Fresnel Lens Gamma Ray Telescope

Data Systems

Frank Stocklin
Ron Vento
Leslie Ambrose

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Overview

- X/Ka communications system to Earth via DSN 34m
  - Command/telemetry/ranging @ 1 AU
  - Store data & dump 15 minutes/day
- S Band communications for backup & Near Earth
  - Command/telemetry/ranging
- Intersatellite RF & Laser link required to effectively position both Lens & Collector S/C. S Band RF link proposed.

Driving Requirements & Assumptions

- Launch: 2012
- Mission Life: 3 year requirement, 5 year goal
- Nominal Orbit: Drift away
- Orbit determination via DSN ranging
- One Collector & Lens S/C separated by maximum of 750 kkm
  - Both essentially same telecommunications design
- No latency
- BER 10^{-7}

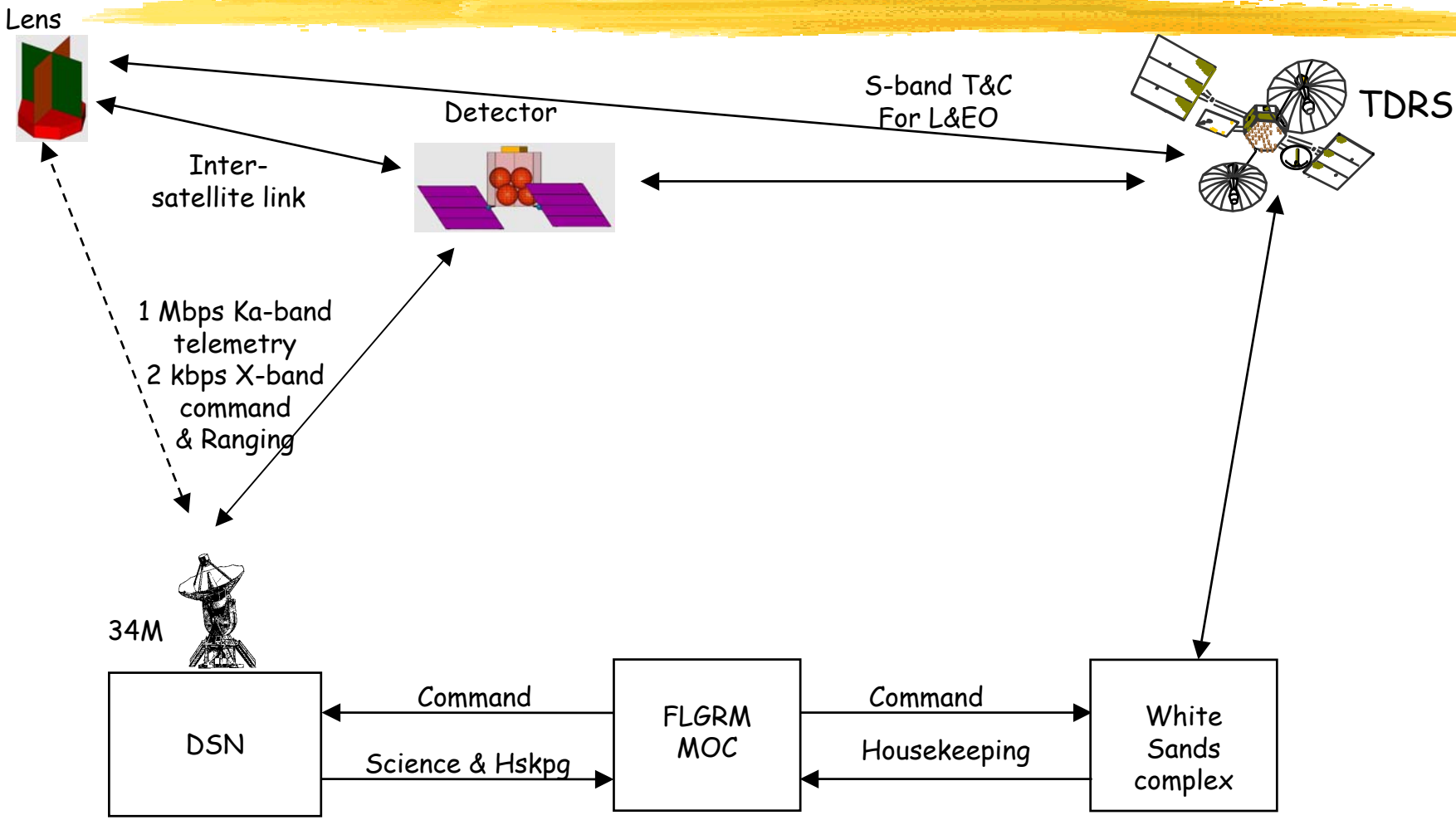
Selected Configuration & Rationale

- **X/Ka-band communications using DSN 34**
  - Total data rate = 6 Kbps (detector)/5 Kbps (Lens)
    - Detector rate = 1Kbps
    - Hskpg =4 Kbps
    - Overhead = 15%
  - Store & playback 15 min/day @ 1Mbps
  - Ranging
    - Best expected position accuracy = 1m
    - Orbit accuracy expected = 1 Km
  - Selective redundancy
- **S-band communications**
  - 26 meter for early launch phase
  - 70 meter for emergency support
  - TDRS SSA for early launch phase
- **Inter-satellite communications system will be required for positioning (see next slide)**

