Proposal for a Geostationary Microwave Amateur Radio Payload

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AMSAT-DL
Satelliten für Kommunikation, Wissenschaft und Bildung
Satellites for Communication, Science and Education

Considerations

Orbit

Satellite & Platform

Payload

technical requirements and demands of radio amateurs

Orbit – GEO pro‘s and con‘s

Among the possible orbits such as LEO, MEO, HEO and GEO, the **GEO** orbit has proven to be the <u>most suitable</u> orbit for the requirements based on the extensive experience with OSCAR-100.

Advantages:

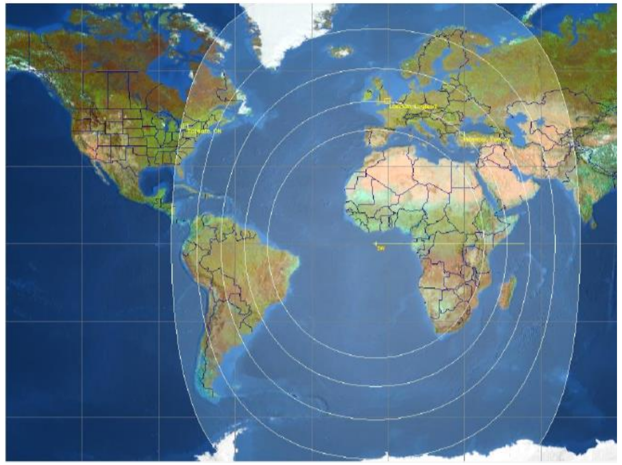
+ Great coverage (a GEO satellite can see the surface of the Earth up to 81 degrees away from its sub-satellite-point).
+ No problems on the ground with tracking using high-gain antennas with amateur equipment
+ Reliable 24/7 availability even in the case of emergency radio applications for radio amateurs
+ Relaxed requirements with respect to radiation hardness as outside of Van Allan belt

Disadvantages:

- Orbit position (ITU compliant) depending on the host (co-flight)
- Hosted payload (limited control possibilities and telemetry/science data)
- Not all areas of the world can be reached. If possible an orbit position should be chosen which covers a high population of radio amateurs

A HEO orbit would be second best and still a viable option.

Orbit – positions to reach many radio amateurs



Elevation contours 10deg increments
(Source: AMSAT-UK)

Coverage from a GEO satellite at 5 degrees west. Not ideal because the area of North America / Canada is not properly covered

Coverage from a GEO satellite located at 47 degrees west. Almost ideal, with the disadvantage that some eastern European countries and Asia is not covered. North America and most of Canada with a large number of active radio amateurs are covered.

Good compromise would be a position at ~43 degrees west which supports also the Eastern European countries and still most of North America including Canada

Orbit - positions to reach many radio amateurs

Canadian Provinces East of and Including Ontario

Canadian Population (2019) 39 million

Total Land Area (km2) 9.93 million

Province	Population	Percentage of total population	Percentage of land area
Ontario	15.110m	38.74	10.84
Quebec	8.695	22.29	15.53
New Brunswick	0.812	2.08	0.734
Nova Scotia	1.020	2.62	0.557
Prince Edward Island	0.171	0.44	0.057
Newfoundland / Labrador	0.526	1.35	4.080
Totals	26.334	67.52	31.75

Source: Population Canada (from AMSAT-UK proposal)

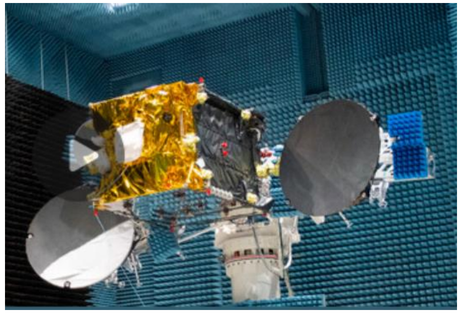
Although the longitude selected for the mission will primarily depend on the availability of a suitable partner and launch, it is worth comparing the populations of Europe and Canada. Europe, as a whole, has a population of 742 million while the table below shows Canada has 39 million inhabitants. It can be shown from population distribution, that **it is possible to provide a service to 67% of the Canadian population who live within 31% of the total land area.**

Satellite and Platform

With regard to the costs for satellite platforms and also launching a satellite, the following must be taken into account for an amateur radio satellite:

Hosted Payload (fly with a provider who also determines the orbit position):

	Small GEO chemical	Small GEO hybrid	Small GEO electrical	Micro GEO electrical
estimated Payload Power	~2,5kW	~3,6kW	~9,5kW	~1,5kW
estimated Gbps/BW	~25	~35	~100	~5
Payload Mass		~400kg	~500kg	~150kg


Satellite and Platform

Advantages of a solution based on a hosted payload:

+ With OSCAR-100, radio amateurs can draw on experience in operating a payload as a hosted payload.
+ From a cost perspective, this is an ideal way to fly a small payload.
+ There is a relatively large amount of DC power available
+ The radio amateurs have no effort when it comes to, for example, attitude control and management & control (Launch-And-Early-Orbit-Phase LEOP, In-Orbit-Testing IOT) of the satellite.

Disadvantages of a solution based on a hosted payload:

- Orbit position cannot be freely chosen (given by provider)
- No influence on steering and maneuvers. (Transponders are simply turned on or off)
- Any changes to the settings (LCAMPS gain, FGM. ALC, etc.) must be adjusted via the Satellite-Communications-Controller (SCC).
- Difficulties with AMSAT's own developments (qualification, influencing the main payload).
- No own telecommand/telemetry for control and monitoring purposes (possibly solvable with own OBP).
- No real time access and control of experiments (e.g. from schools / universities).

Satellite and Platform

Own AMSAT (amateur radio) mission based on a Micro GEO supported by ESA:

- An ideal solution would be a Micro GEO satellite for amateur radio. As described above, we are in the ~**1.5kW/150kg** class, which would be ideal for a payload for amateur radio.

- Small electric powered engines make it possible to adjust the satellite's orbit position if necessary. All areas of the world can be reached here. The small satellite can also be used easily in the event of an emergency radio situation.

- A development of such a **Micro GEO Platform** in an e.g. ESA program (e.g. by industry with the support of AMSAT for a suitable payload) would be an ideal situation.

- This approach also supports AMSAT's goals for training, science and development as well as the opportunity for industry to develop and test a Micro GEO Platform and to inspire young people for technology through the free frequencies of amateur radio.

