GALILEO GALILEI (GG)

SYSTEM BUDGETS REPORT

DRL/DRD: DEL-33

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. SCOPE AND PURPOSE

This document is submitted in partial fulfilment of Work Package 1A-ADA of the GG Phase A2 Study (DRL item DEL-33).

The purpose of the document is to provide the budget status of the reference GG configuration, documented in [RD-4].

2. REFERENCES

2.1 Applicable Documents

[AD 1] ASI, “Progetto Galileo Galilei-GG Fase A-2, Capitolato Tecnico”, DC-IPC-2007-082, Rev. B, 10-10-2007 and applicable documents defined therein

2.2 Standards

[SD 1] ECSS-M-00-02A, Space Project Management – Tailoring of Space Standards, 25 April 2000

[SD 2] ECSS-E-ST-10C, Space Engineering - System Engineering General Requirements, 6 March 2009

[SD 3] ECSS-E-10-02A, Space Engineering – Verification

[SD 4] ECSS-Q-00A, Space Product Assurance - Policy and Principles, and related Level 2 standards.

2.3 ASI Reference Documents

[RD 1] GG Phase A Study Report, Nov. 1998, revised Jan. 2000, available at: http://eotvos.dm.unipi.it/nobili/ggweb/phaseA/index.html

[RD 2] Supplement to GG Phase A Study (GG in sun-synchronous Orbit) “Galileo Galilei-GG”: design, requirements, error budget and significance of the ground prototype”, A.M. Nobili et al., Physics Letters A 318 (2003) 172–183, available at: http://eotvos.dm.unipi.it/nobili/documents/generalpapers/GG_PLA2003.pdf

[RD 3] A. Nobili, DEL001: GG Science Requirements, Pisa, September 2008

2.4 GG Phase A2 Study Notes

[RD 4] SD-RP-AI-0625, GG Final Report / Satellite Detailed Architecture Report, Issue 1

[RD 5] SD-RP-AI-0626, GG Phase A2 Study Executive Summary, Issue 1

[RD 6] SD-TN-AI-1163, GG Experiment Concept and Requirements Document, Issue 3

[RD 7] SD-RP-AI-0620, GG System Performance Report, Issue 2

[RD 8] SD-TN-AI-1167, GG Mission Requirements Document, Issue 2

[RD 9] SD-RP-AI-0590, GG System Concept Report (Mission Description Document), Issue 3

[RD 10] SD-SY-AI-0014, GG System Functional Specification and Preliminary System Technical Specification, Issue 1

[RD 11] SD-RP-AI-0631, GG Consolidated Mission Description Document, Issue 1

[RD 12] SD-TN-AI-1168, GG Mission Analysis Report, Issue 2

[RD 13] DTM, GG Structure Design and Analysis Report, Issue 1

[RD 14] SD-RP-AI-0627, GG Thermal Design and Analysis Report, Issue 1

[RD 15] SD-RP-AI-0268, GG System Budgets Report, Issue 1

[RD 16] SD-RP-AI-0621, Technical Report on Drag and Attitude Control, Issue 2

[RD 17] TL25033, Payload Architectures and Trade-Off Report, Issue 3

[RD 18] SD-RP-AI-0629, Technical Report on Simulators, Issue 1

[RD 19] GG.ALT.TN.2003, FEEP Microthruster System Technical Report, Issue 1

[RD 20] TASI-FI-44/09, Cold Gas Micro Thruster System for Galileo Galilei (GG) Spacecraft - Technical Report, Issue 1, May 2009

[RD 21] SD-RP-AI-0630, Spin Sensor Design, Development and Test Report, Issue 1

[RD 22] SD-TN-AI-1169, GG Launcher Identification and Compatibility Analysis Report, Issue 1

[RD 23] ALTEC-AD-001, GG Ground Segment Architecture and Design Report, Issue 1

[RD 24] SD-TN-AI-1218, GG Preliminary Product Tree, Issue 1

[RD 25] SD-PL-AI-0227, GG System Engineering Plan (SEP), Issue 2

[RD 26] TAS-I, Payload Development and Verification Plan, Issue 1

[RD 27] SD-PL-AI-0228, GG System Verification and Validation Plan, Issue 1

[RD 28] SD-TN-AI-1219, Report on Frequency Management Issues, Issue 1

[RD 29] SD-RP-AI-0632, GG Mission Risk Assessment And Mitigation Strategies Report, Issue 1

[RD 30] SD-RP-AI-0633, Report on Mission Costs Estimates, Issue 1

3. MASS BUDGETS

3.1 System Mass Budget

Galileo Galilei					
		Target Spacecraft Mass at Launch		1000,00 kg	
		Below Mass Target by:		482,18 kg	
	Without Margin	Margin		Total	% of Total
Dry mass contributions		%	kg	kg	
Structure	104,61 kg	18,09	18,92	123,53	23,86
Thermal Control	8,70 kg	20,00	1,74	10,44	2,02
Communications	9,60 kg	10,00	0,96	10,56	2,04
Data Handling	16,00 kg	20,00	3,20	19,20	3,71
AOCS	5,92 kg	13,11	0,78	6,69	1,29
Propulsion	37,66 kg	13,95	5,26	42,92	8,29
Power	57,68 kg	14,82	8,55	66,23	12,79
Harness	12,50 kg	20,00	2,50	15,00	2,90
Payload	55,34 kg	12,77	7,07	62,41	12,05
Total Dry(excl.adapter)	308,01			356,98 kg	
System margin (excl.adapter)		20,00 %		71,40 kg	
Total Dry with margin (excl.adapter)				428,38 kg	
Other contributions					
Wet mass contributions					
Propellant	4,75 kg	100,00	4,75	9,50	1,83
Adapters mass (including sep. mech.), kg	79,94 kg	0,00	0,00	79,94	15,44
Total wet mass (excl.adapter)				437,88 kg	
Launch mass (including adapter)				517,82 kg	

Table 3.1-1: Launch mass budget

3.2 PGB Mass Budgets

3.2.1 Detailed Experiment Mechanics Mass Budget

Name	No.	Unit Mass [kg]	Total Mass [kg]	Margin [%]	Margin [kg]	Total Mass with margin [kg]
Inner Test Mass	**1**	**10,000**	**10**	**0**	**0,00**	**10,00**
Outer Test Mass	**1**	**10,000**	**10**	**0**	**0,00**	**10,00**
PGB Shaft			**2,879**	**20**	**0,58**	**3,45**
Mollette giunto 1	1	0,102	0,102			
Mollette giunto 2	1	0,071	0,071			
Mollette supporto piezo 1	1	0,098	0,098			
Mollette supporto piezo 2	1	0,030	0,03			
Assy supporto centrale	1	0,060	0,06			
Cilindro Giunto interno 1	1	0,161	0,161			
Cilindro Giunto interno 2	1	0,049	0,049			
Cilindro portante	1	1,082	1,082			
Piastre capacitive	1	1,164	1,164			
Piastrine capacitive	1	0,062	0,062			
PGB Shell allocation (TBC)	***1***	***7,60***	***7,60***	***20***	***1,52***	***9,12***
µmetal on PGB shell	**1**	**1,76**	**1,76**	**20**	**0,35**	**2,11**
PGB interface spring	**8**	**0,11**	**0,86**	**20**	**0,17**	**1,04**
Plasma shielding grid allocation	**4**	**0,01**	**0,04**	**20**	**0,01**	**0,05**
Locking mechanisms allocation (TBC)	***1***	***8,40***	***8,40***	***20***	***1,68***	***10,08***
Inch Worm	**16**	**0,10**	**1,60**	**20**	**0,32**	**1,92**
		PAYLOAD TOTALS	**43,14**	**10,7%**	**4,63**	**47,77**

Table 3.2-1: PGB mechanics mass budget

3.3 SVM Mass Budget

Element 1 - Galileo Galilei						
FUNCTIONAL SUBSYSTEM	nr	ass (kg) per u	otal Mass (kg	Margin (%)	Margin (kg)	Mass (kg) with Margin
Structure			**104,61**	**18,09**	**18,92**	**123,53**
Upper Platform	1	1,23	1,23	20,00	0,25	1,48
Upper Cone	1	7,08	7,08	20,00	1,42	8,50
Outermost Cylinder	1	11,35	11,35	20,00	2,27	13,62
Lower Cone	1	7,08	7,08	20,00	1,42	8,50
Lower Platform	1	1,23	1,23	20,00	0,25	1,48
Cone to Cylinder I/F ring	2	14,58	29,16	20,00	5,83	34,99
Cone to Platform I/F ring	2	4,03	8,06	20,00	1,61	9,67
PGB shell lock/unlock mech.	2	2,50	5,00	20,00	1,00	6,00
Separation system ring	1	2,50	2,50	20,00	0,50	3,00
Miscellaneous (inserts. cleats. etc.	1	9,00	9,00	20,00	1,80	10,80
Ballast mass	1	10,00	10,00	0,00	0,00	10,00
Payload support cone	2	4,80	9,60	20,00	1,92	11,52
PGB interface	2	1,66	3,32	20,00	0,66	3,98
Thermal Control			**8,70**	**20,00**	**1,74**	**10,44**
MLI thermal blanket	1	4,30	4,30	20,00	0,86	5,16
Paints & tapes	1	1,20	1,20	20,00	0,24	1,44
Heating line	1	0,20	0,20	20,00	0,04	0,24
Doublers	1	2,00	2,00	20,00	0,40	2,40
Miscellanea	1	1,00	1,00	20,00	0,20	1,20
Communications			**9,60**	**10,00**	**0,96**	**10,56**
XPDN S-Band 1	1	3,60	3,60	10,00	0,36	3,96
XPDN S-Band 2	1	3,60	3,60	10,00	0,36	3,96
RFDN S-Band	1	1,20	1,20	10,00	0,12	1,32
S-Band Antenna 1	1	0,60	0,60	10,00	0,06	0,66
S-Band Antenna 2	1	0,60	0,60	10,00	0,06	0,66
Data Handling			**16,00**	**20,00**	**3,20**	**19,20**
CTU+RTU	1	16,00	16,00	20,00	3,20	19,20
AOCS			**5,92**	**13,11**	**0,78**	**6,69**
Smart Sun Sensor	2	0,33	0,66	5,00	0,03	0,69
Spin Rate Sensor	2	0,70	1,40	20,00	0,28	1,68
Spin Rate Sensor el.	2	0,90	1,80	20,00	0,36	2,16
Magnetometer	3	0,19	0,56	5,00	0,03	0,58
Gyroscope	2	0,75	1,50	5,00	0,08	1,58
Propulsion			**37,66**	**13,95**	**5,26**	**42,92**
EPS Assembly	2	9,27	18,54	20,00	3,71	22,25
EPS Miscellanea	1	2,14	2,14	20,00	0,43	2,57
Nitrogen Thrusters	8	0,10	0,80	5,00	0,04	0,84
Nitrogen Tank	2	7,19	14,38	5,00	0,72	15,10
Lines & Valves	1	1,80	1,80	20,00	0,36	2,16
Power			**57,68**	**14,82**	**8,55**	**66,23**
Solar Array	2	13,91	27,82	20,00	5,56	33,38
PCDU	1	13,50	13,50	10,00	1,35	14,85
Battery	1	16,36	16,36	10,00	1,64	18,00
Harness			**12,50**	**20,00**	**2,50**	**15,00**
Power Harness	1	12,50	12,50	20,00	2,50	15,00
Payload			**55,34**	**12,77**	**7,07**	**62,41**
Inner test mass	1	10,00	10,00	0,00	0,00	10,00
Outer test mass	1	10,00	10,00	0,00	0,00	10,00
PGB Shaft	1	2,88	2,88	20,00	0,58	3,45
PGB Shell allocation	1	7,60	7,60	20,00	1,52	9,12
ECE	1	5,40	5,40	20,00	1,08	6,48
CPE	1	7,20	7,20	20,00	1,44	8,64
Locking Mechanisms allocation	1	8,40	8,40	20,00	1,68	10,08
Inch Worms allocation	12	0,10	1,20	20,00	0,24	1,44
Plasma shielding grids allocation	4	0,01	0,04	20,00	0,01	0,05
mumetal on PGB shell	1	1,76	1,76	20,00	0,35	2,11
PGB interface spring	8	0,11	0,86	20,00	0,17	1,04
Propellant						**4,75**

Table 3.3-1: SVM mass budget

3.4 Propellant Mass Budgets

3.4.1 Attitude Control propellant mass budget

The attitude control has in charge the management of the rate damping and Sun acquisition after launcher separation, and satellite spin-up to initiate the scientific mission.

