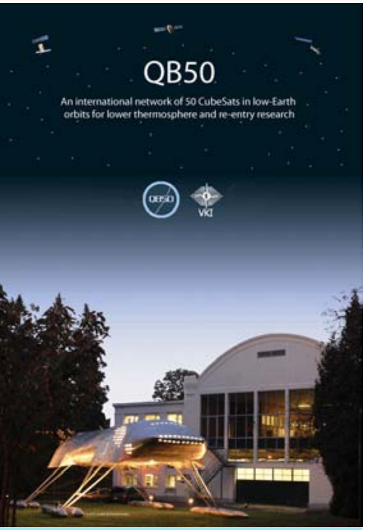
- Launch
  - 50 Cubesats in one launch
  - 50 development teams
  - Different mass, ballistic coefficient, etc...
  - Possible collisions between satellites
- Operations
- Communications

Challenges in QB50



- Launch
- Operations
  - Extremely short lifetime (3 - 12 weeks)
  - Extremely short commissioning (~ 1 day)
  - Short satellite passes:
    7 min max at the beginning
    4 ÷ 5 min max at the end
  - TLE not reliable during decay
  - Scientific data cannot be lost
- Communications

Challenges in QB50

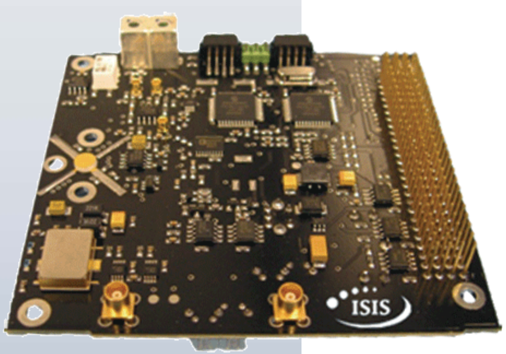


- Launch
- Operations
- Communications
  - 10 ÷ 30 sats visible at the beginning at the same time
  - 2 ÷ 5 sats visible at the end at the same time
  - Limited spectrum available (Radio Amateur bands, VHF / UHF / S)
  - Limited power onboard
  - Single satellite tracking is not efficient

Solutions

Software Defined Radio

- Move complexity to Software
- Standard hardware platform
- High flexibility (modulation / datarate)
- Simple reconfiguration / upgrade




SDR Transmitter / Transceivers

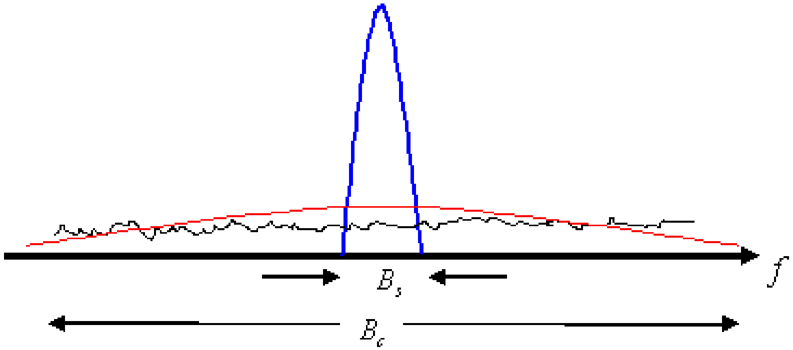
Ground station Transceiver

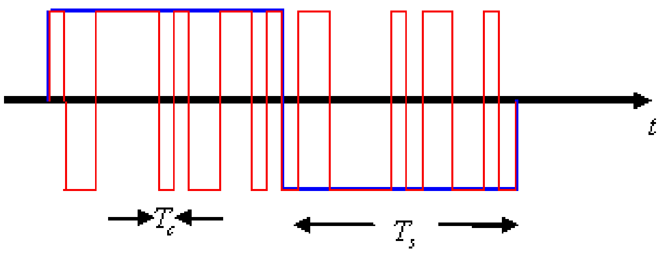
Software Defined Radio

- Bandwidth efficient modulations:
  - BPSK, QPSK
  - Variable datarate: 1.2 ÷ 1000 kbit/s
  - Good performances with noise
- Advanced channel access mechanisms can be used
  - FDMA & TDMA can have a lower efficiency (frequency drift, clock drift)
  - CDMA can be a viable anternative

Code Division Multiple Access

- Used in 3G phones
- Spectrum is spread over a wider bandwidth using a pseudo-random noise generator
- Less interferences due to narrow-band signals





