Providing LEO TTC Services Using Mobile Phone Technology and Networks
- Study Executive Summary -

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to provide the executive summary of the LEO TTC services study.

1.2 SCOPE

This document provides the summary of LEO TTC services study, the main results and conclusions.

2 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

This document shall be read in conjunction with documents listed hereafter, which form part of this document to the extent specified herein. In case of a conflict between any provisions of this document and the provisions of the documents listed hereafter, the content of the contractually higher document shall be considered as superseding.

[AD1] Statement of Work, Providing LEO TT&C Services Using Mobile Phone Technology and Networks, DOPS-GST-SOW-1004-OPS-HAS, Issue 1, 09/12/2008

[AD2] Conditions of Tender For The European Space Agency's Small Space Procurements (SSP), Appendix 3 to AO/1-6009/08/F/MOS

2.2 REFERENCE DOCUMENTS

[RD01] PLSS-OHB-TN-0001, Feasibility of Using Mobile Phone Ground Based Systems With and Without Network for LEO TT&C Services

[RD02] PLSS-OHB-TN-0002

[RD03] PLSS-OHB-TN-0003

[RD04] PLSS-OHB-TN-0004

[RD05] LEOTTC_Final_Presentation_30_08_2010

3 MOBILE GROUND BASED SYSTEM FEASIBILITY SUMMARY

3.1 CONCEPT FOR LEO TT&C

The feasibility of using mobile phone ground based systems with and without network for LEO TT&C services is described in the first technical note of the study, see [RD01].

An overview of existing mobile phone technology and the worldwide coverage is provided in order to understand the available networks on ground, which could be used as well for the communication with satellites in LEO.

The following Figure 3.1-1 shows the short overview of the mobile ground based system development history, mobile cell main technical parameters, achievable data rates for different networks and the ground base station typical antenna pattern.

History of development		
1G	analog mobile communication	1958 – 2000 A-, B-, and C-Net
2G	digital mobile communication	since 1991 global system for mobile communication (GSM)
2,5	digital mobile communication	since 1999 GPRS
3G	digital mobile communication	since 2002 universal mobile telecommunication system (UMTS)

Table 3-1: History of development

	Global (World Cell)	Suburban (Macro Cell)	Urban (Micro Cell)	Inbuilding (Pico Cell)
Cell Radius	>20 km	350 m – 20 km	50 – 300 m	< 50 m
Max. Velocity	100 km/h	500 km/h	120 km/h	10 km/h
Max. Data Rate	144 kb/s	144 kb/s	384 kb/s	2 Mb/s

Table 3-2 Overview FDD UMTS Cell Ranges

Technology	Mobile Phone -> BTS	BTS -> Mobile Phone
GPRS	8 – 16 kbps	24 – 40 kbps
EDGE	80 – 96 kbps	120 – 176 kbps
UMTS	60 kbps	320 kbps
HSPA	300 kbps	1000 – 3000 kbps

Table 3-3 Overview Achievable User Data Rates

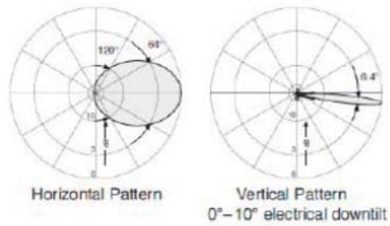

Figure 3-6: Typical macrocellular antenna radiation pattern

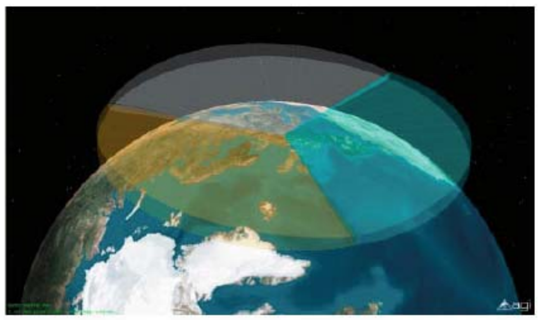

Figure 3-7: Antenna radiation characteristics transferred to LEO

Figure 3.1-1: Overview of the mobile ground based system development history, mobile cell main technical parameters, achievable data rates for different networks and the ground base station typical antenna pattern.

