

The World's Smallest Moon Lander OMOTENASHI

Outstanding MOon exploration Technologies
demonstrated by NAno Semi-Hard Impactor

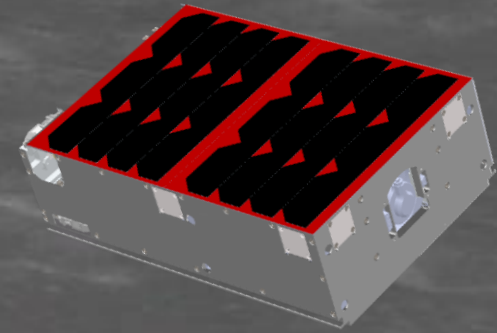
OMOTENASHI will be Launched
by NASA SLS(Space Launch System) Rocket in 2019 (TBD)

Delivery time to NASA : (TBD)

Total mass : 14 kg

Missions :

- **Development and Verification of the world's smallest moon lander**
 - Development of ultra-compact transponder and solid motor
 - Verification of the semi-hard landing with airbag and others
 - The trajectory design for robust horizontal landing based on precision orbit determination
- **Environment measurement for manned exploration in the future**
 - Measuring the radiation environment near the earth and moon



Mission Sequence

Measuring the radiation environment during this sequence

OM : Orbiting Module
SP : Surface Probe

< Launch day >
Attitude control
for pointing sun

< day 2 >
Orbit control to
lunar impact orbit

< day 4-5 : just before landing >

spin-up

SP is separated from OM.
Deceleration by solid motor

Landing!!

Total mass 14kg

OM will be destroyed because of colliding with
the lunar surface impact in 2500m/s.

The emission from SP will stop in a few hour
after landing as it works with primary battery.

Solid motor 4.3 kg

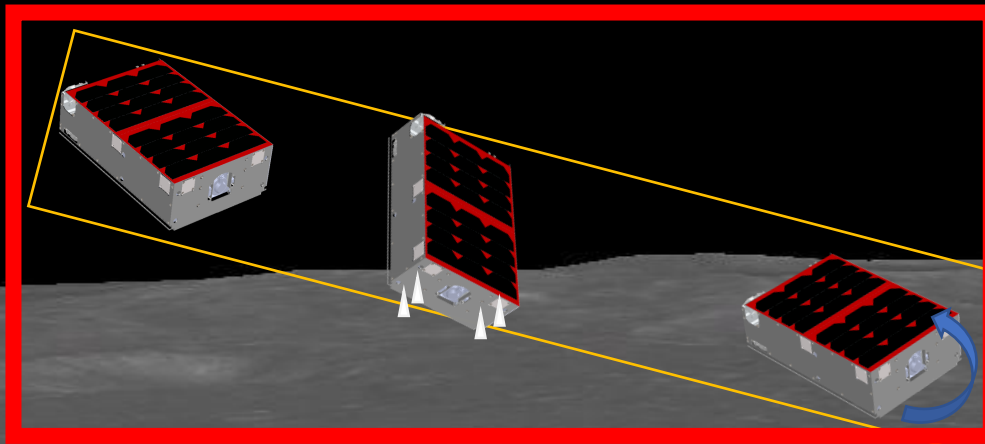
Surface Probe 0.7 kg

Communication with Amateur Band

Surface Probe : 437.41MHz

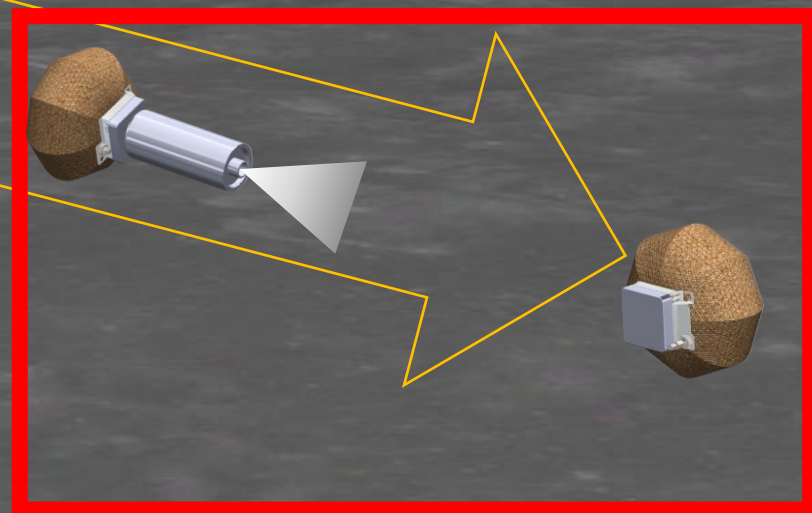
Transmitting UHF band signal during primary battery survive from separated to after landing (it lasts for a few or several tens of minutes).