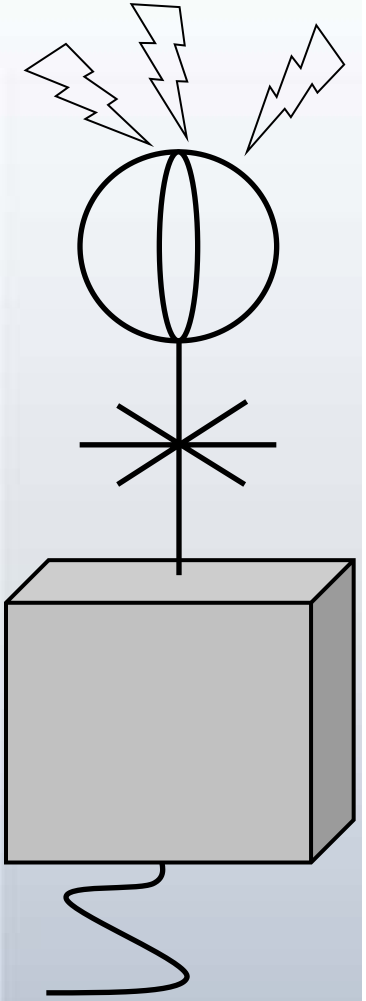
Increase contact time

- Ground station network
  - Automatic data delivery
  - Ex: RASCAL, GENSO
- All limited to 1 satellite at once
  - Limiting factor for QB50
  - Requires ground station capable to receive multiple satellites at once
  - Massive increase in contact time

Omnidirectional ground station

- Tracking ground station has limited field of view
  - Limited by antenna beamwidth
- Omni-directional ground station can monitor the whole sky
  - Simultaneous multiple satellite reception: 10 ÷ 20 in QB50
  - Requires a more complex receiver Multiple simultaneous SDR receivers
  - TLE are not necessary: They can even be computed!

Omnidirectional ground station



- Omni-directional
  - Cheap setup, easy installation
  - Omni-directional antenna: ~3 dB gain
  - Low datarate: 1.2 ÷ 9.6 kbit/s
  - Simple requirements for roof mounting: no moving antennas, small area required
  - Multiple receivers
  - Medium computational power required
  - Can compute satellite TLEs
  - GPS receiver for precise frequency, time and position reference

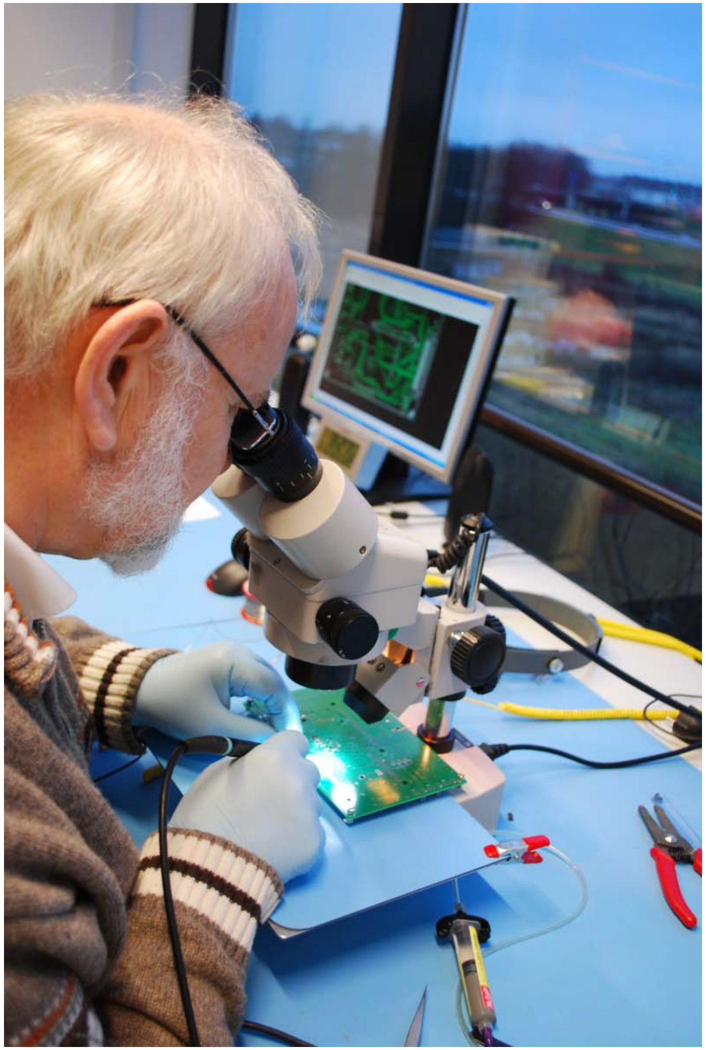
Higher Speed: S-band

- Wider bandwidth available
  - Amateur: 2 MHz
  - Commercial: requires license
- High datarate possible
  - 38k4 ÷ 1000 kBit/s
- Short contact time
  - 5 min pass
  - 6 ÷ 18 Mbyte per pass