Taking into account the proposed cold-gas assembly, the following total impulse budget has been computed:

Rate damping+Sun acquisition	:	30 Ns
Holding phase before spin-up	:	900 Ns
Spin-up	:	4600 Ns
Total impulse	:	5530 Ns

Considering a specific impulse of 60s, the total propellant mass equals 9.4kg (9.5kg has been considered available, providing an additional total impulse of about 60Ns).

3.4.2 FEEP propellant mass budget

The propellant mass has been derived considering a simplified assembly (optimization will be still possible).

Without FEEP failure	:	2060 Ns	(two years mission, each thruster)
After one FEEP failure	:	4065 Ns	(two years mission, thruster)
Total impulse	:	< 4500 Ns	

At the end, considering a two years mission, the propellant required for each thruster shall be compatible with a total impulse of 4500Ns each thruster.

3.4.3 CGPS propellant mass budget (alternative)

The propellant mass has been derived considering a simplified assembly (optimization will be still possible).

Assembly	:	13380Ns (two years mission)

Considering a two years mission, the propellant required is 23kg (Isp=60s).

4. MASS PROPERTIES

4.1 Centre of Mass, Direction cosines of the Principal Axes and Inertia Matrix

In the following, CoM, direction cosines and inertia matrix tables are provided, as follows.

- for the full spacecraft in Table 4.1-1;
- for the spacecraft without the PGB assembly in Table 4.1-2;
- for the PGB assembly without the proof masses in Table 4.1-3;
- for the outer proof mass in Table 4.1-4;
- for the inner proof mass in Table 4.1-5