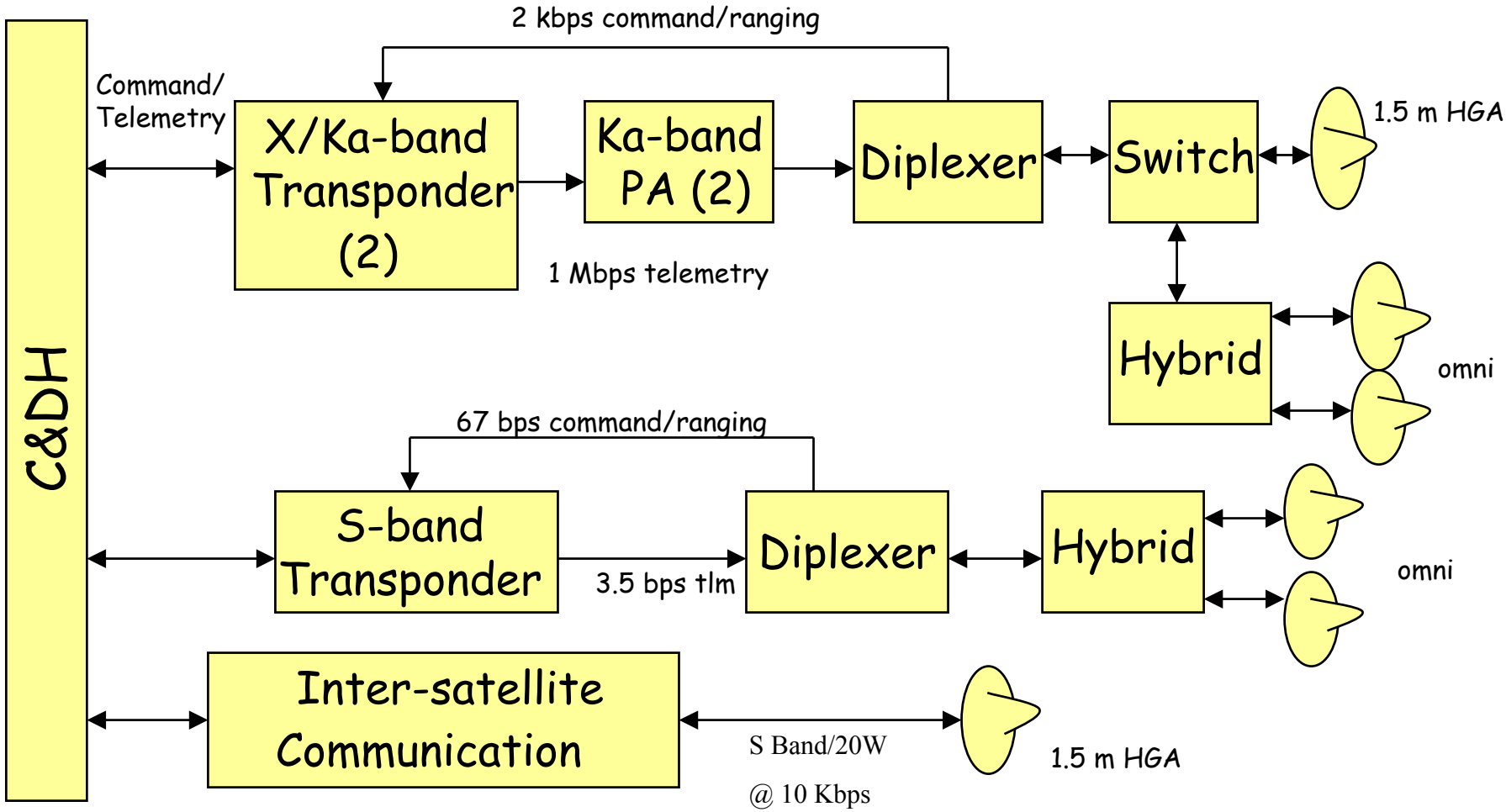
Inter-Satellite Link

- **Possible solution: Use both RF and LASER**
  - RF systems consist of:
    - 20 watt transmitters
    - 1.5 M antennas
    - S-Band receivers
    - 10 kbps of data
  - LASER (not defined or costed in this study; identified as part of metrology system)
    - Could be used only for alignment of spacecraft
    - Could be used for alignment and transmission of data
- **Support Scenario**
  - Use DSN to locate spacecraft coarse position WRT each other
  - Use RF system to maneuver spacecraft to alignment where lasers can be used for fine positioning