1. Emitting PM-modulated radio wave.
This is modulated with the measured acceleration of the impact on landing(TBD).
2. After 1., transmit the recorded acceleration data by encoding to digital bits as long as battery survive.

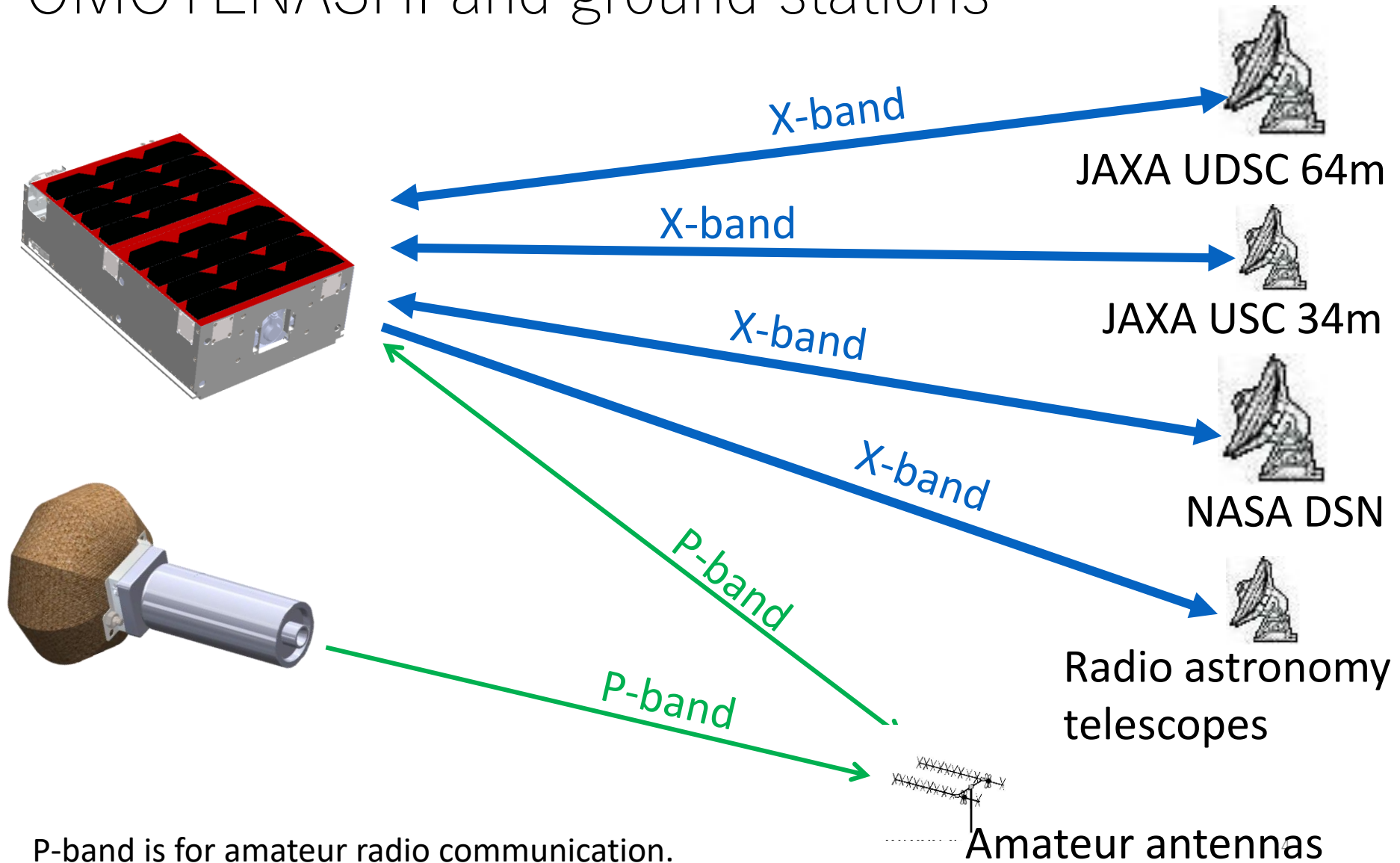


Orbiting Module : 437.31MHz

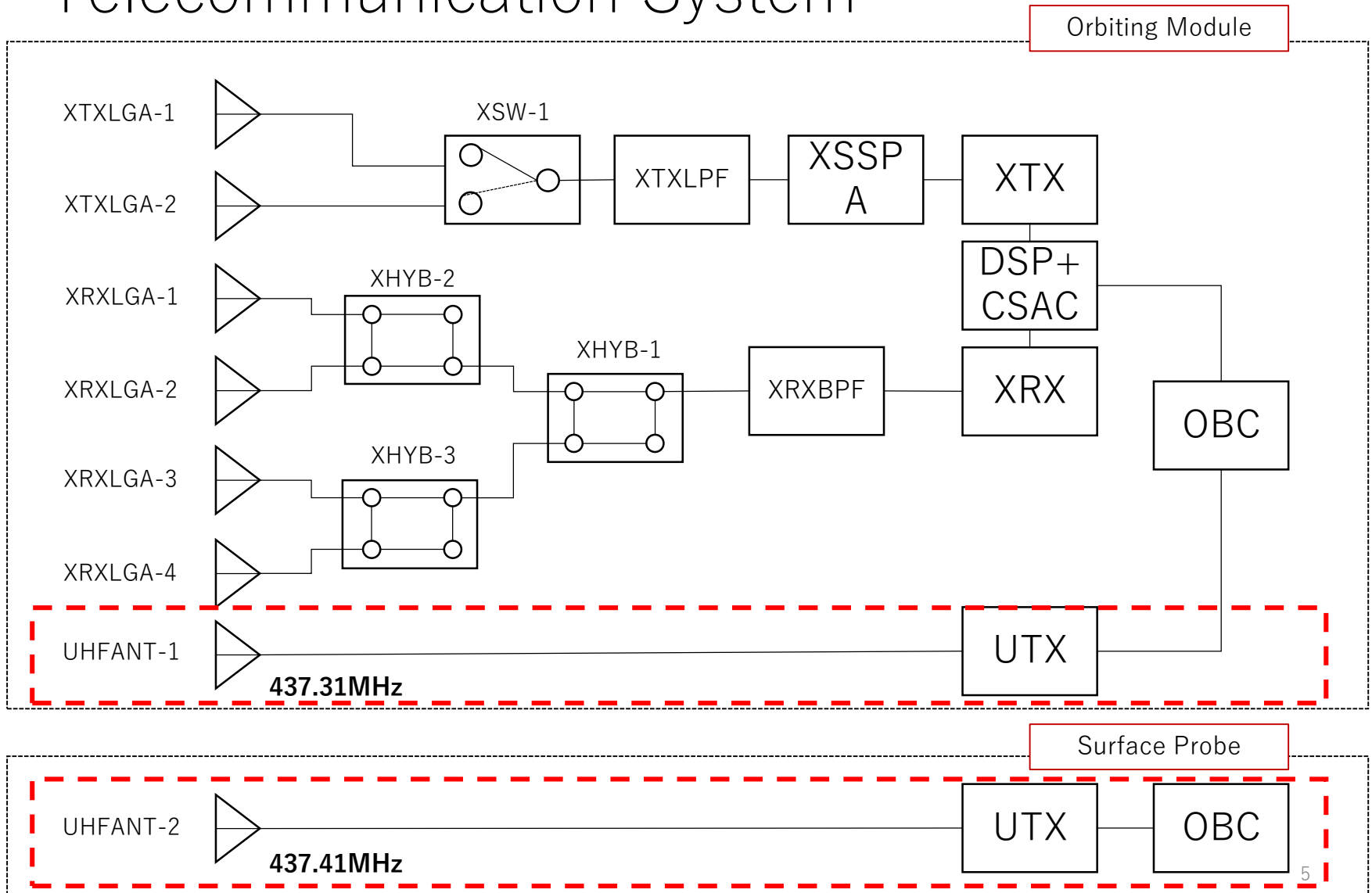
Determination the transmitting schedule in view of the balance of total power consumption and the power SAP generate from OM separated by SLS rocket to separating SP.



Schematic of communication between OMOTENASHI and ground stations



OMOTENASHI Telecommunication System



Link budget (Command : FSK300 bps)