The data for worldwide coverage are given in Annex A of [RD01]. The following Figure 3.1-2 shows some examples of coverage maps.

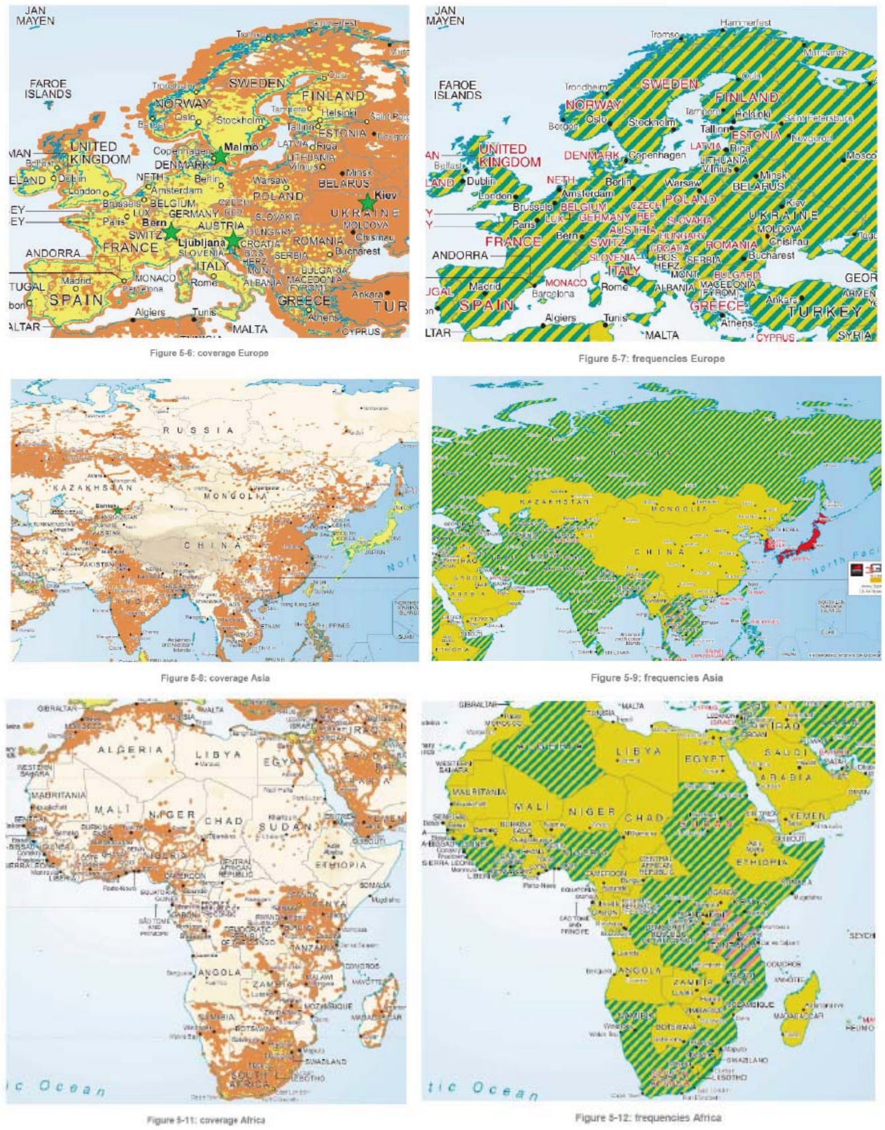

Figure 3.1-2: Examples of mobile ground networks worldwide coverage maps (based on GSM Association & Europa Technologies LTD publications).

The following aspects are described and considered for the planned LEO TT&C use of mobile ground based systems:

- Cell Range,
- Propagation Delay,
- Doppler Shift,
- Hand Over,
- Achievable user data rates,
- Link budgets,
- Frequency allocation.