    - Beamwidth = 8 deg = 100000km at 750000km
  - Use LASER for positional control
- **ROM Cost (Laser not included)**
  - 2 S Band Transponders = $XX
  - 2 S Band HGA = $XX
  - 2 S Band 20W PA= $XX

Selected Configuration & Rationale



Data Systems
Selected Configuration and Rational

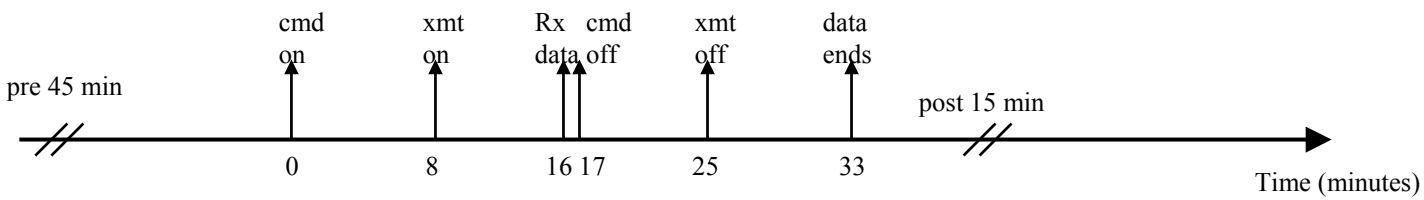


H/W Cost Summary

Component	DC Power (watts) pk/avg	Mass (kg)	Cost ($)
X/Ka Transponder (2)	30/30	3	
X/Ka Antenna	16/1	25	
Ka PA (2)	150/65	20	
X/Ka Omni	--	1	
S-band Transponder	8/9	6	
S-band Omni	--	1	
S Band Intersatellite	90/75	30	
Misc	--	5	
TOTALS	294/180	91 Kg	