Satellite and Platform – possible launcher

An Amateur Radio Micro GEO satellite might also be the ideal test vehicle for the upcoming European launchers

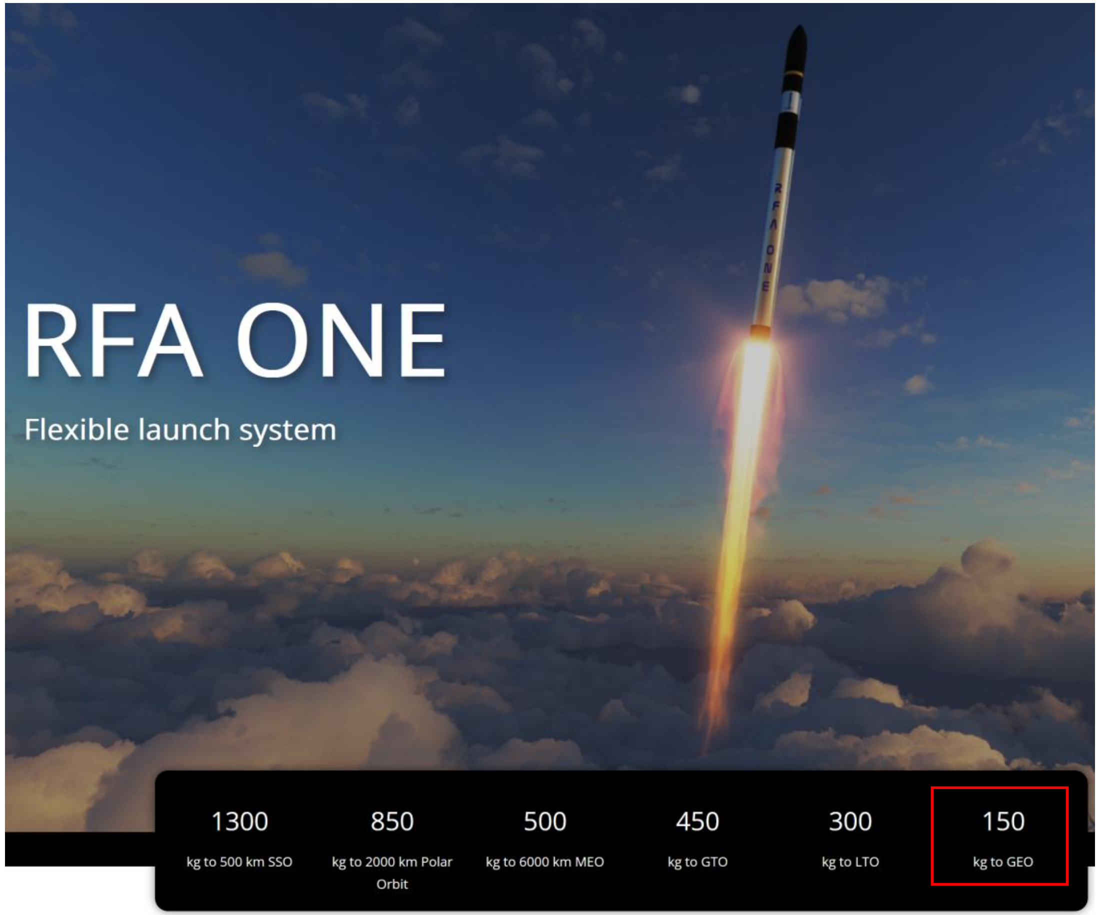


Image Internet, Rocket Factory Augsburg

Satellite and Platform

Image Internet, Astranis
https://aviationweek.com/defense-space/space/astranis-wins-space-force-contract-option-demo-microgeo-sat

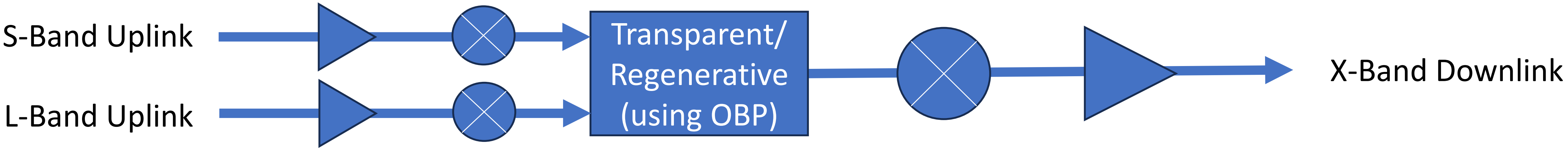
Example for a Micro GEO Satellite

Payload ideas

A payload for amateur radio should allow the greatest possible scope for experiments in different bands. In addition, the payload should also be cost/benefit optimized and thus keep the effort on the satellite as low as possible. It also makes sense to use modules that are compatible with the SGEO platform (100V bus, CAN bus, HPC, HVC).

A main downlink in the **10GHz band (3cm)** is essentially suitable for narrow and broadband applications. Reception in the 10GHz band makes it relatively easy as there is a wide range of converters, LNBs and antennas on the market. You can also access a broad wealth of experience from OSCAR-100 and use existing receiving stations.

A wide range of amateur frequency bands could be used for the uplink, which allows a wide spectrum for experiments on the ground. Crossband operation such as **23cm uplink** and **13cm uplink** with a common downlink on the **3cm band** would be conceivable.



EXAMPLE

Payload ideas – feasible frequency bands

IARU Amateur satellite allocations (revision January 2020)

Frequency range	Allocation (P=primary, S=secondary)	Regions	Remarks
144-146 MHz	(P)	1,2,3	
435-438 MHz	(S)	1,2,3	
1260-1270 MHz	(S)	1,2,3	only Earth to Space (uplink)
2400-2450 MHz	(S)	1,2,3	(2400-2403 MHz only narrowband)
3402-3410 MHz	(S)	2,3 only	only Space to Earth (downlink)
5650-5670 MHz	(S)	1,2,3	only Earth to Space (uplink)
5830-5850 MHz	(S)	1,2,3	only Space to Earth (downlink)
10450-10500 MHz	(S)	1,2,3	
24000-24050 MHz	(P)	1,2,3	24000-24048 MHz & 24049-24050 MHz
47000-47200 MHz	(P)	1,2,3	47088-47090 MHz
76000-77500 MHz	(S)	1,2,3	
77500-77501 MHz	(P)	1,2,3	

Payload ideas – feasible frequency bands

The following frequency bands are available for amateur radio via satellites:

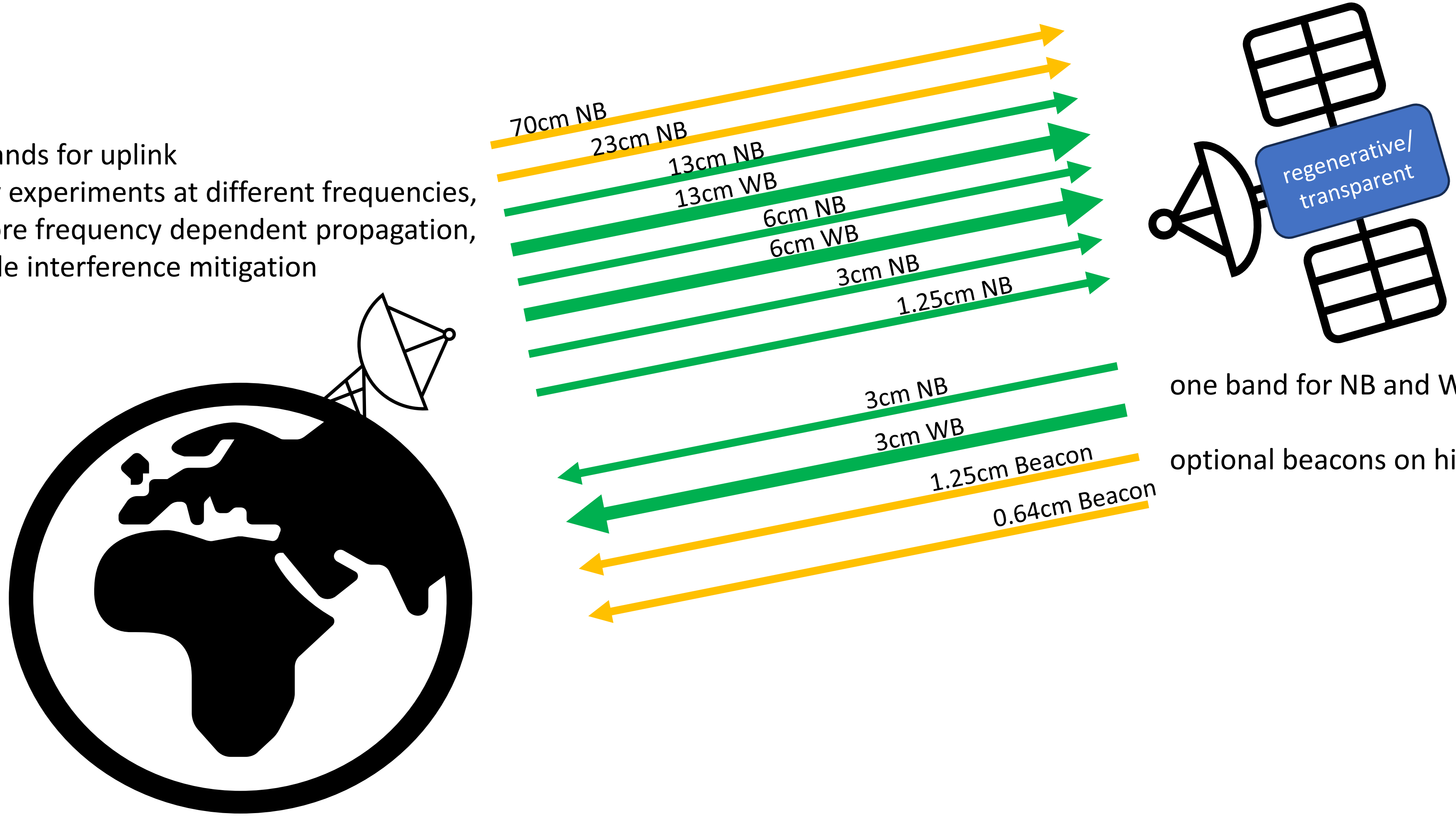
Downlink NB	Uplink NB	Accommodation possible	Remarks
3cm Band (higher section)	144–146 MHz / 2m Band	red	antenna size with reasonable gain very large
3cm Band (higher section)	435–438 MHz / 70cm Band	orange	antenna size with reasonable gain large, t.b.c.
3cm Band (higher section)	1 260–1 270 MHz / 23cm Band	orange	if band still available most countries
3cm Band (higher section)	2 400–2 450 MHz / 13cm Band	green	like OSCAR-100
3cm Band (higher section)	3402–3410 MHz / 9cm Band	red	only Space-to-Earth and not in all regions available
3cm Band (higher section)	5 650–5 670 MHz / 6cm Band	green	accommodation of antennas feasible
10,450-10,500 GHz / 3cm Band (higher section)	10,450-10,500 GHz / 3cm Band (lower section)	green	feasible with a suitable duplexer
3cm Band (higher section)	24–24,05 GHz Band / 1,25cm Band	green	horn antenna / accommodation ok /maybe beacon
3cm Band (higher section)	47–47,2 GHz Band	orange	horn antenna / difficult for users, maybe beacon
3cm Band (higher section)	76–77,5 GHz Band	red	horn antenna / difficult for users

Advantage: no ITU regulation needed

Remark: to cover the whole visible footprint of the satellite an antenna gain of approx. 17dBi is needed

Payload ideas – feasible frequency bands

six bands for uplink
allow experiments at different frequencies,
explore frequency dependent propagation,
enable interference mitigation