From the technical point of view the link budget analysis provides the most interesting information about the necessary transceiver and antenna systems on ground and in space for mobile ground based system use for LEO TT&C purposes. Four different cases with low and high gain antennas on ground were selected as depicted as an overview in the Figure 3.1-3, showing the different parameters and results.

Case Nr.	Tx on S/C	S/C Antenna Gain	G/S Antenna Gain	Max. User Date Rate	Result
1	20 W	0 dBi	15 dBi	7.5 kbps	PFD ok, system reserve problem (0.13 dB)
2a	20 W	15 dBi	15 dBi	120 kbps	negativ margin of PFD, system reserve ok (3.09 dB)
2b	20 W	6 dBi	15 dBi	15 kbps	PFD ok, system reserve ok (3.12 dB)
3	20 W	0 dBi	30 dBi	120 kbps	PFD ok, system reserve ok (3.09 dB)
4	4 W	0 dBi	31.05 dBi	00 kbps	PFD ok, system reserve ok (3.03 dB)

Figure 3.1-3: Selected scenarios for mobile ground based system link budget calculations for LEO TT&C services

The Case #3 would provide a good solution for LEO TT&C services, and the main features would be the following:

- On ground parabolic dish antenna of 30dBi (replaced standard antenna),
- In orbit transmitter of 20W with two hemispheric coverage antennas of 0dBi,
- Achieved system reserve of 3,1 dB.

The details of the Case#3 link budget analysis are shown in Figure 3.1-4.

Case 3

2. System Parameters			
Frequency	MHz	2000,00	
Tx Power	W	20,00	
Altitude	km	1000,00	
Data rate (DPDCH channel bit rate)	kbps	240,00	
Elevation	deg.	90	5
Slant range	km	1.000,0	3.194,5
3. Transmission Path (Space-Earth)			
S/C Transmit Power (Tx)	dBW	13,01	13,01
S/C Antenna Gain (Tx)	dBi	0,00	0,00
S/C Feeder/Cable Losses (Tx)	dB	1,50	1,50
S/C Splitting Losses	dB	3,00	3,00
S/C Transmit EIRP (Tx)	dBW	8,51	8,51
Free Space Path Loss	dB	158,46	168,55
Atmospheric Loss	dB	0,40	0,40
Rain Margin	dB	0,22	0,22
Scintillation Fade Margin	dB	1,00	1,00
Polarisation Mismatch Loss	dB	3,00	3,00
Pointing Error Loss	dB	0,10	0,10
G/S Antenna Gain (Rx)	dBi	30,00	30,00
G/S System Noise Temperature (Rx)	dB-K	26,80	26,94
Ground Station G/T	dB/K	3,20	3,06
Boltzmann's Constant	dBW/K-Hz	-228,60	-228,60
Received Power @ Antenna O/P	**dBm**	**-94,67**	**-104,76**
G/S Implementation Loss (Rx)	dB	2,00	2,00
Data rate	dB-bit/s	53,80	53,80
Eb/No	dB	21,32	11,10
Interference Margin	dB	3,00	3,00
Required Eb/No	dB	8,00	8,00
System Reserve	**dB**	**13,32**	**3,10**
4. Power Flux-Density at the Earth´s surface			
Bandwidth (chip rate)	dB-chip/s	65,84	65,84
PFD (dBW/(4kHz*m^2))		-152,33	-162,41
Max. allowed PFD (dBW/(4kHz*m^2))		-144,00	-154,00
Flux Margin	**dB**	**8,33**	**8,41**

Figure 3.1-4: Downlink budget calculation Case#3.

3.2 CONCLUSIONS

The global coverage of mobile ground systems and the link budget calculations for modified system with high gain antenna on ground and increased power transmitter in orbit confirms the technical feasibility for LEO TTC services.

The Doppler Frequency Shift correction shall be implemented for LEO TTC services.