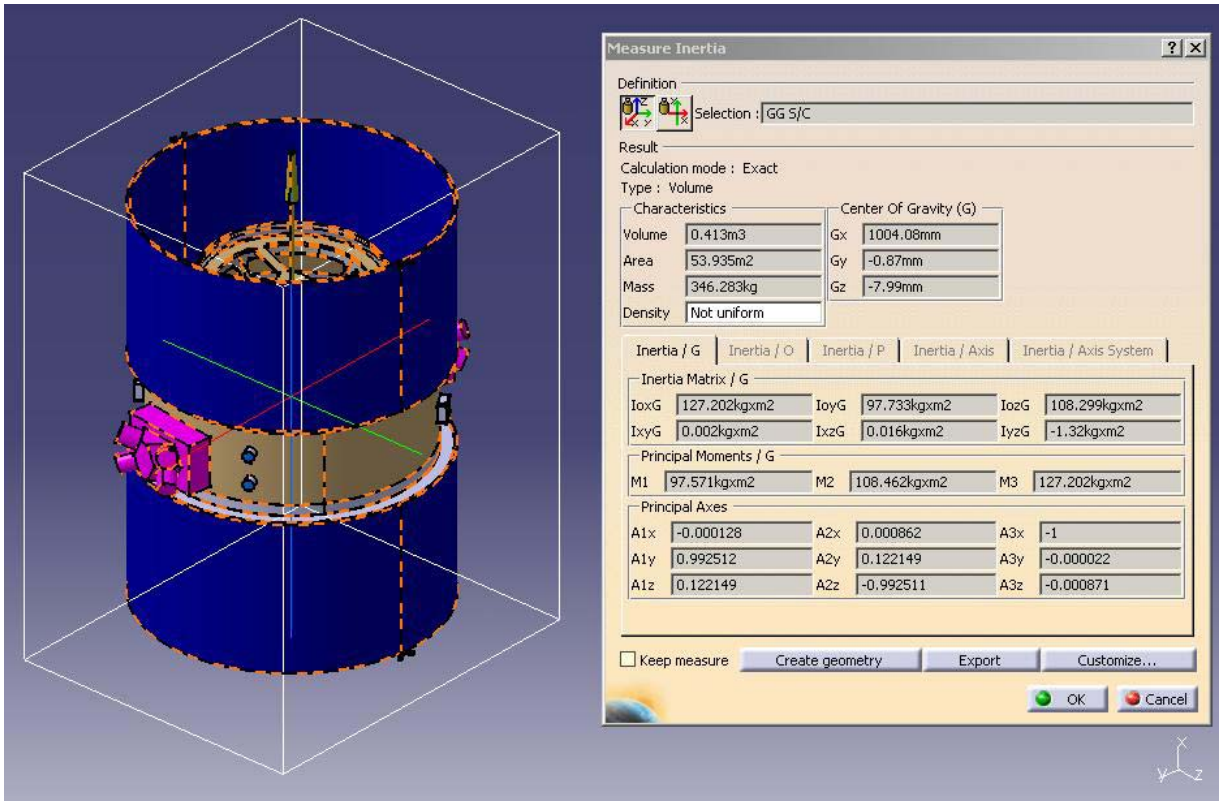

Table 4.1-1: Mass Properties for the full GG spacecraft

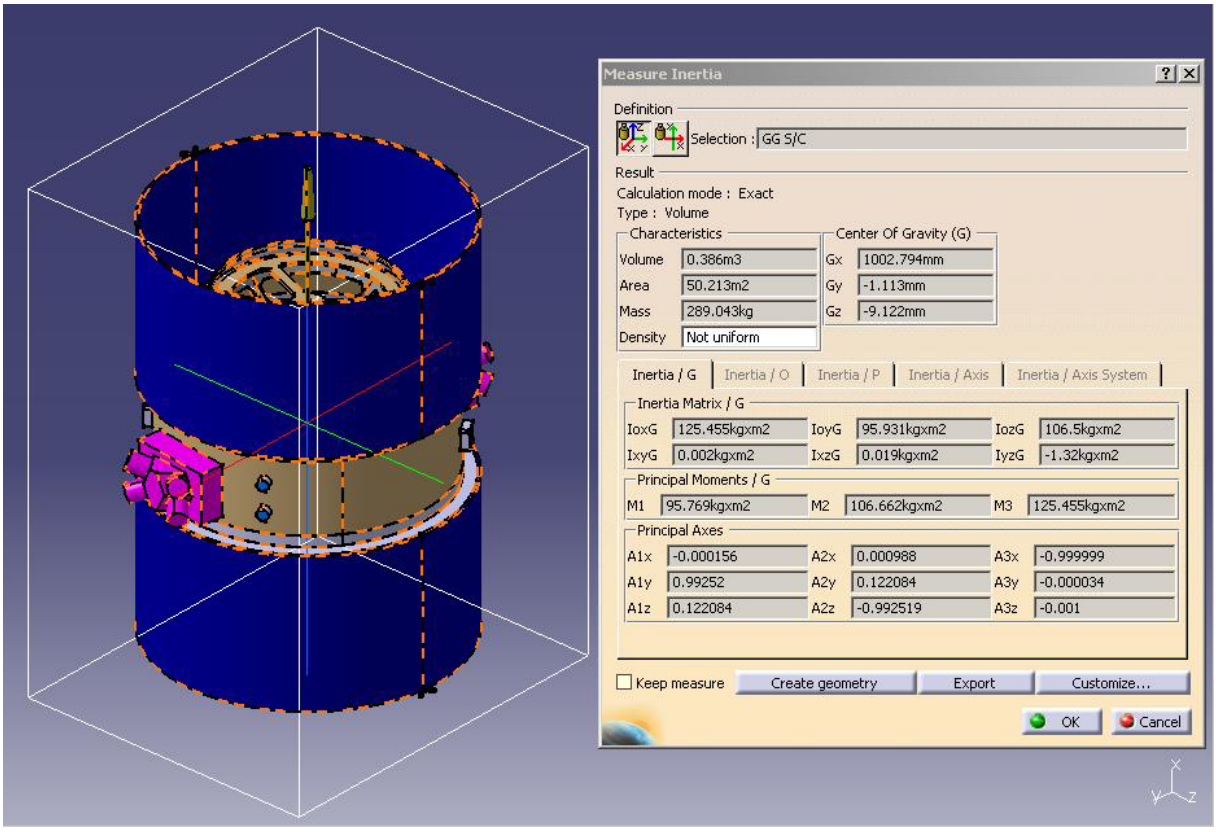

Table 4.1-2: Mass Properties for the GG spacecraft without the PGB assembly

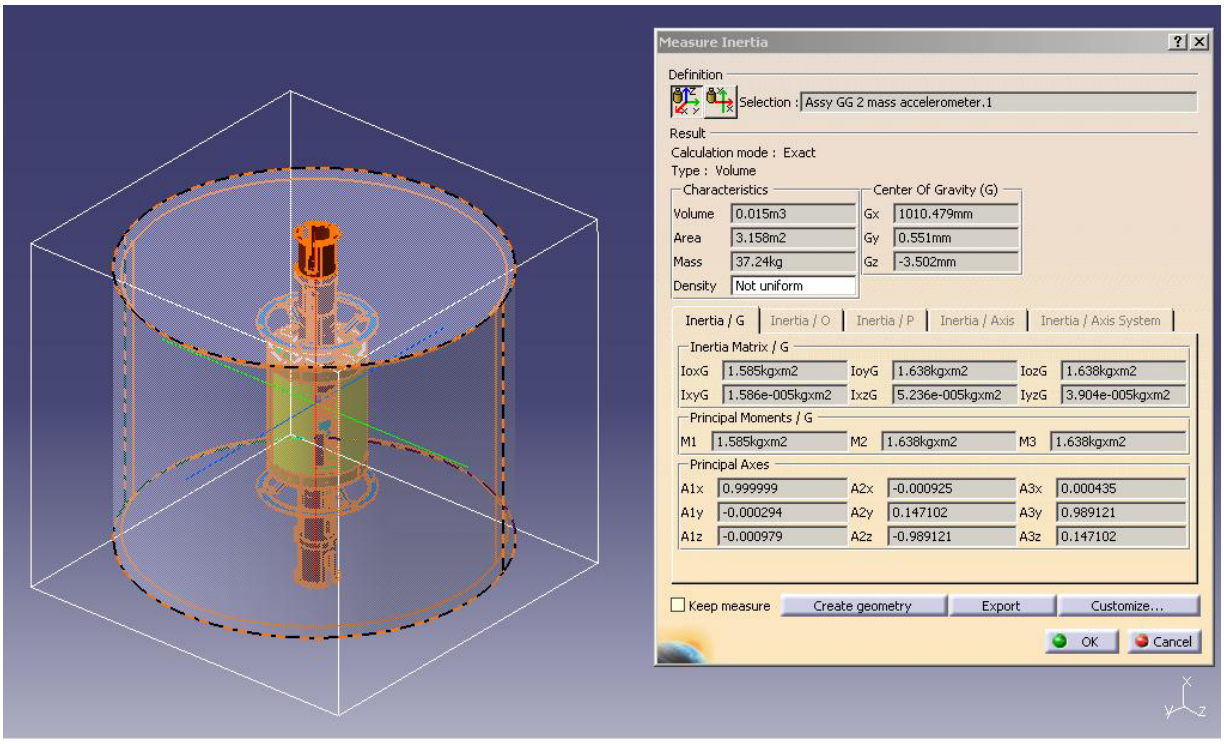

Table 4.1-3: Mass Properties for the PGB assembly without the proof masses

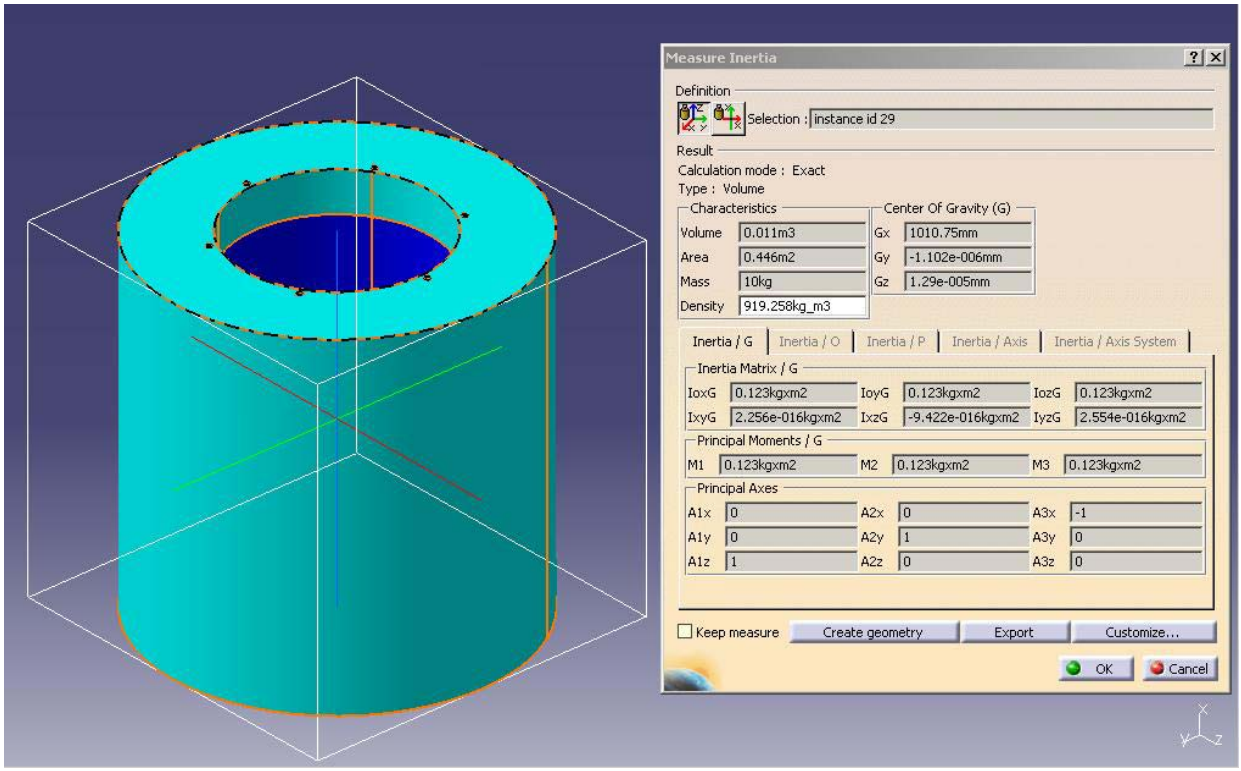

Table 4.1-4: Mass Properties for the outer proof mass

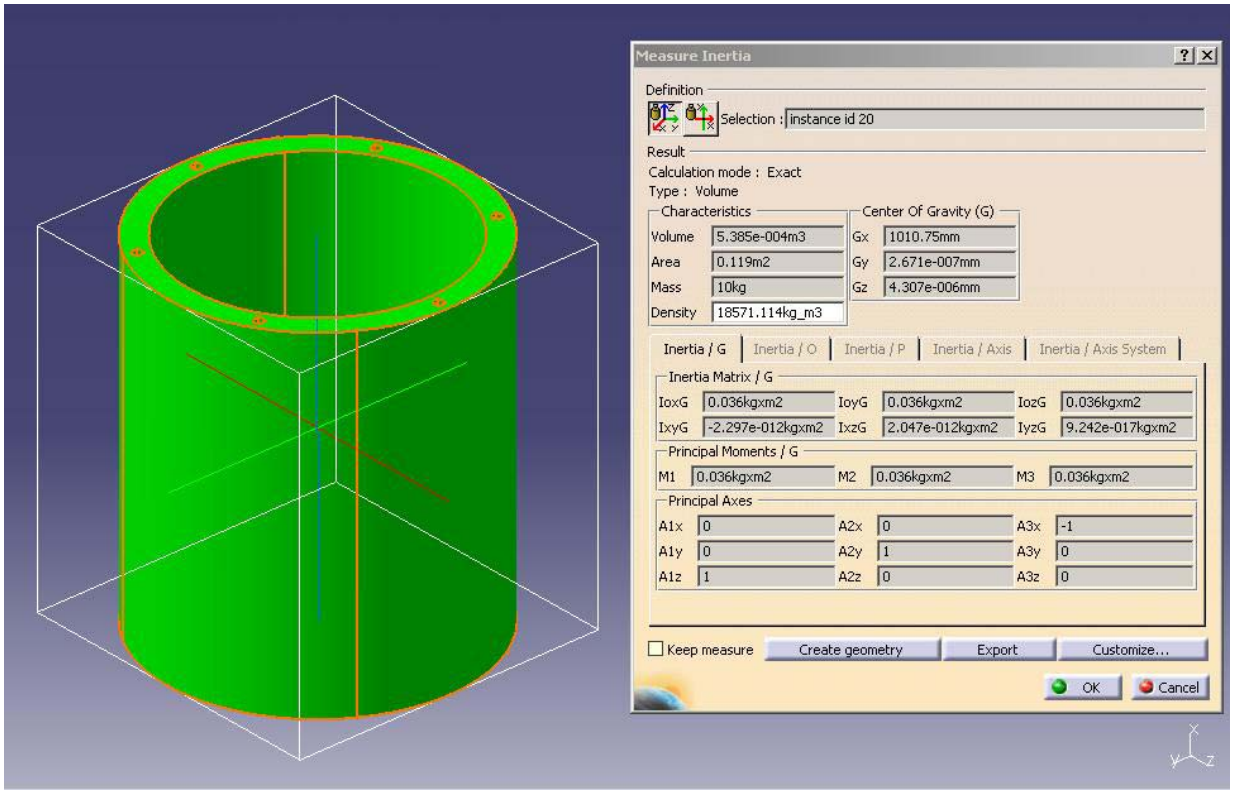

Table 4.1-5: Mass Properties for the inner proof mass

5. POWER BUDGET

5.1 System Power Budget

The power demand of the satellite is computed taking into account the design maturity of each unit (power contingency). The reference configuration used to compute the power budget includes the utilization of the FEEP organized in two clusters with 4 thrust each and assuming an average total thrust of 350 uN.

The following table summarizes the satellite power consumption for the reference configuration.

Power Budget (Configuration with 2 FEEP clusters)					Sunlit	Eclipse	
Equipments	No. Of active	Unit Power [W]	Contingency [%]	Power with Contingency [W]	Nominal Power [W]	Nominal Power [W]	LEOP phase [W]
ECE	1	9	20	10.8	10.8	0	0
CPE	1	18	20	21.6	21.6	0	0
Total P/L [W]					**32.4**	**0.0**	**0.0**
CDMU	1	18.0	10	19.8	19.8	19.8	19.8
TRSP1 (Tx + Rx)	1	20.0	3	20.6	20.6	20.6	20.6
TRSP 2 (Tx + Rx)	1	6.5	5	6.8	6.8	6.8	6.8
PCDU	1	25.0	10	27.5	44.5	27.5	27.5
Battery (max charging)	-	-	-	-	180.0	0.0	0.0
TCS (heaters)	1	12.0	20	14.4	14.4	30.0	30.0
Fine Sun sensor	1	1.3	10	1.4	1.4	1.4	0.0
Gyro	0	19.8	10	21.8	0.0	0.0	21.8
Rate Sensor	1	6.0	10	6.6	6.6	6.6	0.0
Magnetometer	3	0.8	10	0.9	2.6	2.6	2.6
FEEP (2 cluster option)	1	133.0	20	159.6	159.6	159.6	0.0
Total Service Module [W]					**456.4**	**275.0**	**129.1**
Total Satellite [W]					**488.8**	**275.0**	**129.1**
PCDU loss [2%]					9.8	5.5	2.6
Harness loss [2%]					10.0	5.6	2.6
GRAND TOTAL w/o system margin [W]					**508.5**	**286.1**	**166.5**

Table 5.1-1: Satellite Power Budget

5.2 Payload Power Budget

Power Budget (Configuration with 2 FEEP clusters)					Sunlit	Eclipse	
Equipments	No. Of active	Unit Power [W]	Contingency [%]	Power with Contingency [W]	Nominal Power [W]	Nominal Power [W]	LEOP phase [W]
ECE	1	9	20	10.8	10.8	0	0
CPE	1	18	20	21.6	21.6	0	0
Total P/L [W]					**32.4**	**0.0**	**0.0**

Table 5.2-1: Payload power budget

5.3 SVM Power Budget

The following table summarizes the calculated power consumption of the SVM. For each unit the power contingency based on design heritage has been considered to estimate the power consumption.

GG - Power Budget 29 Maggio 2009 (Configurazione FEEP with 2 cluster - BASELINE)					Notes
Equipments	No. Of active	Unit Power [W]	Contingency [%]	Power with Contingency [W]	
CDMU	1	18	10	19.8	heritage PRIMA project
TRSP1 (Tx + Rx)	1	20	3	20.6	heritage PRIMA project
TRSP 2 (Tx + Rx)	1	6.5	5	6.825	heritage PRIMA project
PCDU	1	25	10	27.5	heritage PRIMA project
Battery (max charging)	-	-	-	-	
TCS (heaters)	1	12	20	14.4	value derived from preliminary result of thermal analysis
Sun sensor	1	1.3	10	1.43	Selex GA Smart Sun Sensor
Gyro	0	19.8	10	22	Honeywell MIMU. The gyro are not used when the FEEP are operative
Rate Sensor	1	6	10	6.6	value derived from test on BB
Magneto Meter	3	0.8	10	2.64	IAI TAMAM - PRIMA FAMILY platform – Cosmo SkyMed
FEEP (2 cluster option)	3	133	20	160	heritage from LISA PF

Table 5.3-1: SVM power budget

The Solar Array panels have been sized to sustain the load power demand of 509 W during the sunlit period, which includes 180 W required to recharge the battery, assuming a BCR efficiency of 95%.

The battery has been sized considering the power demand during the eclipse period of 288 W (including the BDR efficiency of 95%), and maximum DoD of 30%.

The delivered power by the solar array at BoL and EoL (6 years) is reported in the table below.

Delivered power at BOL, 28°C						
V_{oc} [V]	I_{sc} [A]	V_{mp} [V]	I_{mp} [A]	P_{max} [W]	Pload (28V) [W]	T [°C]
37.7	19.6	31.7	18.7	591.5	544.9	28

Delivered power at EOL SS, 50°C with 1 string loss, 23° SAA						
V_{oc} [V]	I_{sc} [A]	V_{mp} [V]	I_{mp} [A]	P_{max} [W]	Pload (28V)	T [°C]
36.8	18.3	31	17.5	543.8	510	50

Table 5.3-2: Power delivered by the solar array at BoL and after 6 years.

To estimate the power consumption of the PCDU, the models in Figure 5.3-1 and Figure 5.3-2 have been used.

The power loss due to the PCDU power distribution has been calculated as 2% of SC total power demand. The power loss due to the harness resistance has been calculated as 2% of SC total power demand plus PCDU power distribution loss.