incl. IoT, M17, DVB-S2x or 5G-alike

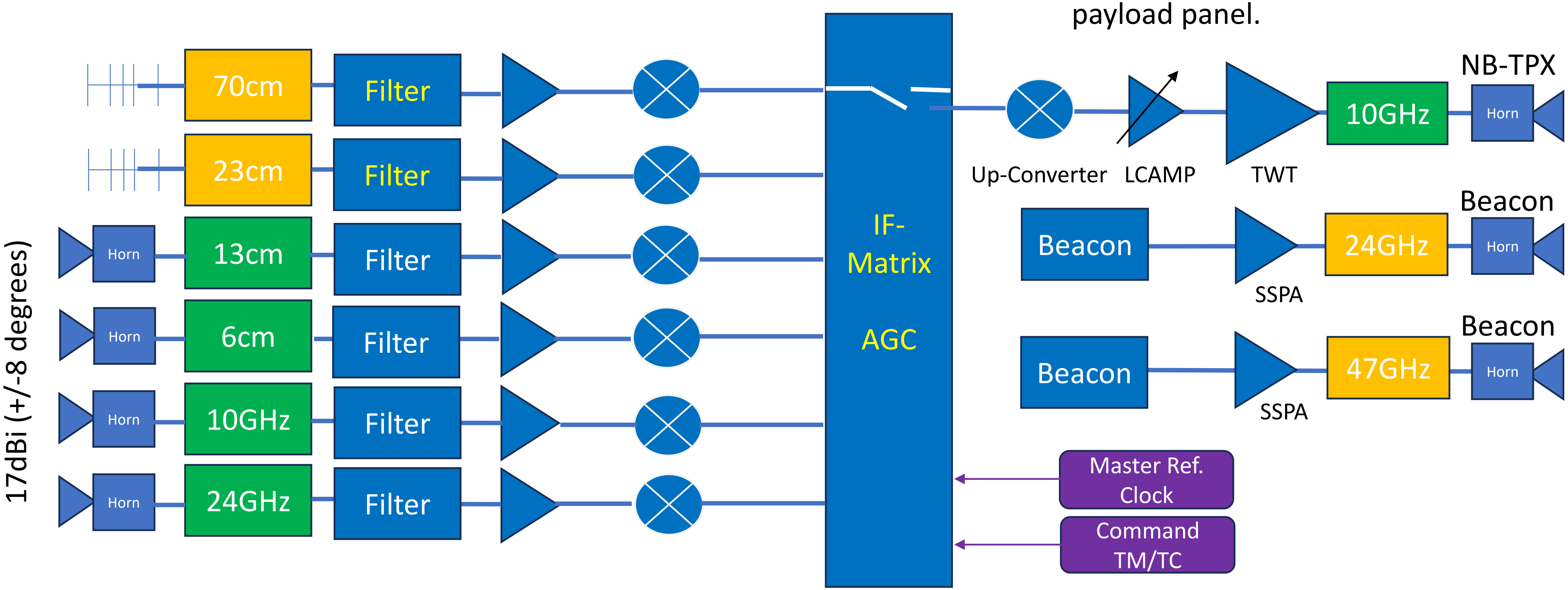
one band for NB and WB downlink (10GHz)

optional beacons on higher GHz bands (24&47GHz)

Payload ideas – transparent transponder

Simple block diagram NB **transparent TPX** (300kHz BW):

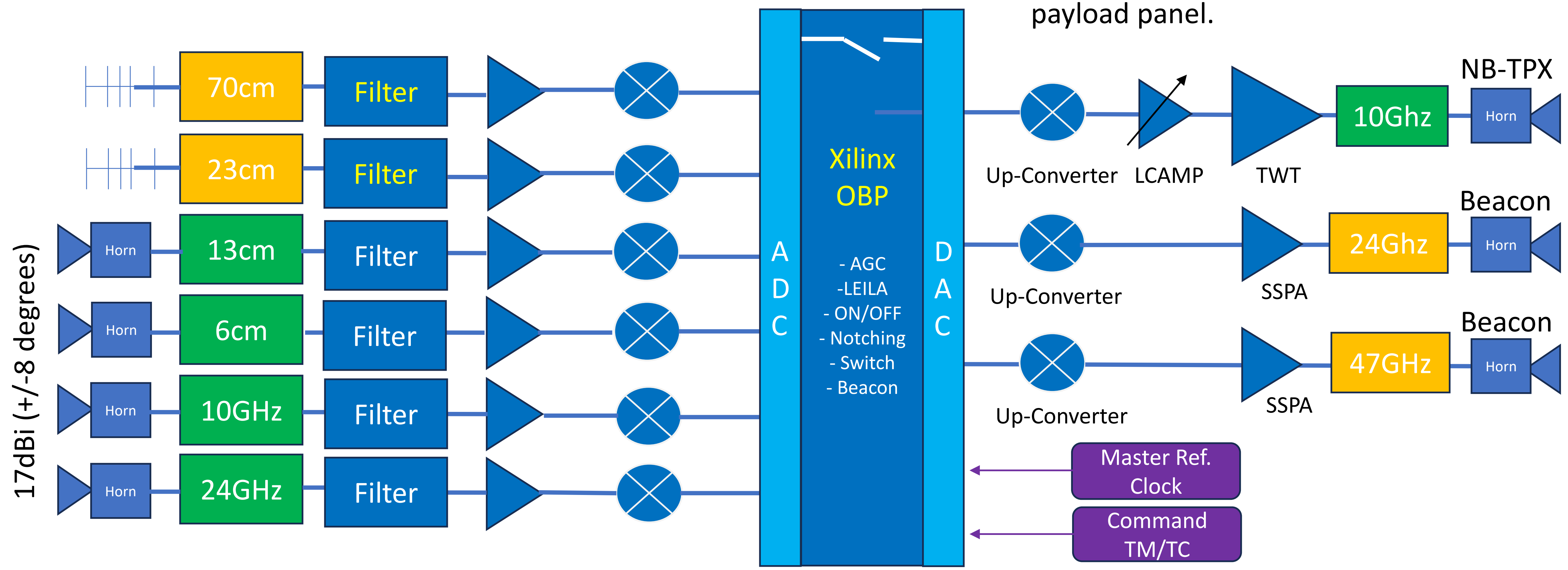
LNA & converter near the Earth deck. All other payload components on the payload panel.



Payload ideas – regenerative transponder

Simple block diagram NB **regenerative TPX** (300kHz BW):

LNA & converter near the Earth deck. All other payload components on the payload panel.