The critical issues which should be considered as possible show-stoppers are:

- Frequency coordination,
- Service contracts with various operators in different countries,
- Cell Hand-over time minimization for effective services in LEO.

4 ISM FREQUENCY FEASIBILITY SUMMARY

4.1 CONCEPT FOR LEO TT&C

The Industry, Science, Medicine (ISM) frequency license free system use concept for LEO TT&C services is shown in the Figure 4.1-1 and described in RD01.

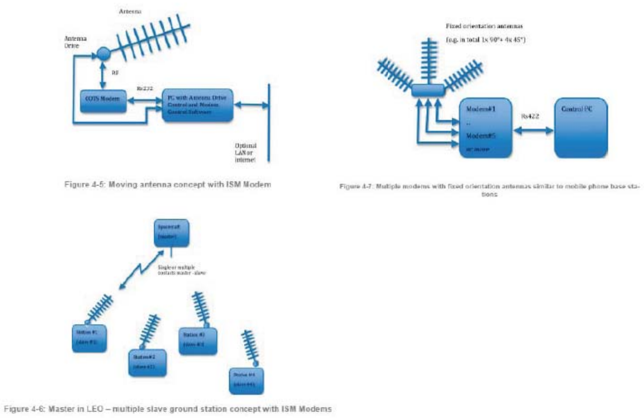

Figure 4.1-1: ISM Frequency System Concepts for LEO TT&C

The expected performance of ISM system in S-band range is depicted in Figure 4.1-2.

Output	30dBm or 1W
Cable loss (in orbit)	-2dB
Antenna gain (in orbit)	0dB (isotrope antenna assumed for worst case)
EIRP	28dBm (limitation of 20dBm in EU to be checked)
Antenna gain on ground	35,3dBi (3m dish assumed)
Cable loss (on ground)	-2dB
Receiver sensitivity	-116dBm (Slow data rate)
System gain	177dB
Path loss (800km orbit)	-161dB
Fade margin (min needed 10dB)	16dB

Figure 4.1-2: Link Budget for Microhard S-band modem

4.2 CONCLUSIONS

Low cost, small size and weight hardware is available in commercial grade quality and could be used for LEO TT&C services.

ISM frequency use is limited by different radiated power levels in different countries and would require new frequency coordination work for higher power devices.

The critical issues, which should be considered as possible show-stoppers are:

- Frequency coordination for use space to ground and ground to space (presently ISM frequency license free operations are defined only for ground to ground applications),
- High number of new ground stations would be needed for LEO TTC global coverage.

5 SPACE BASED SYSTEM FEASIBILITY SUMMARY

5.1 CONCEPT FOR LEO TT&C

The feasibility analysis of space based systems for LEO TTC Services is provided in RD02.

The overview of selected space based systems is shown in Table 5.1-1 and the expected performance is depicted in table 5.1-2.

Nr	System	Type	Number of satellites	Orbit altitude and inclination	Data Service Modes
1	Orbcomm	LEO	29 +6 new	800km, 45° four planes, 48,5° new, two polar planes	Direct data packet transmission mode (Reports and Messages) and store and forward mode (Globalgrams) No inter-satellite links, no voice.
2	Iridium	LEO	68 (incl. 2 spare)	780 km 86,4°	Inter-satellite links, voice and data. Short burst data (SBD) service (~1900 bytes max per message) since 2002
3	Globalstar	MEO	48	1400km 52°	No inter-satellite links, link to ground station needed, voice and data services.
4	Inmarsat D+	GEO	4	36 000km	Short data bursts like pager
5	Inmarsat BGAN	GEO	4	36 000km	Broadband global area network services up to 492 kbit/s like GPRS and ISDN
6	Thyraya	GEO	3	36 000km	Voice and data services
7	MSAT	GEO		36 000km	Broad band data services
8	MSS/ATC	GEO	1	36 000km	Planed system
9	ICO	GEO MEO	2	36 000km	IGO G1 satellite space and Ground Based Beam Forming sting complete
10	VSAT Eutelsat, PanAmSat	GEO		36 000km	Broadband communications