DSN Costs

- **Assumptions**
  - DSN 34 m/Nominal mission
  - Pre-pass time: 45 minutes
  - Post-pass time: 15 minutes
  - Data Transmission: 15 min/day
  - Proposed Scheme:



  - Cost: 564 hours/year @ $XX/min + 10% contingency = $XX/year
  - 3 years = $XX
  - 5 years = $XX

Total Cost
(not including Mission Ops or Laser)

- H/W cost = $XX for 2 spacecraft
- Ground Costs 3/5 years= $XX
- I & T costs(@ 10%) = $XX
- Total Cost 3/5 years = $XX

Link Margin Summary

Link	Data Rate	Margin(db)	Comment
Ka Downlink	1 Mbps	0.2	HGA to 34M
X Uplink	2 kbps	12.9	34M to HGA
S Downlink	3.5 bps	0.3	Omni to 70M
S Uplink	67 bps	0.0	70M to Omni

Back-up Slides

Fresnel Lens Gamma Ray (FLGR) Link Calculations

FLGR Downlink
K-Band to 34M BWG to HGA

GSFC C.L.A.S.S. ANALYSIS #1 DATE & TIME: 1/ 9/ 2 10:44:35 PERFORMED BY: R. VENTO
LINKID: FLGRM FLGR04

FREQUENCY: 32000.0 MHz RANGE: 150000000.0 km POLARIZATION: RHCP

MODULATION: BPSK
DATA RATE: 1000.000 kbps
CODING: RATE 1/2 WITH RS ENCODING
BER: 1.00E-07
S/C 60 WATTS 1.5M ANTENNA
95% AVAILABILITY 34M AT 70 DEG K INCLUDES ADDITIONAL TEMP FROM RAIN AND ATMOSPHERICS

PARAMETER	VALUE	REMARKS
01. USER SPACECRAFT TRANSMITTER POWER - dBW	17.78	NOTE A; 60.0 WATTS
02. USER SPACECRAFT PASSIVE LOSS - dB	3.00	NOTE A
03. USER SPACECRAFT ANTENNA GAIN - dBi	51.44	NOTE A
04. USER SPACECRAFT POINTING LOSS - dB	0.00	NOTE A
05. USER SPACECRAFT EIRP - dBWi	66.22	1 - 2 + 3 - 4
06. POLARIZATION LOSS - dB	0.50	NOTE A
07. FREE SPACE LOSS - dB	286.07	NOTE B
08. ATMOSPHERIC LOSS - dB	0.00	NOTE A
09. RAIN ATTENUATION - dB	0.47	EXC: 5.00% EL: 30.0 DEG
10. MULTIPATH LOSS - dB	0.00	NOTE A
11. GROUND STATION ANTENNA GAIN - dB	77.40	NOTE A
12. GROUND STATION PASSIVE LOSS - dB	0.00	NOTE A
13. GROUND STATION POINTING LOSS - dB	0.00	NOTE A
14. SYSTEM NOISE TEMPERATURE - dB-DEGREES-K	18.45	NOTE A
15. GROUND STATION G/T - dB/DEGREES-K	58.95	11 - 12 - 13 - 14
16. BOLTZMANN'S CONSTANT - dBW/(Hz*K)	-228.60	CONSTANT
17. RECEIVED CARRIER TO NOISE DENSITY - dB/Hz	66.73	5-6-7-8-9-10+15-16
18. MODULATION LOSS - dB	0.00	NOTE A
19. DATA RATE - dB-bps	60.00	NOTE A
20. DIFFERENTIAL ENCODING/DECODING LOSS - dB	0.00	NOTE A
21. USER CONSTRAINT LOSS - dB	0.00	NOTE A
22. RECEIVED Eb/No - dB	6.73	17-18-19-20-21
23. IMPLEMENTATION LOSS - dB	3.00	NOTE A
24. REQUIRED Eb/No - dB	3.50	NOTE B
25. REQUIRED PERFORMANCE MARGIN - dB	0.00	NOTE A
26. MARGIN - dB	0.23	22 - 23 - 24 - 25