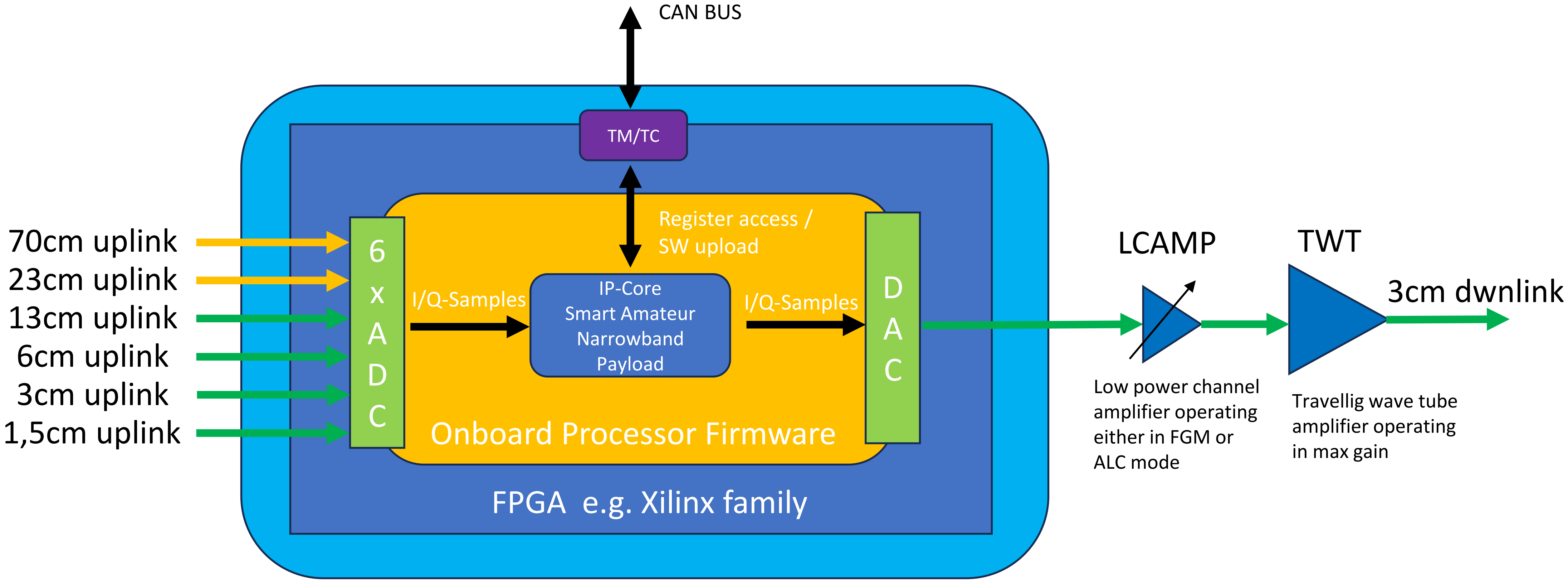


Payload ideas – on board processor (OBP)

- The **transparent** and **regenerative** transponders must be designed in such a way that if the regenerative part fails, the transponder can continue to be operated in an analogue (transparent) manner.

- A good partner for the development of such an IP core or the required hardware could be the company Neosat with support from AMSAT.

Payload ideas – block diagram processor



FPGA Narrowband SDR Radio

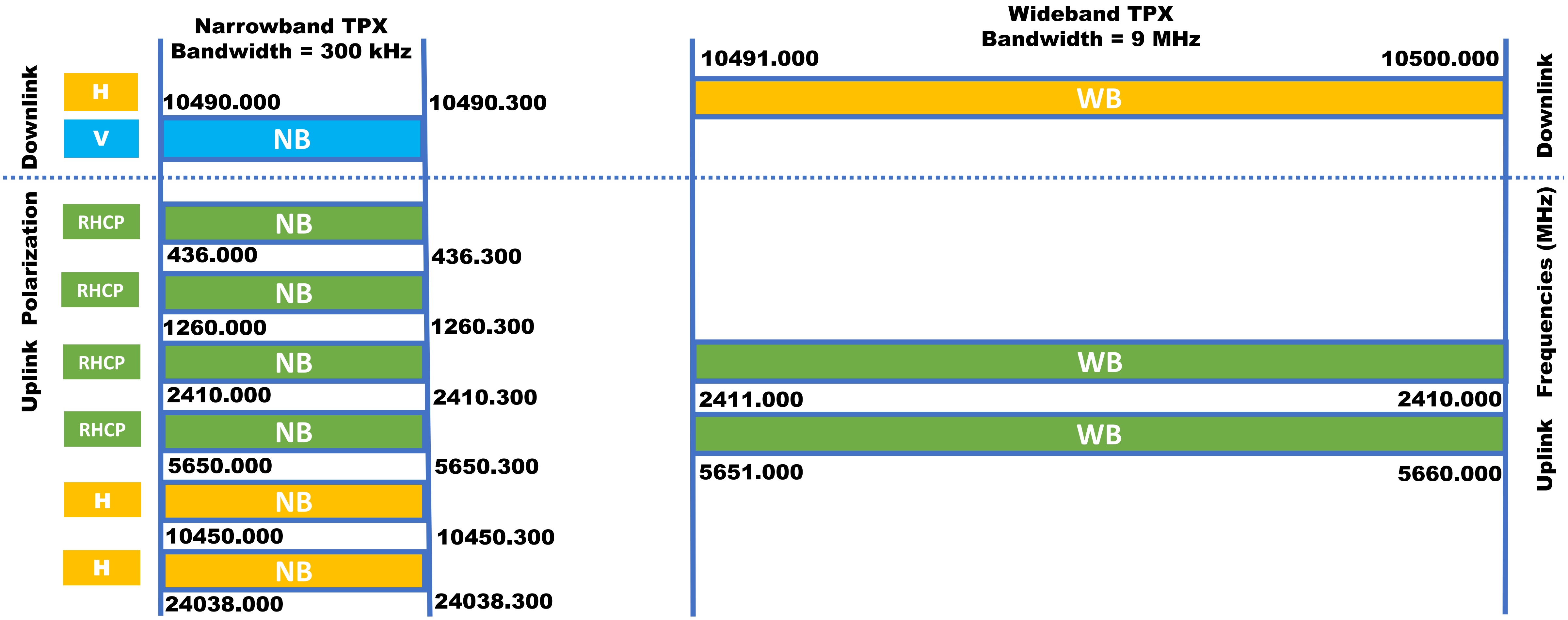
(High Level System View)

Payload ideas - draft frequency plan

Uplinks	Downlinks
435 - 438 MHz (NB)	
1260 - 1270 MHz (NB)	
2410 - 2420 MHz (NB & WB)	
5650 - 5660 MHz (NB & WB)	
10450 - 10460 MHz (NB)	**10490 - 10500 MHz (NB & WB & beacons)**
24038 - 24048 MHz (NB)	24049 - 24050 MHz (beacon)
	47000 - 47200 MHz (beacon)

Main uplink band is 13cm, main downlink band is 3cm.