Table 5.1-1: Selected space based systems for LEO TT&C Services

System	Service	Orbit Type	Data Amount
Inmarsat D+	Pager	GEO	< 1 kbyte/day
GOES, Meteosat	Messaging	GEO	< 5 kbyte/day
Argos	Messaging	LEO	< 5 kbyte/day
Inmarsat C	Messaging	GEO	< 10 kbyte/day
Orbcomm	Messaging	LEO	< 50 kbyte/day
Iridium	Voice	Big LEO	1 Mbyte/hr
Globalstar	Voice	Big LEO (regional)	1 Mbyte/hr
Inmarsat BGAN	Internet	GEO	50 Mbyte/hr

Table 5.1-2: Expected data transmission capabilities of selected space based systems for LEO TT&C Service

The main technical parameters of the Orbcomm, Iridium, Globalstar and Inmarsat space based systems are described. Important for LEO TT&C feasibility assessment are the following features:

- Used frequency range for transmitting and receiving,
- Doppler rate compensation,
- Time delays,
- Quality of service in terms of availability and data rates,
- Power and mass specifications of the available user terminals,
- Frequency allocation or licensing for the service type space to space,
- Cost of terminals and service.

A simplified simulation of LEO TT&C service via different space based systems was made. The following Figure 5.1-1 shows the simulation of Orbcomm network for LEO TTC services.

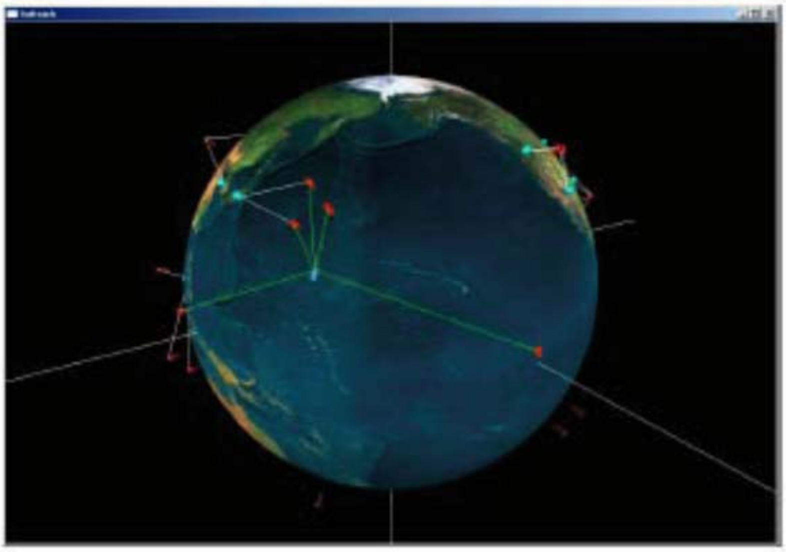

Figure 5.1-1: Simulation of Orbcomm network for LEO TTC services.

Figures 5.1-2 and 5.1-3 show the possible LEO TTC service time slots via Orbcomm and Iridium space based communication systems. The diagrams confirm the practically continuous spacecraft possible access via LEO based satellite communication systems.

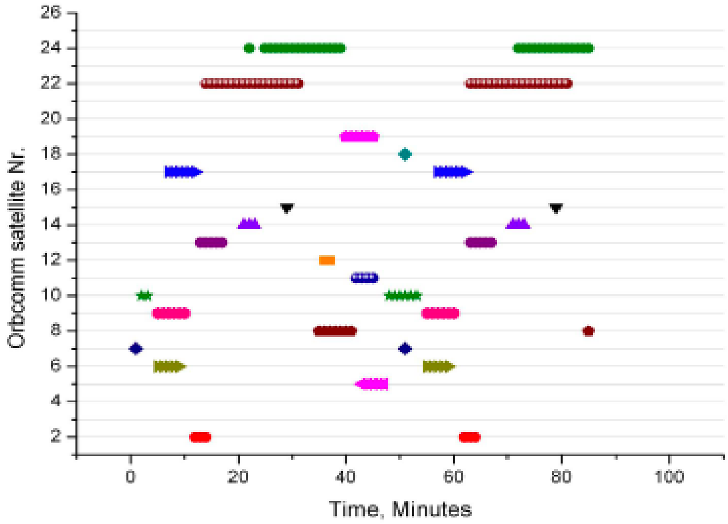

Figure 5.1-2: Time slots of Orbcomm network spacecraft visibility for LEO TTC services