S-band

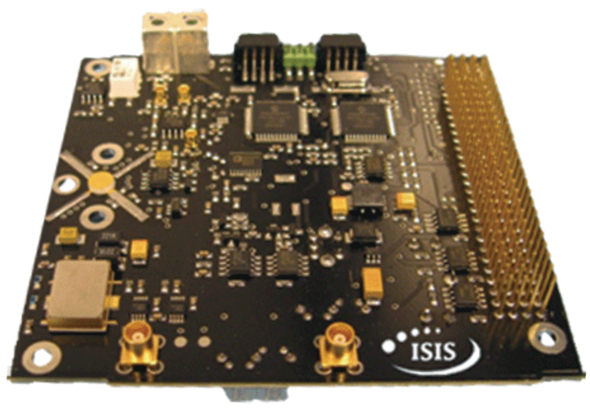
- Communication is limited by average power consumption (~1.5 W avg per orbit)
- Attitude control may be needed depending on satellite antenna
  - Complex during orbit decay
  - Can be compensated with a higher antenna gain on ground
- Downlink in radio-ham frequencies or commercial S-band (shared)
  - Maximum speed should be traded with available bandwidth and number of users

Implementation



Next Generation Transceivers

- TrxUV/TRXVU
  - High output power (up to 1 W)
  - BPSK and QPSK
  - Fully software defined transmitter
- Availability: H1 2012



Next Generation Transmitters

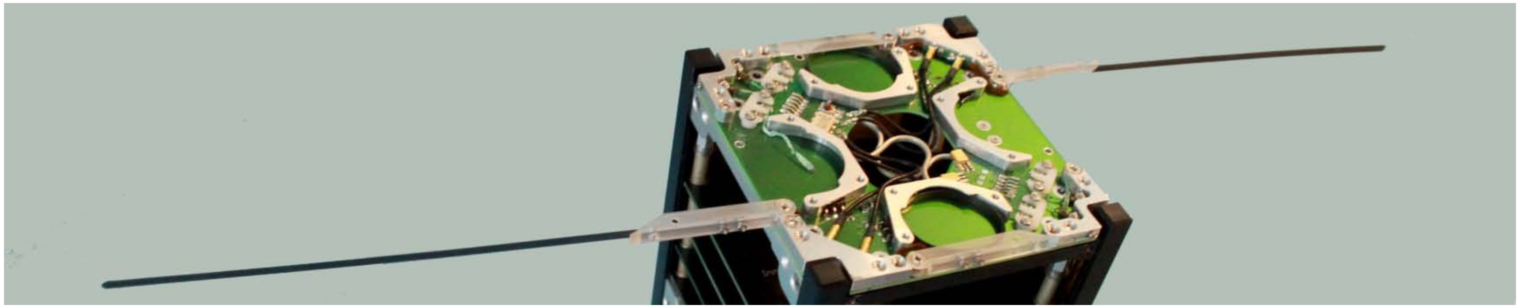
- TXS-100/1000
  - Fully software defined transmitter
  - BPSK, QPSK and GMSK capable
  - Datarate up to 1Mbit/s
  - > 27 dBm output power
  - < 4 W power consumption
- Availability:
  - 38k4: Now
  - 100 kbit/s: Q4 2011
  - 1 Mbit/s: Q2 2012

Next Generation Ground systems

- Completely software defined
  - Datarate, modulation and frequency agile
  - Replacement for out of stock ICOM-910H
  - Wideband receiver, datarates up to 1 Mbit/s available
- VHF / UHF / S-band
  - Up to 3 m dish
  - Radome available for hostile environments
- Central control console for easy operations
- Omnidirectional systems investigated

Conclusions

- Challenges
  - Do better in a more challenging environment
  - Maximizing data received within challenging CubeSat constraints
  - Operate constellations
- Solutions
  - System level optimization
  - New technology implementations on ground and in space
- Current technology and smart solutions can solve these problems



Joost Elstak - j.elstak@isispace.nl - www.isispace.nl – Small Sat Booth 4-5

Code Division Multiple Access

- Pseudo-random noise helps in spreading the bandwidth
- If the pseudo-ramdom sequence is known, data can be de-spread
- If the sequence is unknown, the signal looks like white noise
- Multiple sources can use the same channel without interference

Channel coding

- FEC gives high gain in link budget
  - AO-40: ~ 5 dB gain @ BER = 10^{-6}
  - AO-40: 40% code rate
- Limited use in Cubesats
  - Usually link budgets were not critical, a higher antenna gain or output power was possible
  - Channels are usually bandwidth limited
  - AX-25 does not support it natively (FX-25)
  - Added complexity, longer development time

Channel coding in QB50

- It does not need to be compliant with AX-25
  - No TNC available for BPSK, QPSK
  - SDR or soundcard modem needed
  - Protocol should be public
    freely available software decoder would be a plus
- Many new developments in the amateur world are going this way (ARISSat)
  - AX25-like protocol, with convolutional codes

S-band

- Communication is limited by average power consumption (~1.5 W avg per orbit)
  - 5 ÷ 10 W power consumption for few minutes every orbit
  - Only one ground station contact per orbit
- Attitude control may be needed depending on satellite antenna
  - Complex during orbit decay
  - Can be compensated with a higher antenna gain on ground
- Requires precise TLEs
  - Complex during orbit decay
  - Use VHF/UHF beacon for more precise tracking

Omnidirectional ground station

- Beam steering antenna array
  - No moving parts
  - High gain
  - Multiple satellites visible: 10 ÷ 20
  - Requires a quite complex receiver Multiple simultaneous SDR receivers
  - High computational power required