Payload ideas - draft frequency plan



Payload ideas - link budget 70cm/3cm TPX

- UX-NB-transponder
- Uplink: 438MHz / 70cm band
- Downlink: 10GHz / 3cm band
- GEO satellite position:
  -43° West
- Ground station position:
  San Francisco (at the very edge of the footprint)

Uplink

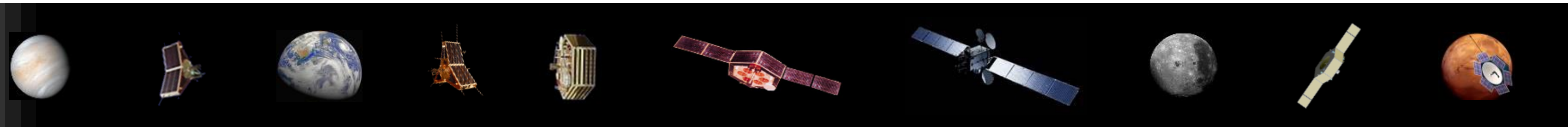
TX ground terminal		
Freq	0.438	GHz
Wavelength	0.684931507	m
Dish size	1.2	m
Aperture efficiency	0.65	
Gain	12.9	dBic
Beamwidth	40.0	deg
PA output	50	W
TX losses	3.0	dB
EIRP	**26.9**	dBW
Path		
TX lat	37.7562	deg N
TX lon	-122.443	deg E
Slant range	41720	km
Path loss	177.7	dB
Atmospheric losses	0	dB
Fade margin	1	dB
Transponder input		
Spacecraft G/T	-23	dB/K
C/No	53.9	dBHz
Channel BW	2400	Hz
C/N	**20.1**	dB
Pointing data TX		
Azimuth	96.5	deg
Elevation	0.4	deg

Downlink

Transponder output		
Freq	10.5	GHz
Wavelength	0.029	m
TWTA output	100	W
Output back off	6	dB
TX losses	1.5	dB
Ant gain	17	dBi
EIRP	29.5	dBi
Power sharing	50	channels
EIRP per channel	**12.5**	dBW
Path		
RX lat	37.7562	deg N
RX lon	-122.443	deg E
Slant range	41720	km
Path loss	205.3	dB
Atmospheric losses	1	dB
Fade margin	1	dB
RX ground terminal		
Dish size	0.8	m
Aperture efficiency	0.65	
Gain	37.0	dBi
Beamwidth	2.5	deg
Antenna noise temp	45	K
LNA noise figure	1.2	dB
LNA noise temp	92.3	K
Ground terminal G/T	**15.6**	dB/K
C/No	49.5	dBHz
Channel BW	2400	Hz
C/N per user	**15.7**	dB
Pointing data RX		
Azimuth	96.5	deg
Elevation	0.4	deg

1.2m dish with 12.9dBic gain has been chosen to reflect a mid sized cross Yagi

Source Spreadsheet: G0TLE



Payload ideas - link budget 23cm/3cm TPX

- LX-NB-transponder
- Uplink: 1.27GHz / 23cm band
- Downlink: 10GHz / 3cm band
- GEO satellite position:
  -43° West
- Ground station position:
  San Francisco (at the very edge of the footprint)

Uplink

TX ground terminal		
Freq	1.27	GHz
Wavelength	0.236220472	m
Dish size	1	m
Aperture efficiency	0.65	
Gain	20.6	dBic
Beamwidth	16.5	deg
PA output	10	W
TX losses	3.0	dB
EIRP	**27.6**	dBW
Path		
TX lat	37.7562	deg N
TX lon	-122.443	deg E
Slant range	41720	km
Path loss	186.9	dB
Atmospheric losses	0	dB
Fade margin	1	dB
Transponder input		
Spacecraft G/T	-15	dB/K
C/No	53.3	dBHz
Channel BW	2400	Hz
C/N	**19.5**	dB
Pointing data TX		
Azimuth	96.5	deg
Elevation	0.4	deg

Downlink

Transponder output		
Freq	10.5	GHz
Wavelength	0.029	m
TWTA output	100	W
Output back off	6	dB
TX losses	1.5	dB
Ant gain	17	dBi
EIRP	29.5	dBi
Power sharing	50	channels
EIRP per channel	**12.5**	dBW
Path		
RX lat	37.7562	deg N
RX lon	-122.443	deg E
Slant range	41720	km
Path loss	205.3	dB
Atmospheric losses	1	dB
Fade margin	1	dB
RX ground terminal		
Dish size	0.8	m
Aperture efficiency	0.65	
Gain	37.0	dBi
Beamwidth	2.5	deg
Antenna noise temp	45	K
LNA noise figure	1.2	dB
LNA noise temp	92.3	K
Ground terminal G/T	**15.6**	dB/K
C/No	49.5	dBHz
Channel BW	2400	Hz
C/N per user	**15.7**	dB
Pointing data RX		
Azimuth	96.5	deg
Elevation	0.4	deg

Source Spreadsheet: G0TLE

Payload ideas - link budget 13cm/3cm TPX

- SX-NB-transponder
- Uplink: 2.4GHz / 13cm band
- Downlink: 10GHz / 3cm band
- GEO satellite position:
  -43° West
- Ground station position:
  San Francisco (at the very edge of the footprint)

Uplink

TX ground terminal		
Freq	2.4	GHz
Wavelength	0.125	m
Dish size	0.8	m
Aperture efficiency	0.65	
Gain	24.2	dBic
Beamwidth	10.9	deg
PA output	5	W
TX losses	3.0	dB
EIRP	**28.2**	dBW
Path		
TX lat	37.7562	deg N
TX lon	-122.443	deg E
Slant range	41720	km
Path loss	192.5	dB
Atmospheric losses	0	dB
Fade margin	1	dB
Transponder input		
Spacecraft G/T	-12	dB/K
C/No	51.3	dBHz
Channel BW	2400	Hz
C/N	**17.5**	dB
Pointing data TX		
Azimuth	96.5	deg
Elevation	0.4	deg

Downlink

Transponder output		
Freq	10.5	GHz
Wavelength	0.029	m
TWTA output	100	W
Output back off	6	dB
TX losses	1.5	dB
Ant gain	17	dBi
EIRP	29.5	dBi
Power sharing	50	channels
EIRP per channel	**12.5**	dBW
Path		
RX lat	37.7562	deg N
RX lon	-122.443	deg E
Slant range	41720	km
Path loss	205.3	dB
Atmospheric losses	1	dB
Fade margin	1	dB
RX ground terminal		
Dish size	0.8	m
Aperture efficiency	0.65	
Gain	37.0	dBi
Beamwidth	2.5	deg
Antenna noise temp	45	K
LNA noise figure	1.2	dB
LNA noise temp	92.3	K
Ground terminal G/T	**15.6**	dB/K
C/No	49.5	dBHz
Channel BW	2400	Hz
C/N per user	**15.7**	dB
Pointing data RX		
Azimuth	96.5	deg
Elevation	0.4	deg