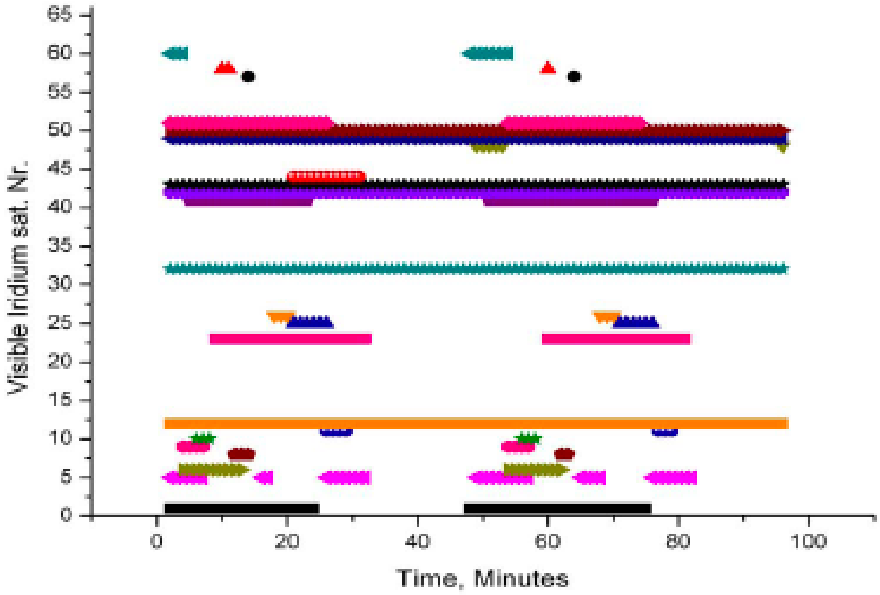

Figure 5.1-3: Time slots of Iridium network spacecraft visibility for LEO TTC services

The Inmarsat SB-SAT new space terminals and service at low or high data rate could be used as well for LEO TTC services. Figure 5.1-4 shows the possible service via geostationary Inmarsat satellites and the needed hardware in LEO for low and high data rate options.