NOTE A: PARAMETER VALUE FROM USER PROJECT - SUBJECT TO CHANGE
NOTE B: FROM CLASS ANALYSIS IF COMPUTED

FLGR Uplink
X-Band 34M BWG to HGA

TABLE A-1 UPLINK DATE & TIME: 01/08/02 12: 7:14
FLGRM FLGR08
FREQUENCY - 7200.000 MHZ
GROUND ANTENNA - . - 34 M BWG
POWER - 4.0000 K WATTS

PARAMETERS	UNITS	VALUES (MAX RNG: 1.003 AU 30.0 EL)	VALUES (MIN RNG: 1.003 AU 90.0 EL)	ESTIMATED TOLERANCES DB FAV	ESTIMATED TOLERANCES DB ADV
EFFECTIVE RADIATED POWER	DBM	133.0	133.0	1.0	-1.0
FREE SPACE DISPERSION LOSS	DB	-273.1	-273.1	0.0	0.0
ATMOSPHERIC LOSS	DB	-0.5	0.0	0.0	0.0
POLARIZATION LOSS	DB	-0.5	-0.5	0.0	0.0
SPACECRAFT ANTENNA GAIN	DBI	38.5	38.5	0.0	0.0
SPACECRAFT PASSIVE LOSS	DB	-5.0	-5.0	0.5	-0.5
MAXIMUM TOTAL RECEIVED POWER	DBM	-107.6	-107.1	1.1	-1.1
SPACECRAFT ANTENNA NULL DEPTH	DB	0.0	0.0	0.0	0.0
MINIMUM TOTAL RECEIVED POWER	DBM	-107.6	-107.1	1.1	-1.1
SYSTEM NOISE DENSITY	DBM/HZ	-172.5	-172.5	0.0	0.0
IF NOISE BANDWIDTH(3000.000 KHZ)	DB-HZ	64.8	64.8	0.0	0.0
IF NOISE POWER	DBM	-107.7	-107.7	0.0	0.0
IF SNR (MIN)	DB	0.1	0.6	1.1	-1.1
CARRIER CHANNEL					
CARRIER/TOTAL POWER	DB	-2.9	-2.9	0.3	-0.3
RECEIVED CARRIER POWER	DBM	-110.5	-110.0	1.2	-1.2
CARRIER LOOP NOISE BW(800. HZ)	DB-HZ	29.0	29.0	0.0	0.0
NOISE POWER	DBM	-143.5	-143.5	0.0	0.0
CARRIER/NOISE	DB	33.0	33.5	1.2	-1.2
REQUIRED CARRIER/NOISE	DB	20.0	20.0	0.0	0.0
AVAILABLE CARRIER MARGIN	DB	13.0	13.5	1.2	-1.2
REQUIRED PERFORMANCE MARGIN	DB	3.0	3.0	0.0	0.0
NET MARGIN	DB	10.0	10.5	1.2	-1.2
COMMAND CHANNEL (PCM/PSK/PM)					
COMMAND/TOTAL POWER(MI=1.10 RAD)	DB	-3.5	-3.5	0.3	-0.3
RECEIVED COMMAND POWER	DBM	-111.1	-110.6	1.2	-1.2
PREDETECTION (PSK) NOISE BW(32.000 KHZ)	DB-HZ	45.1	45.1	0.0	0.0
PREDETECTION (PSK) NOISE POWER	DB	-127.4	-127.4	0.0	0.0
PREDETECTION (PSK) SNR	DB	16.3	16.8	1.2	-1.2
COMMAND DATA RATE (2.000KBPS)	DB-BPS	33.0	33.0	0.0	0.0
AVAILABLE ENERGY PER BIT/NOISE DENSITY	DB	28.4	28.9	1.2	-1.2
DECODER DEGRADATION	DB	-2.0	-2.0	0.0	0.0
REQUIRED ENERGY PER BIT/NOISE DENSITY (BER=E-5)	DB	10.5	10.5	0.0	0.0
AVAILABLE COMMAND MARGIN	DB	15.9	16.4	1.2	-1.2
REQUIRED PERFORMANCE MARGIN	DB	3.0	3.0	0.0	0.0
NET MARGIN	DB	12.9	13.4	1.2	-1.2