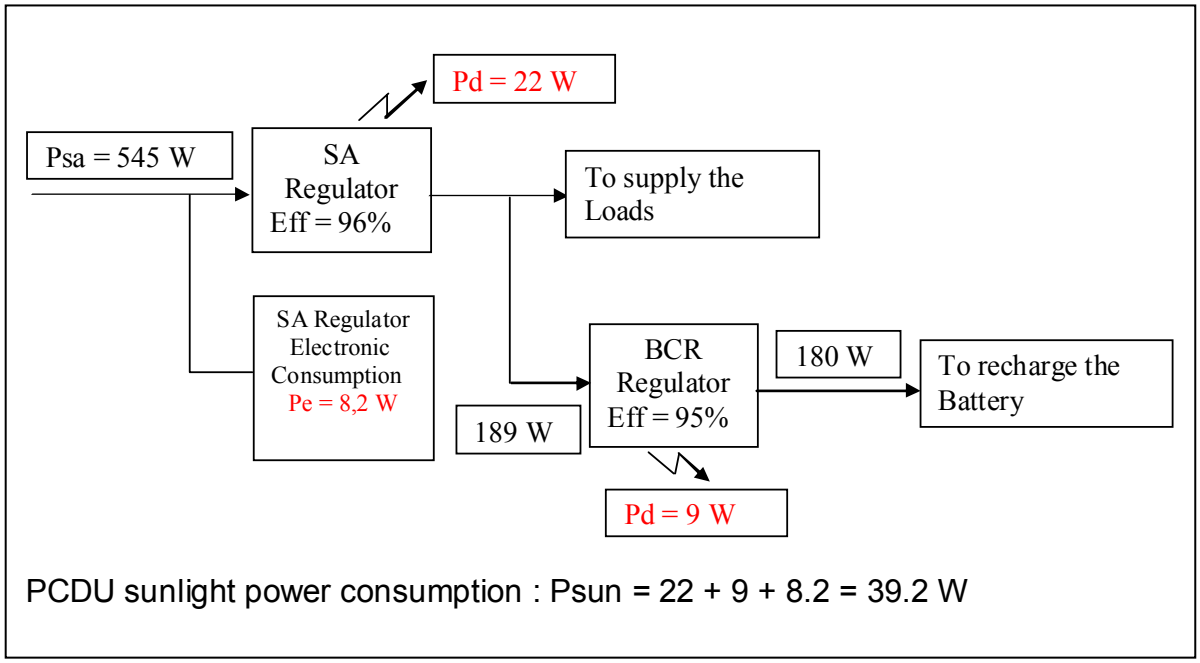

Figure 5.3-1: PCDU sunlight power consumption

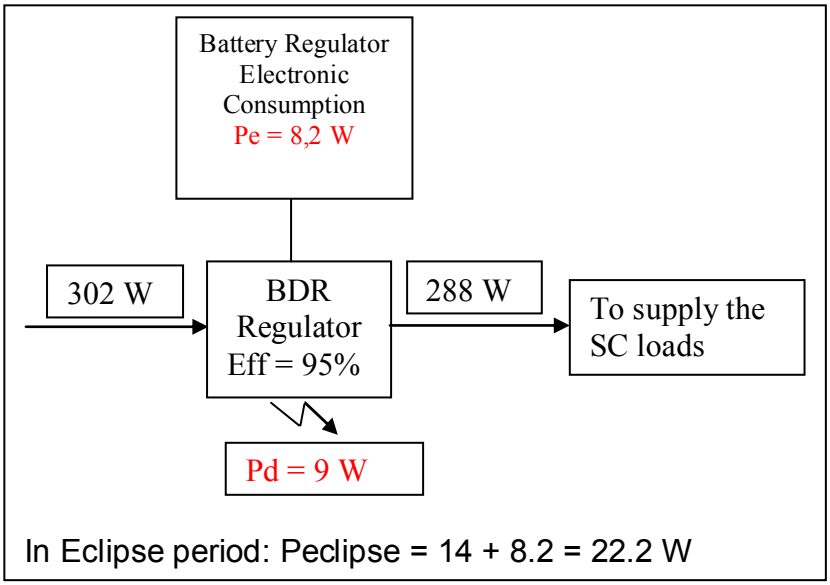

Figure 5.3-2: PCDU eclipse power consumption

6. DATA RATE BUDGET

The mass memory budget and hence the telemetry data rates have been calculated on the basis of the following table.

Data description	Variable list	Number of variables	Freq. [Hz]	Record length [bit]	Data rate [kbit/s]
Diff. TMs displacement	Δx, Δy	2	50	16	1.6
Tme/PGB displacement	Δx, Δy, Δz	3	50	16	2.4
Tmi/PGB displacement	Δx, Δy, Δz	3	50	16	2.4
PGB/Spacecraft displac.	Δx, Δy, Δz	3	50	16	2.4
ω_{SPIN}	ω_x, ω_y, ω_z	3	50	16	2.4
Reference time	t	1	50	16	0.8
Science data					**12.0**
PGB whirl monitoring	Sensing + actuation	6	1	16	0.096
Tme whirl monitoring	Sensing + actuation	6	1	16	0.096
Tmi whirl monitoring	Sensing + actuation	6	1	16	0.096
ADC monitoring	Number of ADC	9	1	16	0.144
Inchworm monitoring	Number of inchworms	6	1	16	0.096
Piezo monitoring	Number of piezo	6	1	16	0.096
PGB Inner temperature monitoring	Number of temperature sensors	20	0.10	16	0.03
Capacitance bridge monitoring	Number of capacitance bridges	9	0.10	16	0.01
Payload HK					**0.7**
Commands to FEEP	Number of commands	6	1	16	0.096
PGB/Spacecraft phase lag	Number of lag sensors	1	0.10	16	0.0016
Commands to actuators	Number of commands	6	50	16	4.8
Sun sensor	1 (2 in case o redundancy)	2	50	16	1.6
FEEP monitoring	Number of FEEP	6	1	16	0.096
SVM (DFACS + other sub-systems)					**10.0**
			Total Data Rate	kbps	**22.7**
			Overhead		**20.0%**
			Total Data Rate with margins	kbps	**27.2**
			Altitude	km	**600**
			Period	s	**5801**
			Data volume	Mbit/orbit	**158**
			Pass duration	minutes	**10**
			Telemetry rate	kbit/s	**263**
			Passages/day		**14**
			Telemetry data volume	Mbit/day	**2350**

Table 5.3-1: GG data rate budget

7. RF LINK BUDGETS

Three main cases of RF link budgets, based on the architecture proposed in the Design Report, have been examined. Followings fixed parameters have been used as inputs:

- Malindi ground station EIRP in uplink and G/T in downlink
- S-Band transponder output power = 23 dBm (200 mW)
- RFDN losses
- SP-L TM modulation
- Reed-Solomon coding for TM
- Galileo Galilei altitude = 520 km
- Elevation over Malindi = 10 degrees
- TC bit rate = 4 kbps
- TC modulation index = 1.0 rad pk
- Ranging uplink modulation index = 0.6 rad pk (where applicable)
- TM modulation index = 1.1 rad pk
- Ranging downlink modulation index = 0.5 rad pk (where applicable)

The parameters changed in the three cases listed here below are:

- LGA gain:
  - the minimum for data rate dimensioning
  - the maximum to verify that power flux density at the Earth limit is not exceeded
- Ranging mode
- TM maximum information rate
  - 450 kbps (that becomes 512 kbps after Reed-Solomon coding) for TM only
  - 225 kbps (that becomes 256 kbps after Reed-Solomon coding) for TM + RNG

In details:

- Case 1: TM only with LGA minimum gain
- Case 2: TM + ranging with LGA minimum gain
- Case 3: TM only with LGA maximum gain

Case 1

RF LINK BUDGET

LINK ID	: QG - LGAmin - PRIMA0.5-520km_450kbps_TM_only_capability		
DATE	: 27/05/2009	S/C TRASPONDER :	PRIMA - 0.5W
S/CRAFT	: Polari-X	S/C ANTENNA	RINSA helix S-Band antenna
ORBIT	: Equatorial	ALTITUDE (1000km)	0.52
G/STATION	: Malindi	ELEVATION (deg) :	10.00
TELECOMMAND BIT RATE (b/s)	:	4000	RANGING : No
EFF. TELEMETRY BIT RATE (b/s)	:	450000	

BASIC UPLINK (1/2)

		NOM	ADV	FAV	MEAN	VAR	PDF
G/S TX POWER	dBW	68.70	68.70	68.70	68.70	0.00	TRI
CIRCUIT LOSS	dB	0.00	0.00	0.00	0.00	0.00	UNI
TX ANT GAIN	dBi	0.00	0.00	0.00	0.00	0.00	UNI
G/S ANT TX AXIAL RATIO	dB	0.00	0.00	0.00			
POINTING LOSS	dB	0.00	0.00	0.00	0.00	0.00	UNI
EIRP G/S	dBW	**68.7**	**68.7**	**68.7**	68.7	0.00	
FREQUENCY	GHz	2.101	2.101	2.101	2.101		
SLANT RANGE	1000*km	1.74	1.74	1.74	1.74		
PATH LOSS	dB	163.72	163.72	163.72	163.72		
ATMOSPHERIC LOSS	dB	0.50	0.60	0.40	0.50	0.00	GAU
IONOSPHERIC LOSS	dB	0.00	0.00	0.00	0.00	0.00	GAU
COPOLAR ANT-GAINS	Y=1/N=0	1.00					
POLARISATION MISMATCH	dB	0.00	0.00	0.00	0.00	0.00	UNI
TOTAL PROPAG. LOSS	dB	164.22	164.32	164.12	164.22	0.00	
POWER-FLUX at S/C	dBm/m^2	**-37.12**	**-37.12**	**-37.12**	-37.12		
S/C RX ANT GAIN	dBi	-3.00	-3.00	-3.00	-3.00	0.00	TRI
S/C POINTING LOSS	dB	0.00	0.00	0.00	0.00	0.00	TRI
S/C ANT RX AXIAL RAT	dB	1.00	1.00	1.00			
ANTENNA NOISE TEMP	K	35.00	35.00	35.00			
ANTENNA/FEED VSWR	:1	1.22	1.22	1.22			
VSWR LOSS	dB	0.04	0.04	0.04	0.04	0.00	TRI
WG PHYSICAL TEMP	K	390.00	430.00	340.00			
WG LOSS	dB	0.72	0.79	0.65	0.72	0.00	UNI
CIRCUITS TEMPERATURE	K	390.00	430.00	340.00			
RFDN LOSSES	dB	0.76	0.84	0.68	0.76	0.00	UNI
TOTAL CIRCUITS-LOSS	dB	**1.5**	**1.6**	**1.3**			
DIPL. CIRCUIT LOSS (*)	dB	0.00	0.00	0.00	0.00	0.00	UNI
RECEIVER NOISE FIGURE	dB	3.00	3.50	2.50			
REF SYSTEM TEMP (**)	K	578.63	649.23	515.70			
RX SYSTEM TEMP (**)	K	428.98	521.24	343.48			
RX SYSTEM TEMP (**)	dBK	26.32	27.17	25.36	26.26	0.09	GAU
NOISE FLOOR (**)	dBm/Hz	-172.28	-171.43	-173.24			
S/C RX G/T	dB/K	-30.85	-31.84	-29.73			
RX POWER (**)	dBm	-70.04	-70.29	-69.80	-70.04	0.00	
THEOR CAR THRSH (**)	dBm	-131.95					
CAR ACQ THRSH (**)	dBm	-128.00	-128.00	-128.00			
THEOR TC THRSH (**)	dBm	-119.24					
TC RX THRSH (**)	dBm	-110.00	-110.00	-110.00			
REQ RX POWER (**)	dBm	-110.00	-110.00	-110.00	-110.00		