Distance : 20,000km			
Parameter	Unit	Uplink	
Frequency	MHz	435	435-436MHz
Tranmit. Power	dBm	60.0	1 kW
Transmit. Feeder Loss	dB	-1.7	
Transmit. Antenna Gain	dBi	28.9	BW: ± 2 deg
EIRP	dBm	87.3	
Transmit. Point. Loss	dB	-1.0	± 0.5 deg
Polarization Loss	dB	-3.0	
Range	AU	0.000134	20000 km
Space Loss	dB	-171.2	
Absorb Loss	dB	-0.3	
Rain Loss	dB	0.0	Fine Weather
Receiv. Point. Loss	dB	0.0	
Receiv. Antenna Gain	dBi	0.0	UHFANT-1
Receiv. Feeder Loss	dB	-0.5	
Receiv. Signal Power	dBm	-88.8	Ta : 10K
System Noise temp.	K	190.3	NF : 1.6dB
Noise Power Density	dBm/Hz	-175.8	Loss : 0.5dB
G/T	dB/K	-23.3	
C/No	dB • Hz	87.0	
		FSK	
Modulation Index	rad	0.0	
Modulation Loss	dB	0.0	
Hardware Loss	dB	1.0	
Bit Rate or Bandwidth	dB • Hz	24.8	300 bps
Coding Gain	dB		
Required Eb/No or S/N	dB	12.3	1.00E-04 BER
Required C/No	dB • Hz	38.1	
Margin	dB	48.9	

Distance : 400,000km			
Parameter	Unit	Uplink	
Frequency	MHz	435	435-436MHz
Tranmit. Power	dBm	60.0	1 kW
Transmit. Feeder Loss	dB	-1.7	
Transmit. Antenna Gain	dBi	28.9	BW: ± 2 deg
EIRP	dBm	87.3	
Transmit. Point. Loss	dB	-1.0	± 0.5 deg
Polarization Loss	dB	-3.0	
Range	AU	0.002674	400000 km
Space Loss	dB	-197.3	
Absorb Loss	dB	-0.3	
Rain Loss	dB	0.0	Fine Weather
Receiv. Point. Loss	dB	0.0	
Receiv. Antenna Gain	dBi	0.0	UHFANT-1
Receiv. Feeder Loss	dB	-0.5	
Receiv. Signal Power	dBm	-114.8	Ta : 10K
System Noise temp.	K	190.3	NF : 1.6dB
Noise Power Density	dBm/Hz	-175.8	Loss : 0.5dB
G/T	dB/K	-23.3	
C/No	dB • Hz	61.0	
		FSK	
Modulation Index	rad	0.0	
Modulation Loss	dB	0.0	
Hardware Loss	dB	1.0	
Bit Rate or Bandwidth	dB • Hz	24.8	300 bps
Coding Gain	dB		
Required Eb/No or S/N	dB	12.3	1.00E-04 BER
Required C/No	dB • Hz	38.1	
Margin	dB	22.9	

Link budget (CW)

Distance : 20,000km			
Parameter	Unit	Downlink	
Frequency	MHz	437.31	
Transmit. Power	dBm	30.0	1 W
Transmit. Feeder Loss	dB	-0.5	
Transmit. Antenna Gain	dBi	0.0	UHFANT-1
EIRP	dBm	29.5	
Transmit. Point. Loss	dB	0.0	
Polarization Loss	dB	-3.0	
Range	AU	0.000134	20000 km
Space Loss	dB	-171.3	
Absorb Loss	dB	-0.3	
Rain Loss	dB	0.0	Fine Weather
Receiv. Point. Loss	dB	-1.0	$\pm 0.5\text{deg}$
Receiv. Antenna Gain	dBi	28.9	BW: $\pm 2\text{deg}$
Receiv. Feeder Loss	dB	-1.7	
Receiv. Signal Power	dBm	-118.8	Ta : 300K
System Noise temp.	K	525.7	NF : 1.0dB
Noise Power Density	dBm/Hz	-171.4	Loss : 1.5dB
G/T	dB/K	-1.0	
C/No	dB • Hz	52.6	

Distance : 400,000km			
Parameter	Unit	Downlink	
Frequency	MHz	437.31	
Transmit. Power	dBm	30.0	1 W
Transmit. Feeder Loss	dB	-0.5	
Transmit. Antenna Gain	dBi	0.0	UHFANT-1
EIRP	dBm	29.5	
Transmit. Point. Loss	dB	0.0	
Polarization Loss	dB	-3.0	
Range	AU	0.002674	400000 km
Space Loss	dB	-197.3	
Absorb Loss	dB	-0.3	
Rain Loss	dB	0.0	Fine Weather
Receiv. Point. Loss	dB	-1.0	$\pm 0.5\text{deg}$
Receiv. Antenna Gain	dBi	28.9	BW: $\pm 2\text{deg}$
Receiv. Feeder Loss	dB	-1.7	
Receiv. Signal Power	dBm	-144.8	Ta : 300K
System Noise temp.	K	525.7	NF : 1.0dB
Noise Power Density	dBm/Hz	-171.4	Loss : 1.5dB
G/T	dB/K	-1.0	
C/No	dB • Hz	26.5	

Link budget (Telemetry : PSK31 31.25bps)