FLGR Downlink
S-Band Omni to 70M

GSFC C.L.A.S.S. ANALYSIS #1 DATE & TIME: 1/ 9/ 2 11: 7:51 PERFORMED BY: R. VENTO
LINKID: FLGRM FLGR02

FREQUENCY: 2250.0 MHz RANGE: 150000000.0 km

MODULATION: BPSK
DATA RATE: 0.004 kbps
CODING: RATE 1/2 WITH RS ENCODING
BER: 1.00E-05
S/C OMNI AT 5 WATTS
70 METER DSN ON GROUND

PARAMETER	VALUE	REMARKS
01. USER SPACECRAFT TRANSMITTER POWER - dBW	6.99	NOTE A; 5.0 WATTS
02. USER SPACECRAFT PASSIVE LOSS - dB	5.00	NOTE A
03. USER SPACECRAFT ANTENNA GAIN - dBi	0.00	NOTE A
04. USER SPACECRAFT POINTING LOSS - dB	0.00	NOTE A
05. USER SPACECRAFT EIRP - dBWi	1.99	1 - 2 + 3 - 4
06. POLARIZATION LOSS - dB	0.50	NOTE A
07. FREE SPACE LOSS - dB	263.01	NOTE B
08. ATMOSPHERIC LOSS - dB	0.23	EL: 10.0 DEG
09. RAIN ATTENUATION - dB	0.00	NOTE A
10. MULTIPATH LOSS - dB	0.00	NOTE A
11. GROUND STATION ANTENNA GAIN - dBi	61.76	70.0 M, EFF: 55.0%
12. GROUND STATION PASSIVE LOSS - dB	0.00	NOTE A
13. GROUND STATION POINTING LOSS - dB	0.00	NOTE A
14. SYSTEM NOISE TEMPERATURE - dB-DEGREES-K	16.99	NOTE A
15. GROUND STATION G/T - dB/DEGREES-K	44.77	11 - 12 - 13 - 14
16. BOLTZMANN'S CONSTANT - dBW/(Hz*K)	-228.60	CONSTANT
17. RECEIVED CARRIER TO NOISE DENSITY - dB/Hz	11.62	5-6-7-8-9-10+15-16
18. MODULATION LOSS - dB	0.00	NOTE A
19. DATA RATE - dB-bps	5.44	NOTE A
20. DIFFERENTIAL ENCODING/DECODING LOSS - dB	0.00	NOTE A
21. USER CONSTRAINT LOSS - dB	0.00	NOTE A
22. RECEIVED Eb/No - dB	6.18	17-18-19-20-21
23. IMPLEMENTATION LOSS - dB	3.00	NOTE A
24. REQUIRED Eb/No - dB	2.90	NOTE B
25. REQUIRED PERFORMANCE MARGIN - dB	0.00	NOTE A
26. MARGIN - dB	0.28	22 - 23 - 24 - 25

NOTE A: PARAMETER VALUE FROM USER PROJECT - SUBJECT TO CHANGE
NOTE B: FROM CLASS ANALYSIS IF COMPUTED

FLGR Uplink
S-Band 70M to Omni

TABLE A-1 UPLINK DATE & TIME: 01/09/02 11:28:17
FLGRM FLGR06
FREQUENCY - 2071.000 MHZ
GROUND ANTENNA - . - 70 METER
POWER - 20.0000 K WATTS