RX POWER MARGIN	**dB**	**39.96**	39.71	40.20	39.96	0.00
MEAN-3*SIGMA	**dB**	**39.75**				
MARGIN - w.c. RSS	**dB**	**39.81**				

RX S/No	dBHz	102.23	101.14	103.44	102.29	0.10

*) Diplexer Losses included in RFDN Losses
**) Reference at XPND/RFDN Interface (i.e. at XPND input)

RF LINK BUDGET

LINK ID	: *GG – LGAmin – PRIMA0.5–520km_450kbps_TM_only_capabilitr*		
DATE	: *27/05/2009*	S/C TRASPONDER :	*PRIMA – 0.5W*
S/CRAFT	: *Polari–X*	S/C ANTENNA	*RIMSA helix S–Band antenna*
ORBIT	: *Equatorial*	ALTITUDE (1000km)	*0.52*
G/STATION	: *Malindi*	ELEVATION (deg) :	*10.00*
TELECOMMAND BIT RATE (b/s)	:	4000	RANGING : No
EFF.TELEMETRY BIT RATE (b/s)	:	450000	

UPLINK (2/2)

		NOM	ADV	FAV	MEAN	VAR	PDF
RX S/No	dBHz	**102.23**	**101.14**	**103.44**	102.29	*0.10*	
MODULATION INDICES			MAX	MIN			
TELECOMMAND	rad pk	*1.00*	1.05	0.95	(sine)		
RANGING (RNG)	rad pk	*0.00*	0.00	0.00			
RNG, sine(1) or sqre(2)		*1*					
CARRIER RECOVERY							
CARRIER SUPPRESSION	dB	2.32	2.58	2.08	2.33	0.01	TRI
BPL (1), non–coh AGC (2) or coherent AGC (3) ?		*3*					
AGC INPUT BANDWIDTH	kHz	*3.00*	3.30	2.70			
PLL–BDW 2*Blo (*)	Hz	*800.00*	960.00	640.00			
THRSHD C/N in 2*Blo	dB	*10.00*	(common Definition)				
PLL DAMPING (*)		*0.73*	0.80	0.66			
Effect PLL DAMPING		0.73	0.80	0.66			
Effect PLL–BDW 2*Bl	Hz	800.00	960.00	640.00			
Max ACQ SWEEP RATE	kHz/s	32.00	30.23	32.00	31.12		
Effect PLL–BDW 2*Bl	dBHz	29.03	29.82	28.06	28.94	0.13	TRI
BP–LIMT SYSTEM LOSS	dB	0.00	0.00	0.00	0.00	0.00	TRI
IMPLEMENTATION LOSS	dB	*1.00*	*1.00*	*1.00*	1.00	0.00	TRI
REQ C/N in PLL–BDW	dB	*10.00*	*10.00*	*10.00*	10.00		
CARRIER MARGIN	dB	**59.88**	57.73	62.30	60.02	0.24	
MEAN–3*SIGMA	dB	**58.56**					
MARGIN – w.c. RSS	dB	**58.68**					
TELECOMMAND RECOVERY							
MODULATION LOSS	dB	4.12	4.45	3.81	4.13	0.02	TRI
IMPLMENT LOSS (**)	dB	*2.00*	*2.00*	*2.00*	2.00	0.00	TRI
BIT RATE	b/s	4000	4000	4000			
BIT RATE	dBHz	36.02	36.02	36.02	36.02		
REQ Eb/No (***)	dB	*9.60*	9.60	9.60	9.60		
TELECOMMAND MARGIN	dB	**50.49**	49.06	52.01	50.54	0.11	
MEAN–3*SIGMA	dB	**49.53**					
MARGIN – w.c. RSS	dB	**49.57**					
TRANSPD RANG.–CHANNEL							
TC in RNG–Vdbd	Y=1/N=0	*1*					
TONE MODULATION LOSS	dB	No RG	No RG	No RG			
RNG NOISE BNDWIDTH	kHz	*3000.00*	3300.00	2700.00			
RNG NOISE BNDWIDTH	dBHz	64.77	65.19	64.31			
IMPLEMENTATION LOSS	dB	*1.50*	*1.50*	*1.10*			
S(Tone)/N in Videobd	dB	No RG	No RG	No RG			
S(TC)/N in RG–Videobd	dB	31.84	34.22	30.00			

*) Reference at Carrier Acquisition Threshold.
**) Demod Loss includes: PSK demod + TC BPSK Decoder Loss.
***) Theoretical TC Decoder Required Eb/No.

END of UpLink GG – LGAmin – PRIMA0.5–520km_450kbps_TM_only_capa

RF LINK BUDGET

LINK ID	: *QG - LGAmin - PRIMA0.5-520km_450kbps_TM_only_capabilit*		
DATE	: *27/05/2009*	S/C TRASPONDER :	*PRIMA - 0.5W*
S/CRAFT	: *Polari-X*	S/C ANTENNA	*RINSA helix S-Band antenna*
ORBIT	: *Equatorial*	ALTITUDE (1000km) :	*0.52*
G/STATION:	*Malindi*	ELEVATION (deg):	*10.00*
TELECOMMAND BIT RATE (b/s) :		4000	RANGING : No
EFF. TELEMETRY BIT RATE (b/s) :		450000	with CODING : Reed Sol

BASIC DOWNLINK (1/2)

		NOM	ADV	FAV	MEAN	VAR	PDF
S/C TX POWER	dBW	*-6.99*	*-6.99*	*-6.99*	-6.99	0.00	TRI
DIPL. CIRCUIT LOSS (*)	dB	*0.00*	*0.00*	*0.00*			
RFDN LOSSES	dB	*0.76*	*0.84*	*0.68*			
WG LOSS	dB	*0.72*	*0.79*	*0.65*			
ANT. VSWR, overall	:1	*1.22*	*1.22*	*1.22*			
VSWR LOSSES	dB	0.04	0.04	0.04			
TOTAL CIRCUITS LOSS	dB	1.52	1.67	1.37	1.52	0.00	TRI
S/C TX ANT GAIN	dBi	*-3.00*	*-3.00*	*-3.00*	-3.00	0.00	TRI
S/C ANT TX AXIAL RATIO	dB	*1.80*	*1.80*	*1.80*			
POINTING LOSS	dB	*0.00*	*0.00*	*0.00*	0.00	0.00	UNI
EIRP S/C	dBW	**-11.51**	**-11.66**	**-11.36**	-11.51	*0.00*	
FREQUENCY	GHz	*2.282*	2.282	2.282	2.282		
SLANT RANGE	1000*km	1.744	1.744	1.744	1.74		
PATH LOSS	dB	164.44	164.44	164.44	164.44		
ATMOSPHERIC LOSS	dB	*0.50*	*0.60*	*0.40*	0.50	0.00	GAU
IONOSPHERIC LOSS	dB	*0.00*	*0.00*	*0.00*	0.00	0.00	GAU
COPOLAR ANT-GAINS	Y=1/N=0	*1*					
POLARISATION MISMATCH	dB	0.05	0.05	0.05	0.05	0.00	UNI
TOTAL PROPAGATION LOSS	dB	164.99	165.09	164.89	164.99	*0.00*	
FLUX at G/S	dBm/m^2	-117.33	-117.48	-117.19	-117.33	*0.00*	
POWER FLUX DENS	dBW/m^2	-154.20	-152.40	-156.53	(in 4 kHz)		
MAXIM FLUX DENS	dBW/m^2	-151.50	-151.50	-151.50	(S- or X-Bnd)		-151.50
FLUX MARGIN	**dB**	**2.70**	0.90	5.03			
G/S RX ANT GAIN	dBi	*45.01*	*45.01*	*45.01*	45.01	0.00	TRI
G/S POINTING LOSS	dB	*0.20*	*0.20*	*0.20*	0.20	0.00	UNI
G/S ANT RX AXIAL RATIO	dB	*1.00*	*1.00*	*1.00*			
RECEIVED POWER	dBm	-101.69	-101.94	-101.44			
SYSTEM NOISE TEMP	dBK	*23.71*	*23.71*	*23.71*	23.71	0.00	GAU
RX G/T	**dB/K**	**21.30**	**21.30**	**21.30**	21.30	0.00	
RX S/No	dBHz	73.20	72.95	73.45	73.20	*0.00*	
S/N in RANGING BW							
S(Tone)/N in Videobd	dB	No RG	No RG	No RG			
S(TC)/N in RG-Videobd	dB	31.84	34.22	30.00			
		0	0	0			
		1527.64838	2641.47754	999.3306642			
MODULATION INDICES			MAX	MIN			
TELEMETRY (TM)	rad pk	*1.10*	1.21	0.99			
TM, sine(1) or sqre(2)		*2*					
RANGING	rad pk	*0.00*	0.00	0.00			
RANG. TONE effec	rad pk	0.00	0.00	0.00			
TC in RG-Videobd	rad pk	0.00	0.00	0.00			
NOISE INDEX		0.00	0.00	0.00			

*) Diplexer Losses included in RFDN Losses

RF LINK BUDGET

LINK ID	: GG – LGAmin – PRIMA0.5-520km_450kbps_TM_only_capabilit		
DATE	: 27/05/2009	S/C TRASPONDER :	PRIMA – 0.5W
S/CRAFT	: Polari-X	S/C ANTENNA	RIMSA helix S-Band antenna
ORBIT	: Equatorial	ALTITUDE (1000km) :	0.52
G/STATION	: Malindi	ELEVATION (deg) :	10.00
TELECOMMAND BIT RATE (b/s) :		4000	RANGING : No
EFF. TELEMETRY BIT RATE (b/s) :		450000	with CODING : Reed Sol

DOWNLINK (2/2)

		NOM	ADV	FAV	MEAN	VAR	PDF
RX S/No	dBHz	73.20	72.95	73.45	73.20	0.00	
CARRIER RECOVERY		0.000	0.000	0.000			
CARRIER SUPPRESSION	dB	6.87	9.04	5.21	7.13	0.61	TRI
PLL BANDWIDTH 2*Bl	Hz	10.00	12.00	8.00			
PLL BANDWIDTH	dBHz	10.00	10.79	9.03	9.91	0.13	TRI
G/S required C/N in 2BI	dB	17.00	17.00	17.00	17.00		
CARRIER MARGIN	**dB**	39.33	36.11	42.20	39.16	0.75	
MEAN-3*SIGMA	**dB**	36.57					
MARGIN – w.c. RSS	**dB**	37.01					
TELEMETRY RECOVERY							
TLM MODULATION LOSS	dB	1.00	0.58	1.56	1.07	0.04	TRI
DEMODULATOR TECH LOSS	dB	0.90	1.00	0.80	0.90	0.00	TRI
BIT RATE	b/s	450000	450000	450000			
BIT RATE	dbHz	56.53	56.53	56.53	56.53		
CODING GAIN	dB	5.80	5.80	5.80			
CODING RATE 1/R		1.14					
REQ Eb/No (PFL=1.E-5)	dB	6.70	6.70	6.70	6.70		
TELEMETRY MARGIN	**dB**	8.07	8.14	7.86	8.00	0.05	
MEAN-3*SIGMA	**dB**	7.35					
MARGIN – w.c. RSS	**dB**	7.60					
TONE RECOVERY		0	0	0			
TONE MODULATION LOSS	dB	No RG	No RG	No RG	No RG	No RG	TRI
IMPLEMENTATION LOSS	dB	2.00	2.00	2.00	2.00	0.00	TRI
REQ S(Tone)/N	dB	19.00	19.00	19.00	19.00		
		10.00	10.00	10.00	10		
RANGING MARGIN (*)	**dB**	No RG	No RG	No RG	No RG	#VALUE!	
MEAN-3*SIGMA	**dB**	No RG					
MARGIN – w.c. RSS	**dB**	No RG		0			
COMB. CARR. JITTER (**)							
RX TRSPD-PLL JITT	deg	0.01	0.02	0.01	0.01		
TRANSMT CARR. JITT	deg	2.00	3.00	1.00	2.00		
JITT BDW 2*B (***)	Hz	5.00	10.00	3.00	6.50		
RX COMBD CARR JITT	deg	0.82	1.58	0.32	1.42		

*) The required MINIMUM Loop-Bandwith supported by MPTS is 1.25 mHz;
the valued assumed here is 10 mHz.
**) Coherent transponder mode assumed for RX COMBD CARR JITTer at G/S.
***) 2*B is the bandwidth of the jitter from the TX chain or a HPA.