Source Spreadsheet: G0TLE

Payload ideas - link budget 6cm/3cm TPX

- SX-NB-transponder
- Uplink: 5.7GHz / 6cm band
- Downlink: 10GHz / 3cm band
- GEO satellite position:
  -43° West
- Ground station position:
  San Francisco (at the very edge of the footprint)

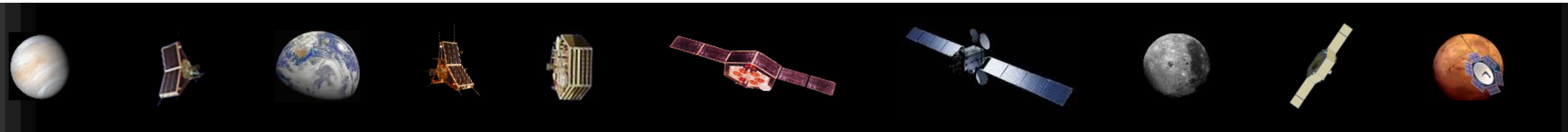
Uplink

TX ground terminal		
Freq	5.6	GHz
Wavelength	0.053571429	m
Dish size	0.8	m
Aperture efficiency	0.65	
Gain	31.6	dBic
Beamwidth	4.7	deg
PA output	10	W
TX losses	3.0	dB
EIRP	**38.6**	dBW
Path		
TX lat	37.7562	deg N
TX lon	-122.443	deg E
Slant range	41720	km
Path loss	199.8	dB
Atmospheric losses	1	dB
Fade margin	1	dB
Transponder input		
Spacecraft G/T	-12	dB/K
C/No	53.3	dBHz
Channel BW	2400	Hz
C/N	**19.5**	dB
Pointing data TX		
Azimuth	96.5	deg
Elevation	0.4	deg

Downlink

Transponder output		
Freq	10.5	GHz
Wavelength	0.029	m
TWTA output	100	W
Output back off	6	dB
TX losses	1.5	dB
Ant gain	17	dBi
EIRP	29.5	dBi
Power sharing	50	channels
EIRP per channel	**12.5**	dBW
Path		
RX lat	37.7562	deg N
RX lon	-122.443	deg E
Slant range	41720	km
Path loss	205.3	dB
Atmospheric losses	1	dB
Fade margin	1	dB
RX ground terminal		
Dish size	0.8	m
Aperture efficiency	0.65	
Gain	37.0	dBi
Beamwidth	2.5	deg
Antenna noise temp	45	K
LNA noise figure	1.2	dB
LNA noise temp	92.3	K
Ground terminal G/T	**15.6**	dB/K
C/No	49.5	dBHz
Channel BW	2400	Hz
C/N per user	**15.7**	dB
Pointing data RX		
Azimuth	96.5	deg
Elevation	0.4	deg

Source Spreadsheet: G0TLE



Payload ideas - link budget 3cm/3cm TPX

- XX-NB-transponder
- Uplink: 10GHz / 3cm band
- Downlink: 10GHz / 3cm band
- GEO satellite position: -43° West
- Ground station position: San Francisco (at the very edge of the footprint)

Uplink

TX ground terminal		
Freq	10.5	GHz
Wavelength	0.028571429	m
Dish size	1	m
Aperture efficiency	0.65	
Gain	39.0	dBic
Beamwidth	2.0	deg
PA output	5	W
TX losses	3.0	dB
EIRP	**42.9**	dBW
Path		
TX lat	37.7562	deg N
TX lon	-122.443	deg E
Slant range	41720	km
Path loss	205.3	dB
Atmospheric losses	1	dB
Fade margin	1	dB
Transponder input		
Spacecraft G/T	-12	dB/K
C/No	52.3	dBHz
Channel BW	2400	Hz
C/N	**18.5**	dB
Pointing data TX		
Azimuth	96.5	deg
Elevation	0.4	deg

Downlink

Transponder output		
Freq	10.5	GHz
Wavelength	0.029	m
TWTA output	100	W
Output back off	6	dB
TX losses	1.5	dB
Ant gain	17	dBi
EIRP	29.5	dBi
Power sharing	50	channels
EIRP per channel	**12.5**	dBW
Path		
RX lat	37.7562	deg N
RX lon	-122.443	deg E
Slant range	41720	km
Path loss	205.3	dB
Atmospheric losses	1	dB
Fade margin	1	dB
RX ground terminal		
Dish size	0.8	m
Aperture efficiency	0.65	
Gain	37.0	dBi
Beamwidth	2.5	deg
Antenna noise temp	45	K
LNA noise figure	1.2	dB
LNA noise temp	92.3	K
Ground terminal G/T	**15.6**	dB/K
C/No	49.5	dBHz
Channel BW	2400	Hz
C/N per user	**15.7**	dB
Pointing data RX		
Azimuth	96.5	deg
Elevation	0.4	deg

Source Spreadsheet: G0TLE

Payload ideas - link budget 1.25cm/3cm TPX

- KX-NB-transponder
- Uplink: 24GHz / 1.25cm band
- Downlink: 10GHz / 3cm band
- GEO satellite position:
  -43° West
- Ground station position:
  San Francisco (at the very edge of the footprint)

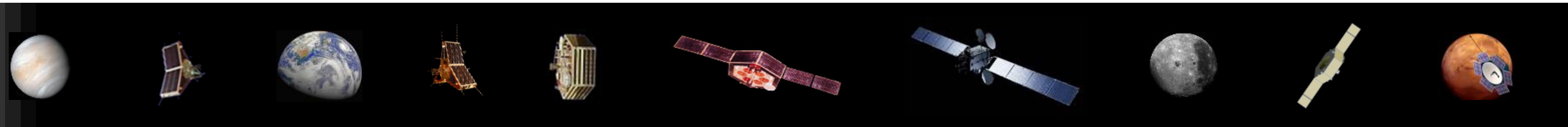
Uplink

TX ground terminal		
Freq	24	GHz
Wavelength	0.0125	m
Dish size	1.2	m
Aperture efficiency	0.65	
Gain	47.7	dBic
Beamwidth	0.7	deg
PA output	2	W
TX losses	3.0	dB
EIRP	**47.7**	dBW
Path		
TX lat	37.7562	deg N
TX lon	-122.443	deg E
Slant range	41720	km
Path loss	212.5	dB
Atmospheric losses	1	dB
Fade margin	1	dB
Transponder input		
Spacecraft G/T	-12	dB/K
C/No	49.9	dBHz
Channel BW	2400	Hz
C/N	**16.1**	dB
Pointing data TX		
Azimuth	96.5	deg
Elevation	0.4	deg