Distance : 20,000km			
Parameter	Unit	Downlink	
Frequency	MHz	437.31	
Transmit. Power	dBm	30.0	1 W
Transmit. Feeder Loss	dB	-0.5	
Transmit. Antenna Gain	dBi	0.0	UHFANT-1
EIRP	dBm	29.5	
Transmit. Point. Loss	dB	0.0	
Polarization Loss	dB	-3.0	
Range	AU	0.000134	20000 km
Space Loss	dB	-171.3	
Absorb Loss	dB	-0.3	
Rain Loss	dB	0.0	Fine Weather
Receiv. Point. Loss	dB	-1.0	±0.5deg
Receiv. Antenna Gain	dBi	28.9	BW: ±2deg
Receiv. Feeder Loss	dB	-1.7	
Receiv. Signal Power	dBm	-118.8	Ta : 300K
System Noise temp.	K	525.7	NF : 1.0dB
Noise Power Density	dBm/Hz	-171.4	Loss : 1.5dB
G/T	dB/K	-1.0	
C/No	dB · Hz	52.6	
		PSK31	
Modulation Index	rad	0.0	
Modulation Loss	dB	0.0	
Hardware Loss	dB	1.0	
Bit Rate or Bandwidth	dB · Hz	14.9	31.25 bps
Coding Gain	dB		
Required Eb/No or S/N	dB	9.6	1.00E-05 BER
Required C/No	dB · Hz	25.5	
Margin	dB	27.0	

Distance : 400,000km			
Parameter	Unit	Downlink	
Frequency	MHz	437.31	
Transmit. Power	dBm	30.0	1 W
Transmit. Feeder Loss	dB	-0.5	
Transmit. Antenna Gain	dBi	0.0	UHFANT-1
EIRP	dBm	29.5	
Transmit. Point. Loss	dB	0.0	
Polarization Loss	dB	-3.0	
Range	AU	0.002674	400000 km
Space Loss	dB	-197.3	
Absorb Loss	dB	-0.3	
Rain Loss	dB	0.0	Fine Weather
Receiv. Point. Loss	dB	-1.0	±0.5deg
Receiv. Antenna Gain	dBi	28.9	BW: ±2deg
Receiv. Feeder Loss	dB	-1.7	
Receiv. Signal Power	dBm	-144.8	Ta : 300K
System Noise temp.	K	525.7	NF : 1.0dB
Noise Power Density	dBm/Hz	-171.4	Loss : 1.5dB
G/T	dB/K	-1.0	
C/No	dB · Hz	26.5	
		PSK31	
Modulation Index	rad	0.0	
Modulation Loss	dB	0.0	
Hardware Loss	dB	1.0	
Bit Rate or Bandwidth	dB · Hz	14.9	31.25 bps
Coding Gain	dB		
Required Eb/No or S/N	dB	9.6	1.00E-05 BER
Required C/No	dB · Hz	25.5	
Margin	dB	1.0	

Link budget (Telemetry : PCM/PSK/PM 31.25bps)

Distance : 20,000km					
Parameter	Unit	Downlink			
Frequency	MHz	437.31			
Transmit. Power	dBm	30.0	1	W	
Transmit. Feeder Loss	dB	-0.5			
Transmit. Antenna Gain	dBi	0.0	UHFANT-1		
EIRP	dBm	29.5			
Transmit. Point. Loss	dB	0.0			
Polarization Loss	dB	-3.0			
Range	AU	0.000134	20000	km	
Space Loss	dB	-171.3			
Absorb Loss	dB	-0.3			
Rain Loss	dB	0.0	Fine Weather		
Receiv. Point. Loss	dB	-1.0	±0.5deg		
Receiv. Antenna Gain	dBi	28.9	BW: ±2deg		
Receiv. Feeder Loss	dB	-1.7			
Receiv. Signal Power	dBm	-118.8	Ta : 300K		
System Noise temp.	K	525.7	NF : 1.0dB		
Noise Power Density	dBm/Hz	-171.4	Loss : 1.5dB		
G/T	dB/K	-1.0			
C/No	dB • Hz	52.6			
		CARRIER		TLM	
Modulation Index	rad	1.0		1.0	
Modulation Loss	dB	2.3		4.1	
Hardware Loss	dB			1.0	
Bit Rate or Bandwidth	dB • Hz	10.0	2BL (Hz) = 10	14.9	31.25 bps
Coding Gain	dB				
Required Eb/No or S/N	dB	13.5	1.00E-04 BER	9.6	1.00E-05 BER
Required C/No	dB • Hz	25.8		29.7	
Margin	dB	26.7		22.9	