END of DownLink GG – LGAmin – PRIMA0.5-520km_450kbps_TM_only_capab

Case 2

RF LINK BUDGET

LINK ID :	*GG - IGAmin - PRIMA0.5-520km_225kbps_TM_+RNG*		
DATE :	*27/05/2009*	S/C TRASPONDER :	*PRIMA - 0.5W*
S/CRAFT :	*Polari-X*	S/C ANTENNA	*RINSA helix S-Band antenna*
ORBIT :	*Equatorial*	ALTITUDE (1000km)	*0.52*
G/STATION:	*Malindi*	ELEVATION (deg):	*10.00*
TELECOMMAND BIT RATE (b/s) :		4000	RANGING : Yes
EFF. TELEMETRY BIT RATE (b/s) :		225000	

BASIC UPLINK (1/2)

		NOM	ADV	FAV	MEAN	VAR	PDF
G/S TX POWER	dBW	*68.70*	*68.70*	*68.70*	68.70	0.00	TRI
CIRCUIT LOSS	dB	*0.00*	*0.00*	*0.00*	0.00	0.00	UNI
TX ANT GAIN	dBi	*0.00*	*0.00*	*0.00*	0.00	0.00	UNI
G/S ANT TX AXIAL RATIO	dB	*0.00*	*0.00*	*0.00*			
POINTING LOSS	dB	*0.00*	*0.00*	*0.00*	0.00	0.00	UNI
EIRP G/S	dBW	**68.7**	**68.7**	**68.7**	68.7	*0.00*	
FREQUENCY	GHz	2.101	2.101	2.101	2.101		
SLANT RANGE	1000*km	1.74	1.74	1.74	1.74		
PATH LOSS	dB	163.72	163.72	163.72	163.72		
ATMOSPHERIC LOSS	dB	*0.50*	*0.60*	*0.40*	0.50	0.00	GAU
IONOSPHERIC LOSS	dB	*0.00*	*0.00*	*0.00*	0.00	0.00	GAU
COPOLAR ANT-GAINS	Y=1/N=0	*1.00*					
POLARISATION MISMATCH	dB	0.00	0.00	0.00	0.00	0.00	UNI
TOTAL PROPAG. LOSS	dB	164.22	164.32	164.12	164.22	*0.00*	
POWER-FLUX at S/C	dBm/m^2	**-37.12**	**-37.12**	**-37.12**	-37.12		
S/C RX ANT GAIN	dBi	*-3.00*	*-3.00*	*-3.00*	-3.00	0.00	TRI
S/C POINTING LOSS	dB	*0.00*	*0.00*	*0.00*	0.00	0.00	TRI
S/C ANT RX AXIAL RAT	dB	*1.00*	*1.00*	*1.00*			
ANTENNA NOISE TEMP	K	*35.00*	*35.00*	*35.00*			
ANTENNA/FEED VSWR	:1	*1.22*	*1.22*	*1.22*			
VSWR LOSS	dB	0.04	0.04	0.04	0.04	0.00	TRI
WG PHYSICAL TEMP	K	*390.00*	*430.00*	*340.00*			
WG LOSS	dB	*0.72*	*0.79*	*0.65*	0.72	0.00	UNI
CIRCUITS TEMPERATURE	K	*390.00*	*430.00*	*340.00*			
RFDN LOSSES	dB	*0.76*	*0.84*	*0.68*	0.76	0.00	UNI
TOTAL CIRCUITS-LOSS	dB	**1.5**	**1.6**	**1.3**			
DIPL. CIRCUIT LOSS (*)	dB	*0.00*	*0.00*	*0.00*	0.00	0.00	UNI
RECEIVER NOISE FIGURE	dB	*3.00*	*3.50*	*2.50*			
REF SYSTEM TEMP (**)	K	578.63	649.23	515.70			
RX SYSTEM TEMP (**)	K	428.98	521.24	343.48			
RX SYSTEM TEMP (**)	dBK	26.32	27.17	25.36	26.26	0.09	GAU
NOISE FLOOR (**)	dBm/Hz	-172.28	-171.43	-173.24			
S/C RX G/T	dB/K	-30.85	-31.84	-29.73			
RX POWER (**)	dBm	-70.04	-70.29	-69.80	-70.04	*0.00*	
THEOR CAR THRSH (**)	dBm	-131.95					
CAR ACQ THRSH (**)	dBm	*-128.00*	*-128.00*	*-128.00*			
THEOR TC THRSH (**)	dBm	-118.44					
TC RX THRSH (**)	dBm	*-110.00*	*-110.00*	*-110.00*			
REQ RX POWER (**)	dBm	-110.00	-110.00	-110.00	-110.00		
RX POWER MARGIN	**dB**	**39.96**	39.71	40.20	39.96	0.00	
MEAN-3*SIGMA	**dB**	**39.75**					
MARGIN - w.c. RSS	**dB**	**39.81**					
RX S/No	dBHz	102.23	101.14	103.44	102.29	*0.10*	

*) Diplexer Losses included in RFDN Losses
**) Reference at XPND/RFDN Interface (i.e. at XPND input)

RF LINK BUDGET

LINK ID	: *GG – LGAmin – PRIMA0.5–520km_225kbps_TM_+RNG*		
DATE	: *27/05/2009*	S/C TRASPONDER :	*PRIMA – 0.5W*
S/CRAFT	: *Polari–X*	S/C ANTENNA	*RIMSA helix S–Band antenna*
ORBIT	: *Equatorial*	ALTITUDE (1000km)	*0.52*
G/STATION:	*Malindi*	ELEVATION (deg):	*10.00*
TELECOMMAND BIT RATE (b/s) :		4000	RANGING : Yes
EFF.TELEMETRY BIT RATE (b/s) :		225000	

UPLINK (2/2)

		NOM	ADV	FAV	MEAN	VAR	PDF
RX S/No	dBHz	**102.23**	**101.14**	**103.44**	102.29	*0.10*	
MODULATION INDICES			MAX	MIN			
TELECOMMAND	rad pk	*1.00*	1.05	0.95	(sine)		
RANGING (RNG)	rad pk	*0.60*	0.63	0.57			
RNG, sine(1) or sqre(2)		*1*					
CARRIER RECOVERY							
CARRIER SUPPRESSION	dB	3.12	3.47	2.80	3.14	0.02	TRI
BPL (1), non–coh AGC (2) or coherent AGC (3) ?		*3*					
AGC INPUT BANDWIDTH	kHz	*3.00*	3.30	2.70			
PLL–BDW 2*Blo (*)	Hz	*800.00*	960.00	640.00			
THRSHD C/N in 2*Blo	dB	*10.00*	(common Definition)				
PLL DAMPING (*)		*0.73*	0.80	0.66			
Effect PLL DAMPING		0.73	0.80	0.66			
Effect PLL–BDW 2*Bl	Hz	800.00	960.00	640.00			
Max ACQ SWEEP RATE	kHz/s	32.00	30.23	32.00	31.11		
Effect PLL–BDW 2*Bl	dBHz	29.03	29.82	28.06	28.94	0.13	TRI
BP–LIMT SYSTEM LOSS	dB	0.00	0.00	0.00	0.00	0.00	TRI
IMPLEMENTATION LOSS	dB	*1.00*	*1.00*	*1.00*	1.00	0.00	TRI
REQ C/N in PLL–BDW	dB	*10.00*	*10.00*	*10.00*	10.00		
CARRIER MARGIN	dB	**59.08**	56.85	61.58	59.21	0.24	
MEAN–3*SIGMA	dB	**57.73**					
MARGIN – w.c. RSS	dB	**57.86**					
TELECOMMAND RECOVERY							
MODULATION LOSS	dB	4.92	5.34	4.53	4.94	0.03	TRI
IMPLMENT LOSS (**)	dB	*2.00*	*2.00*	*2.00*	2.00	0.00	TRI
BIT RATE	b/s	4000	4000	4000			
BIT RATE	dBHz	36.02	36.02	36.02	36.02		
REQ Eb/No (***)	dB	*9.60*	9.60	9.60	9.60		
TELECOMMAND MARGIN	dB	**49.69**	48.18	51.29	49.73	0.12	
MEAN–3*SIGMA	dB	**48.68**					
MARGIN – w.c. RSS	dB	**48.74**					
TRANSPD RANG.–CHANNEL							
TC in RNG–Vdbd	Y=1/N=0	*1*					
TONE MODULATION LOSS	dB	10.17	10.83	9.54			
RNG NOISE BNDWIDTH	kHz	*3000.00*	3300.00	2700.00			
RNG NOISE BNDWIDTH	dBHz	64.77	65.19	64.31			
IMPLEMENTATION LOSS	dB	*1.50*	*1.50*	*1.10*			
S(Tone)/N in Videobd	dB	25.79	23.62	28.49			
S(TC)/N in RG–Videobd	dB	31.04	33.50	29.11			

*) Reference at Carrier Acquisition Threshold.
**) Demod Loss includes: PSK demod + TC BPSK Decoder Loss.
***) Theoretical TC Decoder Required Eb/No.

END of UpLink GG – LGAmin – PRIMA0.5–520km_225kbps_TM_+RNG

RF LINK BUDGET

LINK ID	: *QS - LGAmin - PRIMA0.5-520km_225kbps_TM_+RNG*		
DATE	: *27/05/2009*	S/C TRASPONDER	: *PRIMA - 0.5W*
S/CRAFT	: *Polari-X*	S/C ANTENNA	*RINSA helix S-Band antenna*
ORBIT	: *Equatorial*	ALTITUDE (1000km)	: *0.52*
G/STATION	: *Malindi*	ELEVATION (deg)	: *10.00*
TELECOMMAND BIT RATE (b/s)	: 4000	RANGING	: Yes
EFF. TELEMETRY BIT RATE (b/s)	: 225000	with CODING	: Reed Sol

BASIC DOWNLINK (1/2)