Downlink

Transponder output		
Freq	10.5	GHz
Wavelength	0.029	m
TWTA output	100	W
Output back off	6	dB
TX losses	1.5	dB
Ant gain	17	dBi
EIRP	29.5	dBi
Power sharing	50	channels
EIRP per channel	**12.5**	dBW
Path		
RX lat	37.7562	deg N
RX lon	-122.443	deg E
Slant range	41720	km
Path loss	205.3	dB
Atmospheric losses	1	dB
Fade margin	1	dB
RX ground terminal		
Dish size	0.8	m
Aperture efficiency	0.65	
Gain	37.0	dBi
Beamwidth	2.5	deg
Antenna noise temp	45	K
LNA noise figure	1.2	dB
LNA noise temp	92.3	K
Ground terminal G/T	**15.6**	dB/K
C/No	49.5	dBHz
Channel BW	2400	Hz
C/N per user	**15.7**	dB
Pointing data RX		
Azimuth	96.5	deg
Elevation	0.4	deg

Source Spreadsheet: G0TLE



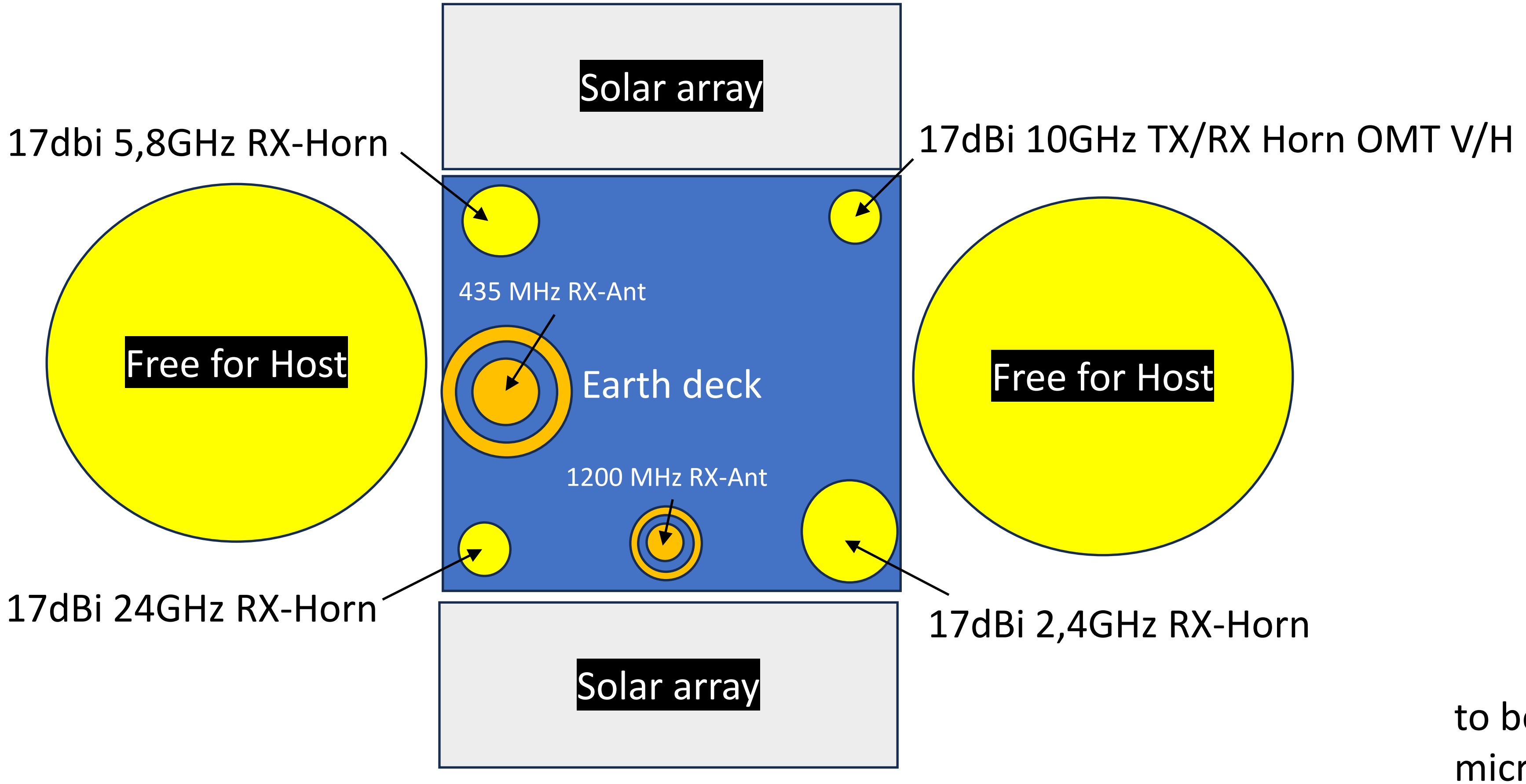
Payload ideas - summary

- All suggested band / NB transponder combinations are feasible with very reasonable effort at the ground station (comparable to QO-100).

- For the WB transponder (S-band uplink and X-band downlink) the effort will be identical to QO-100 (with the option for a second WB uplink in the 6cm band).

Payload ideas - accommodation example

Simple accommodation on a small GEO platform:



to be adapted for a micro GEO platform

Payload ideas – accommodation example

Earthdeck e.g. OHB SGEO Heinrich Hertz Satellite

Image: OHB-System

Payload ideas – other experiments

An own AMSAT (amateur radio) mission based on a Micro GEO supported by ESA provides opportunities for multiple additional experiments supporting AMSAT's goals for training, science and development to inspire young people for technology through the free frequencies of amateur radio.

This could be an excellent platform for further cooperation with organisations like ESERO: "Interactive" experiments of students would feasible as AMSAT could control them in real time and provide the results to the students such as data from cameras and sensors.

Such experiments are normally difficult to be qualified for commercial satellites (when using them as a hosted payload) but in the case of an own GEO such requirements could be relaxed.

Finally such a mission could provide an excellent platform for disaster / emergency communications directly via the GEO satellite transponders (as demonstrated in Turkey during the Earthquake 2023). Using the Micro GEO electrical propulsion system the GEO satellite could be moved to cover respective areas impacted by disasters on short notice.

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Thank you very much !