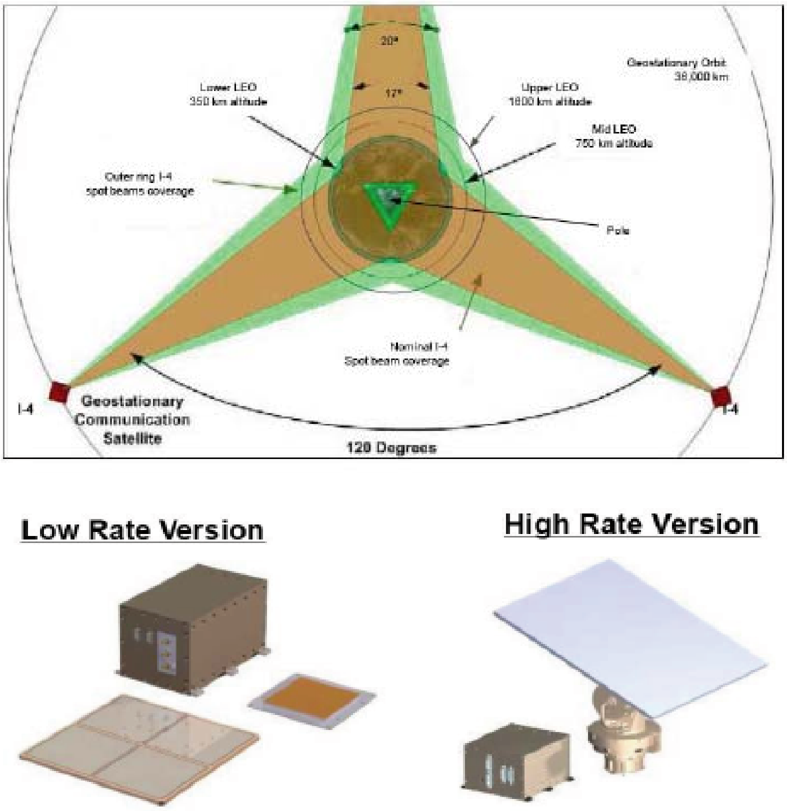

Figure 5.1-4: Inmarsat SB-SAT by ComDev for LEO TTC services

5.2 CONCLUSIONS

The space based systems could be successfully used for LEO TTC services. The already flown missions with Orbcomm, Iridium and Globalstar communicators onboard of small satellites and launch vehicle upper stages confirm the technical feasibility.

An Inmarsat space terminal is now under development by ComDev and this new hardware with associated services could be used in future for LEO TTC services as well.

However, the frequency licensing issue for the services in LEO needs to be solved in future.

For the right systems selection for the LEO TTC services the following aspects should be considered:

- **Doppler rate**
    - Orbcomm, Iridium and Globalstar
        - Positive: no difference between space and terrestrial (COTS) terminals, the Doppler shift compensation and consideration is already done.
    - Inmarsat
        - Negative impact: for Inmarsat space terminals the Doppler shift needs to be compensated and the client satellite position and velocity information is needed based on GPS or orbit propagator on board.
        - Negative impact: Inmarsat COTS hardware could not be used for demonstration missions due the Doppler shift.
        - Positive: SB-SAT terminals with Doppler shift compensation are now in development by ComDev and this project is supported by ESA.

- **Time Delays**
    - Orbcomm
        - Negative: Orbcomm is not a real time system and is working in store and forward mode. Only the near real time modes (Message mode and Report mode) ensure small time delays less than one minute. Data transmission in the Globalgram mode could cause time delays more than one or more hours.
    - Iridium
        - Positive: SBD service ensures the delivery of data typically with time delay less than one minute.
    - Globalstar
        - Negative: partially longer gaps in the service availability.
        - Positive: the above issue could be solved soon, new spacecrafts are recently launched.
    - Inmarsat
        - Positive: Inmarsat is a real time system, the expected latency between 500ms and 1500ms is acceptable for LEO TTC services.

- **Quality of Service**
    - Orbcomm
        - Positive: high number of spacecrafts in orbit ensures practically permanent service availability in LEO. The second generation spacecrafts are in development and first of them will be launched within next 12 months.
        - Positive: the large opening angle of Orbcomm spacecraft antennas ensures good visibility and service for communicators in LEO.
        - Positive: service already tested on Rubin missions by OHB.
        - Negative: the right gateway and satellite (if Globalgram mode) needs to be selected for the command and data uplink.
    - Iridium
        - Positive: high number of spacecrafts and good link margin ensures good service.
    - Inmarsat
        - Positive: quality of service in terms of reliable data transmission and satellite availability or visibility time is very good.

- Space Terminal power and mass specifications
    - Orbcomm, Iridium and Globalstar
        - Positive: low power requirements for the short data bursts.
        - Positive: very small size terminals already available as COTS equipment and are qualified for robust automotive applications.
    - Inmarsat
        - Negative: the SB-SAT terminals are designed for main payload data transmission and have relatively large dimensions and mass.

- Other Capabilities and Constraints
    - Orbcomm, Iridium and Globalstar
        - Negative: the services in space are not yet considered as real business case and therefore the service owner companies are not yet supporting the frequency licensing extension for services in LEO.
    - Inmarsat
        - Positive: Inmarsat is supporting the idea of new services in LEO and is working on frequency licensing issue.