		NOM	ADV	FAV	MEAN	VAR	PDF
S/C TX POWER	dBW	*-6.99*	*-6.99*	*-6.99*	-6.99	0.00	TRI
DIPL. CIRCUIT LOSS (*)	dB	*0.00*	*0.00*	*0.00*			
RFDN LOSSES	dB	*0.76*	*0.84*	*0.68*			
WG LOSS	dB	*0.72*	*0.79*	*0.65*			
ANT. VSWR, overall	:1	*1.22*	*1.22*	*1.22*			
VSWR LOSSES	dB	0.04	0.04	0.04			
TOTAL CIRCUITS LOSS	dB	1.52	1.67	1.37	1.52	0.00	TRI
S/C TX ANT GAIN	dBi	*-3.00*	*-3.00*	*-3.00*	-3.00	0.00	TRI
S/C ANT TX AXIAL RATIO	dB	*1.80*	*1.80*	*1.80*			
POINTING LOSS	dB	*0.00*	*0.00*	*0.00*	0.00	0.00	UNI
EIRP S/C	dBW	**-11.51**	**-11.66**	**-11.36**	-11.51	*0.00*	
FREQUENCY	GHz	*2.282*	2.282	2.282	2.282		
SLANT RANGE	1000*km	1.744	1.744	1.744	1.74		
PATH LOSS	dB	164.44	164.44	164.44	164.44		
ATMOSPHERIC LOSS	dB	*0.50*	*0.60*	*0.40*	0.50	0.00	GAU
IONOSPHERIC LOSS	dB	*0.00*	*0.00*	*0.00*	0.00	0.00	GAU
COPOLAR ANT-GAINS	Y=1/N=0	*1*					
POLARISATION MISMATCH	dB	0.05	0.05	0.05	0.05	0.00	UNI
TOTAL PROPAGATION LOSS	dB	164.99	165.09	164.89	164.99	*0.00*	
FLUX at G/S	dBm/m^2	-117.33	-117.48	-117.19	-117.33	*0.00*	
POWER FLUX DENS	dBW/m^2	-154.75	-152.68	-157.44	(in 4 kHz)		
MAXIM FLUX DENS	dBW/m^2	-151.50	-151.50	-151.50	(S- or X-Bnd)		-151.50
FLUX MARGIN	**dB**	**3.25**	1.18	5.94			
G/S RX ANT GAIN	dBi	*45.01*	*45.01*	*45.01*	45.01	0.00	TRI
G/S POINTING LOSS	dB	*0.20*	*0.20*	*0.20*	0.20	0.00	UNI
G/S ANT RX AXIAL RATIO	dB	*1.00*	*1.00*	*1.00*			
RECEIVED POWER	dBm	-101.69	-101.94	-101.44			
SYSTEM NOISE TEMP	dBK	*23.71*	*23.71*	*23.71*	23.71	0.00	GAU
RX G/T	**dB/K**	**21.30**	**21.30**	**21.30**	21.30	0.00	
RX S/No	dBHz	73.20	72.95	73.45	73.20	*0.00*	
S/N in RANGING BW							
S(Tone)/N in Videobd	dB	25.79	23.62	28.49			
S(TC)/N in RG-Videobd	dB	31.04	33.50	29.11			
		379.685373	230.215897	706.3080847			
		1270.62591	2237.73764	815.2412341			
MODULATION INDICES			MAX	MIN			
TELEMETRY (TM)	rad pk	*1.10*	1.21	0.99			
TM, sine(1) or sqre(2)		*2*					
RANGING	rad pk	*0.50*	0.55	0.45			
RANG. TONE effec	rad pk	0.24	0.37	0.14			
TC in RG-Videobd	rad pk	0.44	0.52	0.33			
NOISE INDEX		0.01	0.02	0.01			

*) Diplexer Losses included in RFDN Losses

RF LINK BUDGET

LINK ID :	GG – LGAmin – PRIMA0.5–520km_225kbps_TM_+RNG		
DATE :	27/05/2009	S/C TRASPONDER :	PRIMA – 0.5W
S/CRAFT :	Polari-X	S/C ANTENNA	RINSA helix S-Band antenna
ORBIT :	Equatorial	ALTITUDE (1000km) :	0.52
G/STATION:	Malindi	ELEVATION (deg):	10.00
TELECOMMAND BIT RATE (b/s) :		4000	RANGING : Yes
EFF. TELEMETRY BIT RATE (b/s) :		225000	with CODING : Reed Sol

DOWNLINK (2/2)

		NOM	ADV	FAV	MEAN	VAR	PDF
RX S/No	dBHz	73.20	72.95	73.45	73.20	0.00	
CARRIER RECOVERY		0.548	0.914	0.278			
CARRIER SUPPRESSION	dB	7.42	9.96	5.49	7.72	0.83	TRI
PLL BANDWIDTH 2*Bl	Hz	10.00	12.00	8.00			
PLL BANDWIDTH	dBHz	10.00	10.79	9.03	9.91	0.13	TRI
G/S required C/N in 2BI	dB	17.00	17.00	17.00	17.00		
CARRIER MARGIN	**dB**	**38.78**	35.20	41.92	38.56	0.97	
MEAN-3*SIGMA	**dB**	**35.61**					
MARGIN – w.c. RSS	**dB**	**36.11**					
TELEMETRY RECOVERY							
TLM MODULATION LOSS	dB	1.55	1.49	1.83	1.66	0.00	TRI
DEMODULATOR TECH LOSS	dB	0.90	1.00	0.80	0.90	0.00	TRI
BIT RATE	b/s	225000	225000	225000			
BIT RATE	dbHz	53.52	53.52	53.52	53.52		
CODING GAIN	dB	5.80	5.80	5.80			
CODING RATE 1/R		1.14					
REQ Eb/No (PFL=1.E-5)	dB	6.70	6.70	6.70	6.70		
TELEMETRY MARGIN	**dB**	**10.53**	10.24	10.59	10.41	0.01	
MEAN-3*SIGMA	**dB**	**10.09**					
MARGIN – w.c. RSS	**dB**	**10.31**					
TONE RECOVERY		15.9006152	20.8768413	11.92883855			
TONE MODULATION LOSS	dB	22.77	29.92	17.14	23.53	6.80	TRI
IMPLEMENTATION LOSS	dB	2.00	2.00	2.00	2.00	0.00	TRI
REQ S(Tone)/N	dB	19.00	19.00	19.00	19.00		
		10.00	10.00	10.00	10		
RANGING MARGIN (*)	**dB**	**49.43**	42.03	55.30	48.67	6.81	
MEAN-3*SIGMA	**dB**	**40.84**					
MARGIN – w.c. RSS	**dB**	**42.27**	51.206487				
COMB. CARR. JITTER (**)							
RX TRSPD-PLL JITT	deg	0.01	0.02	0.01	0.01		
TRANSMT CARR. JITT	deg	2.00	3.00	1.00	2.00		
JITT BDW 2*B (***)	Hz	5.00	10.00	3.00	6.50		
RX COMBD CARR JITT	deg	0.82	1.58	0.32	1.42		

*) The required MINIMUM Loop-Bandwith supported by MPTS is 1.25 mHz;
the valued assumed here is 10 mHz.
**) Coherent transponder mode assumed for RX COMBD CARR JITTer at G/S.
***) 2*B is the bandwidth of the jitter from the TX chain or a HPA.

END of DownLink GG – LGAmin – PRIMA0.5–520km_225kbps_TM_+RNG

Case 3

RF LINK BUDGET

LINK ID	: GG - IGAmax - PRIMA0.5-520km_450kbps_TM_only		
DATE	: 27/05/2009	S/C TRASPONDER	: ISBT - 0.5W
S/CRAFT	: Polari-X	S/C ANTENNA	RINSA helix S-Band antenna
ORBIT	: Equatorial	ALTITUDE (1000km)	0.52
G/STATION	: Malindi	ELEVATION (deg)	: 10.00
TELECOMMAND BIT RATE (b/s)	:	4000	RANGING : No
EFF. TELEMETRY BIT RATE (b/s)	:	450000	

BASIC UPLINK (1/2)

		NOM	ADV	FAV	MEAN	VAR	PDF
G/S TX POWER	dBW	68.70	68.70	68.70	68.70	0.00	TRI
CIRCUIT LOSS	dB	0.00	0.00	0.00	0.00	0.00	UNI
TX ANT GAIN	dBi	0.00	0.00	0.00	0.00	0.00	UNI
G/S ANT TX AXIAL RATIO	dB	0.00	0.00	0.00			
POINTING LOSS	dB	0.00	0.00	0.00	0.00	0.00	UNI
EIRP G/S	dBW	**68.7**	**68.7**	**68.7**	68.7	0.00	
FREQUENCY	GHz	2.101	2.101	2.101	2.101		
SLANT RANGE	1000*km	1.74	1.74	1.74	1.74		
PATH LOSS	dB	163.72	163.72	163.72	163.72		
ATMOSPHERIC LOSS	dB	0.50	0.60	0.40	0.50	0.00	GAU
IONOSPHERIC LOSS	dB	0.00	0.00	0.00	0.00	0.00	GAU
COPOLAR ANT-GAINS	Y=1/N=0	1.00					
POLARISATION MISMATCH	dB	0.00	0.00	0.00	0.00	0.00	UNI
TOTAL PROPAG. LOSS	dB	164.22	164.32	164.12	164.22	0.00	
POWER-FLUX at S/C	dBm/m^2	**-37.12**	**-37.12**	**-37.12**	-37.12		
S/C RX ANT GAIN	dBi	-1.00	-1.00	-1.00	-1.00	0.00	TRI
S/C POINTING LOSS	dB	0.00	0.00	0.00	0.00	0.00	TRI
S/C ANT RX AXIAL RAT	dB	1.00	1.00	1.00			
ANTENNA NOISE TEMP	K	35.00	35.00	35.00			
ANTENNA/FEED VSWR	:1	1.22	1.22	1.22			
VSWR LOSS	dB	0.04	0.04	0.04	0.04	0.00	TRI
WG PHYSICAL TEMP	K	390.00	430.00	340.00			
WG LOSS	dB	0.72	0.79	0.65	0.72	0.00	UNI
CIRCUITS TEMPERATURE	K	390.00	430.00	340.00			
RFDN LOSSES	dB	0.76	0.84	0.68	0.76	0.00	UNI
TOTAL CIRCUITS-LOSS	dB	**1.5**	**1.6**	**1.3**			
DIPL. CIRCUIT LOSS (*)	dB	0.00	0.00	0.00	0.00	0.00	UNI
RECEIVER NOISE FIGURE	dB	3.00	3.50	2.50			
REF SYSTEM TEMP (**)	K	578.63	649.23	515.70			
RX SYSTEM TEMP (**)	K	428.98	521.24	343.48			
RX SYSTEM TEMP (**)	dBK	26.32	27.17	25.36	26.26	0.09	GAU
NOISE FLOOR (**)	dBm/Hz	-172.28	-171.43	-173.24			
S/C RX G/T	dB/K	-28.85	-29.84	-27.73			
RX POWER (**)	dBm	-68.04	-68.29	-67.80	-68.04	0.00	
THEOR CAR THRSH (**)	dBm	-131.95					
CAR ACQ THRSH (**)	dBm	-128.00	-128.00	-128.00			
THEOR TC THRSH (**)	dBm	-119.24					
TC RX THRSH (**)	dBm	-110.00	-110.00	-110.00			
REQ RX POWER (**)	dBm	-110.00	-110.00	-110.00	-110.00		
RX POWER MARGIN	**dB**	**41.96**	41.71	42.20	41.96	0.00	
MEAN-3*SIGMA	**dB**	**41.75**					
MARGIN - w.c. RSS	**dB**	**41.81**					
RX S/No	dBHz	104.23	103.14	105.44	104.29	0.10	

*) Diplexer Losses included in RFDN Losses
**) Reference at XPND/RFDN Interface (i.e. at XPND input)

RF LINK BUDGET

LINK ID	: GG - LGAmax - PRIMA0.5-520km_450kbps_TM_only		
DATE	: 27/05/2009	S/C TRASPONDER	: ISBT - 0.5W
S/CRAFT	: Polari-X	S/C ANTENNA	RIMSA helix S-Band antenna
ORBIT	: Equatorial	ALTITUDE (1000km)	0.52
G/STATION	: Malindi	ELEVATION (deg)	: 10.00
TELECOMMAND BIT RATE (b/s)	:	4000	RANGING : No
EFF.TELEMETRY BIT RATE (b/s)	:	450000	

UPLINK (2/2)