PARAMETERS	UNITS	VALUES (MAX RNG: 1.003 AU 5.0 EL)	VALUES (MIN RNG: 1.003 AU 90.0 EL)	ESTIMATED TOLERANCES DB FAV	ESTIMATED TOLERANCES DB ADV
EFFECTIVE RADIATED POWER	DBM	134.0	134.0	1.0	-1.0
FREE SPACE DISPERSION LOSS	DB	-262.3	-262.3	0.0	0.0
ATMOSPHERIC LOSS	DB	-0.5	0.0	0.0	0.0
POLARIZATION LOSS	DB	-0.5	-0.5	0.0	0.0
SPACECRAFT ANTENNA GAIN	DBI	0.0	0.0	0.0	0.0
SPACECRAFT PASSIVE LOSS	DB	-5.0	-5.0	0.5	-0.5
MAXIMUM TOTAL RECEIVED POWER	DBM	-134.3	-133.8	1.1	-1.1
SPACECRAFT ANTENNA NULL DEPTH	DB	0.0	0.0	0.0	0.0
MINIMUM TOTAL RECEIVED POWER	DBM	-134.3	-133.8	1.1	-1.1
SYSTEM NOISE DENSITY	DBM/HZ	-171.6	-171.6	0.0	0.0
IF NOISE BANDWIDTH(3000.000 KHZ)	DB-HZ	64.8	64.8	0.0	0.0
IF NOISE POWER	DBM	-106.8	-106.8	0.0	0.0
IF SNR (MIN)	DB	-27.5	-27.0	1.1	-1.1
CARRIER CHANNEL					
CARRIER/TOTAL POWER	DB	-2.9	-2.9	0.3	-0.3
RECEIVED CARRIER POWER	DBM	-137.2	-136.7	1.2	-1.2
CARRIER LOOP NOISE BW(800. HZ)	DB-HZ	29.0	29.0	0.0	0.0
NOISE POWER	DBM	-142.6	-142.6	0.0	0.0
CARRIER/NOISE	DB	5.4	5.9	1.2	-1.2
REQUIRED CARRIER/NOISE	DB	20.0	20.0	0.0	0.0
AVAILABLE CARRIER MARGIN	DB	-14.6	-14.1	1.2	-1.2
REQUIRED PERFORMANCE MARGIN	DB	3.0	3.0	0.0	0.0
NET MARGIN	DB	-17.6	-17.1	1.2	-1.2
COMMAND CHANNEL (PCM/PSK/PM)					
COMMAND/TOTAL POWER(MI=1.10 RAD)	DB	-3.5	-3.5	0.3	-0.3
RECEIVED COMMAND POWER	DBM	-137.8	-137.3	1.2	-1.2
PREDETECTION (PSK) NOISE BW(32.000 KHZ)	DB-HZ	45.1	45.1	0.0	0.0
PREDETECTION (PSK) NOISE POWER	DB	-126.5	-126.5	0.0	0.0
PREDETECTION (PSK) SNR	DB	-11.3	-10.8	1.2	-1.2
COMMAND DATA RATE (0.067KBPS)	DB-BPS	18.3	18.3	0.0	0.0
AVAILABLE ENERGY PER BIT/NOISE DENSITY	DB	15.5	16.0	1.2	-1.2
DECODER DEGRADATION	DB	-2.0	-2.0	0.0	0.0
REQUIRED ENERGY PER BIT/NOISE DENSITY (BER=E-5)	DB	10.5	10.5	0.0	0.0
AVAILABLE COMMAND MARGIN	DB	3.0	3.5	1.2	-1.2
REQUIRED PERFORMANCE MARGIN	DB	3.0	3.0	0.0	0.0
NET MARGIN	DB	0.0	0.5	1.2	-1.2