		NOM	ADV	FAV	MEAN	VAR	PDF
RX S/No	dBHz	**104.23**	**103.14**	**105.44**	104.29	0.10	
MODULATION INDICES			MAX	MIN			
TELECOMMAND	rad pk	1.00	1.05	0.95	(sine)		
RANGING (RNG)	rad pk	0.00	0.00	0.00			
RNG, sine(1) or sqre(2)		1					
CARRIER RECOVERY							
CARRIER SUPPRESSION	dB	2.32	2.58	2.08	2.33	0.01	TRI
BPL (1), non-coh AGC (2) or coherent AGC (3) ?		3					
AGC INPUT BANDWIDTH	kHz	3.00	3.30	2.70			
PLL-BDW 2*Blo (*)	Hz	800.00	960.00	640.00			
THRSHD C/N in 2*Blo	dB	10.00	(common Definition)				
PLL DAMPING (*)		0.73	0.80	0.66			
Effect PLL DAMPING		0.73	0.80	0.66			
Effect PLL-BDW 2*Bl	Hz	800.00	960.00	640.00			
Max ACQ SWEEP RATE	kHz/s	32.00	30.23	32.00	31.12		
Effect PLL-BDW 2*Bl	dBHz	29.03	29.82	28.06	28.94	0.13	TRI
BP-LIMT SYSTEM LOSS	dB	0.00	0.00	0.00	0.00	0.00	TRI
IMPLEMENTATION LOSS	dB	1.00	1.00	1.00	1.00	0.00	TRI
REQ C/N in PLL-BDW	dB	10.00	10.00	10.00	10.00		
CARRIER MARGIN	**dB**	**61.88**	59.73	64.30	62.02	0.24	
MEAN-3*SIGMA	**dB**	**60.56**					
MARGIN - w.c. RSS	**dB**	**60.68**					
TELECOMMAND RECOVERY							
MODULATION LOSS	dB	4.12	4.45	3.81	4.13	0.02	TRI
IMPLMENT LOSS (**)	dB	2.00	2.00	2.00	2.00	0.00	TRI
BIT RATE	b/s	4000	4000	4000			
BIT RATE	dBHz	36.02	36.02	36.02	36.02		
REQ Eb/No (***)	dB	9.60	9.60	9.60	9.60		
TELECOMMAND MARGIN	**dB**	**52.49**	51.06	54.01	52.54	0.11	
MEAN-3*SIGMA	**dB**	**51.53**					
MARGIN - w.c. RSS	**dB**	**51.57**					
TRANSPD RANG.-CHANNEL							
TC in RNG-Vdbd	Y=1/N=0	1					
TONE MODULATION LOSS	dB	No RG	No RG	No RG			
RNG NOISE BNDWIDTH	kHz	3000.00	3300.00	2700.00			
RNG NOISE BNDWIDTH	dBHz	64.77	65.19	64.31			
IMPLEMENTATION LOSS	dB	1.50	1.50	1.10			
S(Tone)/N in Videobd	dB	No RG	No RG	No RG			
S(TC)/N in RG-Videobd	dB	33.84	36.22	32.00			

*) Reference at Carrier Acquisition Threshold.
**) Demod Loss includes: PSK demod + TC BPSK Decoder Loss.
***) Theoretical TC Decoder Required Eb/No.

END of UpLink GG - LGAmax - PRIMA0.5-520km_450kbps_TM_only

RF LINK BUDGET

LINK ID	: QG - IGAmax - PRIMA0.5-520km_450kbps_TM_only		
DATE	: 27/05/2009	S/C TRASPONDER	: ISBT - 0,5W
S/CRAFT	: Polari-M	S/C ANTENNA	: RINSA helix S-Band antenna
ORBIT	: Equatorial	ALTITUDE (1000km)	: 0.52
G/STATION	: Malindi	ELEVATION (deg)	: 10.00
TELECOMMAND BIT RATE (b/s)	: 4000	RANGING	: No
EFF. TELEMETRY BIT RATE (b/s)	: 450000	with CODING	: Reed Sol

BASIC DOWNLINK (1/2)

		NOM	ADV	FAV	MEAN	VAR	PDF
S/C TX POWER	dBW	-6.99	-6.99	-6.99	-6.99	0.00	TRI
DIPL. CIRCUIT LOSS (*)	dB	0.00	0.00	0.00			
RFDN LOSSES	dB	0.76	0.84	0.68			
WG LOSS	dB	0.72	0.79	0.65			
ANT. VSWR, overall	:1	1.22	1.22	1.22			
VSWR LOSSES	dB	0.04	0.04	0.04			
TOTAL CIRCUITS LOSS	dB	1.52	1.67	1.37	1.52	0.00	TRI
S/C TX ANT GAIN	dBi	-1.50	-1.50	-1.50	-1.50	0.00	TRI
S/C ANT TX AXIAL RATIO	dB	1.80	1.80	1.80			
POINTING LOSS	dB	0.00	0.00	0.00	0.00	0.00	UNI
EIRP S/C	dBW	**-10.01**	**-10.16**	**-9.86**	-10.01	0.00	
FREQUENCY	GHz	2.282	2.282	2.282	2.282		
SLANT RANGE	1000*km	1.744	1.744	1.744	1.74		
PATH LOSS	dB	164.44	164.44	164.44	164.44		
ATMOSPHERIC LOSS	dB	0.50	0.60	0.40	0.50	0.00	GAU
IONOSPHERIC LOSS	dB	0.00	0.00	0.00	0.00	0.00	GAU
COPOLAR ANT-GAINS	Y=1/N=0	1					
POLARISATION MISMATCH	dB	0.05	0.05	0.05	0.05	0.00	UNI
TOTAL PROPAGATION LOSS	dB	164.99	165.09	164.89	164.99	0.00	
FLUX at G/S	dBm/m^2	-115.83	-115.98	-115.69	-115.83	0.00	
POWER FLUX DENS	dBW/m^2	-152.70	-150.90	-155.03	(in 4 kHz)		
MAXIM FLUX DENS	dBW/m^2	-151.50	-151.50	-151.50	(S- or X-Bnd)		-151.50
FLUX MARGIN	**dB**	**1.20**	-0.60	3.53			
G/S RX ANT GAIN	dBi	45.01	45.01	45.01	45.01	0.00	TRI
G/S POINTING LOSS	dB	0.20	0.20	0.20	0.20	0.00	UNI
G/S ANT RX AXIAL RATIO	dB	1.00	1.00	1.00			
RECEIVED POWER	dBm	-100.19	-100.44	-99.94			
SYSTEM NOISE TEMP	dBK	23.71	23.71	23.71	23.71	0.00	GAU
RX G/T	**dB/K**	**21.30**	**21.30**	**21.30**	21.30	0.00	
RX S/No	dBHz	74.70	74.45	74.95	74.70	0.00	

S/N in RANGING BW				
S(Tone)/N in Videobd	dB	No RG	No RG	No RG
S(TC)/N in RG-Videobd	dB	33.84	36.22	32.00

0 0 0

2421.15951 4186.45978 1583.832367

MODULATION INDICES			MAX	MIN
TELEMETRY (TM)	rad pk	1.10	1.21	0.99
TM, sine(1) or sqre(2)		2		
RANGING	rad pk	0.00	0.00	0.00
RANG. TONE effec	rad pk	0.00	0.00	0.00
TC in RG-Videobd	rad pk	0.00	0.00	0.00
NOISE INDEX		0.00	0.00	0.00

*) Diplexer Losses included in RFDN Losses

RF LINK BUDGET

LINK ID	: *GG – LGAmax – PRIMA0.5-520km_450kbps_TM_only*				
DATE	: *27/05/2009*	S/C TRASPONDER	:	*ISERT – 0.5W*	
S/CRAFT	: *Polari-X*	S/C ANTENNA		*RINSA helix S-Band antenna*	
ORBIT	: *Equatorial*	ALTITUDE (1000km)	:	*0.52*	
G/STATION:	*Malindi*	ELEVATION (deg):		*10.00*	
TELECOMMAND BIT RATE (b/s) :		4000		RANGING :	No
EFF. TELEMETRY BIT RATE (b/s) :		450000		with CODING :	Reed Sol

DOWNLINK (2/2)

		NOM	ADV	FAV	MEAN	VAR	PDF
RX S/No	dBHz	74.70	74.45	74.95	74.70	*0.00*	
CARRIER RECOVERY		0.000	0.000	0.000			
CARRIER SUPPRESSION	dB	6.87	9.04	5.21	7.13	0.61	TRI
PLL BANDWIDTH 2*Bl	Hz	10.00	12.00	8.00			
PLL BANDWIDTH	dBHz	10.00	10.79	9.03	9.91	0.13	TRI
G/S required C/N in 2BI	dB	*17.00*	17.00	17.00	17.00		
CARRIER MARGIN	**dB**	**40.83**	37.61	43.70	40.66	0.75	
MEAN-3*SIGMA	**dB**	**38.07**					
MARGIN – w.c. RSS	**dB**	**38.51**					
TELEMETRY RECOVERY							
TLM MODULATION LOSS	dB	1.00	0.58	1.56	1.07	0.04	TRI
DEMODULATOR TECH LOSS	dB	*0.90*	*1.00*	*0.80*	0.90	0.00	TRI
BIT RATE	b/s	450000	450000	450000			
BIT RATE	dbHz	56.53	56.53	56.53	56.53		
CODING GAIN	dB	*5.80*	5.80	5.80			
CODING RATE 1/R		1.14					
REQ Eb/No (PFL=1.E-5)	dB	*6.70*	6.70	6.70	6.70		
TELEMETRY MARGIN	**dB**	**9.57**	9.64	9.36	9.50	0.05	
MEAN-3*SIGMA	**dB**	**8.85**					
MARGIN – w.c. RSS	**dB**	**9.10**					
TONE RECOVERY		0	0	0			
TONE MODULATION LOSS	dB	No RG	No RG	No RG	No RG	No RG	TRI
IMPLEMENTATION LOSS	dB	*2.00*	*2.00*	*2.00*	2.00	0.00	TRI
REQ S(Tone)/N	dB	*19.00*	19.00	19.00	19.00		
		10.00	10.00	10.00	10		
RANGING MARGIN (*)	**dB**	**No RG**	No RG	No RG	No RG	#VALUE!	
MEAN-3*SIGMA	**dB**	**No RG**					
MARGIN – w.c. RSS	**dB**	**No RG**		0			
COMB. CARR. JITTER (**)							
RX TRSPD-PLL JITT	deg	0.01	0.01	0.01	0.01		
TRANSMT CARR. JITT	deg	*2.00*	*3.00*	*1.00*	2.00		
JITT BDW 2*B (***)	Hz	*5.00*	*10.00*	*3.00*	6.50		
RX COMBD CARR JITT	deg	0.82	1.58	0.32	1.42		

*) The required MINIMUM Loop-Bandwith supported by MPTS is 1.25 mHz;
the valued assumed here is 10 mHz.
**) Coherent transponder mode assumed for RX COMBD CARR JITTer at G/S.
***) 2*B is the bandwidth of the jitter from the TX chain or a HPA.

END of DownLink GG – LGAmax – PRIMA0.5-520km_450kbps_TM_only

8. POINTING BUDGET

Taking into account the specificity of GG mission, only spin-axis pointing budget is relevant.

Two budgets have been considered:

- at spin-up completion;
- after one year mission with 1 failed FEEP thruster.

Error contributor	Satellite spin axis error [deg]
Attitude determination error	1
Control error	0.5
Uncertainty on principal inertia frame attitude	0.5
Total de-pointing	2

Table 5.3-1: Spin axis pointing error at spin-up completion

Error contributor	Satellite spin axis error [deg]
Attitude determination error	1
Control error	0.5
Uncertainty on principal inertia frame attitude	0.5
orbital plane precession	5
solar pressure	2.7
atmospheric drag	3.3
gravity gradient	
residual magnetic dipole	6(*)
eddy current	
residual torque left by thrusters assembly	2 (**)
Total de-pointing	< 21 9.2 (rss)

(*) allocation
(**) no FEEP failure (allocation)

Table 5.3-2: Spin axis pointing error after one year mission with 1 failed thruster

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