Project Subsystem Requirment Validation Example:

Mission Statement: XSat will perform remote sensing of the South American rain forest for environmental study and protection.

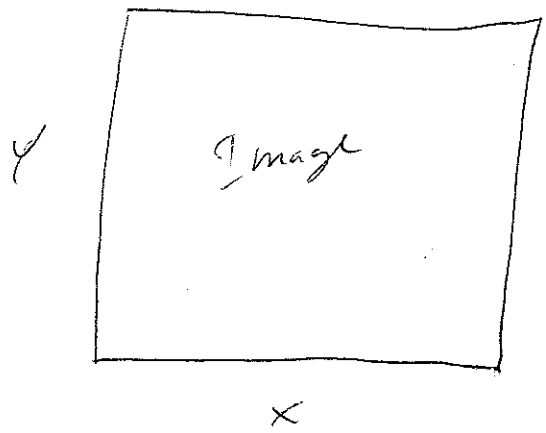
primary objective: Take 2 images of the rain forest daily of approximately 25 m resolution and 100 km square in size in 3 bands.

Derived requirment:

DR1 1) XSat shall capture & download 2 100kx100km 25 m images to the ground each day

DR2 2) XSat shall pass over the Amazon rain forest at least twice a day

Step 1 : Payload image calculation (+ S/C Telemetry)



$X = 100$ km

$Y = 90$ km

25 meter resolution

$X_{pixels} = 100{,}000/25 = 4000$

$Y_{pixels} = 90{,}000/25 = 3600$

Image dimensions in pixels $= 4000 \times 3600$

$= 14.4$ M pixels

1 pixel = 1 byte 1 image band = 14.4 M bytes

3 image bands r, g, b

Total image size $= 3 \times 14.4 = 43.2$ M byte

Requirement is 2 images a day

∴ Total image data per day is 86.4 M bytes

Add 10% overhead and 1 M byte per day for Telemetry

Total Data per day $= 86.4 + 86.4 \times 0.1 + 1 =$ **96.04 M bytes/day**

Step 2. Define System parameters ... then iterate

1) We need at least 100 Mb of memory on board

2) Per day: ground station contact Time x data rate must be > 96.04 Mb

3) data rate directly impacts link budget
both need to work!

After a few iterations

downlink freq = 2000 MHz
data rate = 1.024 Mbps
→ down Link margin > 2

1) Determine GS contact time through simulation
conditions: elevation > 10°

2) Use maximum distance from sim in Link budget

3) Calculate downlinked data per day for a couple (or more) days

Requirement Validation

DR1 : Figure 5 shows up to 100 Mbytes can be downloaded on a typical day.

System design (assumptions)

1.024 Mb Tx data rate

100 km x 90 km 3 band image, Twice a day

1 Mb of S/C telemetry

10% packet overhead + margin on image data

satellite elevation >10° (Figure 2 + 3)

distance < 2500 km (Figure 4)

DR2 : For the selected orbit, Figure 1 shows that 2 passes of the Amazon rain forest is realistic

Link Budget:

uplink/downlink freq 2000 MHz

S/C downlink power 4 watts *

S/C " peak antenna gain 9 dB

max path 2500 km

GS antenna Gain 32 dB (1 meter radius dish)

GS antenna 3dB angle 5.25°

Downlink

Bit Error Rate 10^{-5}

$\frac{Eb}{No} = 9.5$

Downlink Margin ~2.14 db

Uplink Margin ~8 dB

Satellite Link Budget SpreadSheet by Tiago Leao				
Item	**Symbol**	**Units**	**Downlink**	**Uplink**
Frequency	f	MHz	2000	2000
Transmitter Power	P	Watts	4	8
Transmitter Power	P	dBW	6.02059991328	9.03089987
Transmitter Line Loss	Ll	dB	−1	−1
Transmit Antenna Beamwidth	θt	deg	20	5.25
Peak Transmit Antenna gain	Gpt	dBi	9	32
Transmit Antenna Pointing Offset	Θt	deg	10	2.625
Transmit Antenna Pointing Loss	Lpt	dB	−3	−3
Transmit Antenna Gain (net)	Gt	dBi	6	29
Equiv. Isotropic Radiated Power	EIRP	dBW	11.0205999133	37.0308999
Propagation Path Length	S	km	2500	2500
Space Loss	Ls	dB	−166.42940009	−166.42940
Propagation & Polarization Loss	La	dB	−2	−2
Peak receive Antenna Gain	Grp	dBi	32	0
Receive Antenna Beamwidth	θr	deg	5.25	90
Receive Antenna Pointing Offset	Θr	deg	2.625	0
Receive Antenna Pointing Loss	Lpr	dB	−3	0
Receive Antenna Gain (net)	Gr	dBi	29	0
System Noise Temperature	Ts	K	700	300
Data Rate	R	bps	1024000	256000
Eb/No (1)	Eb/No	dB	11.6372198600	18.3478876
Bit Error Rate	BER			
Required Eb/No (2)	Req Eb/No	dB	9.5	10
Margin		dB	2.13721986002	8.34788758

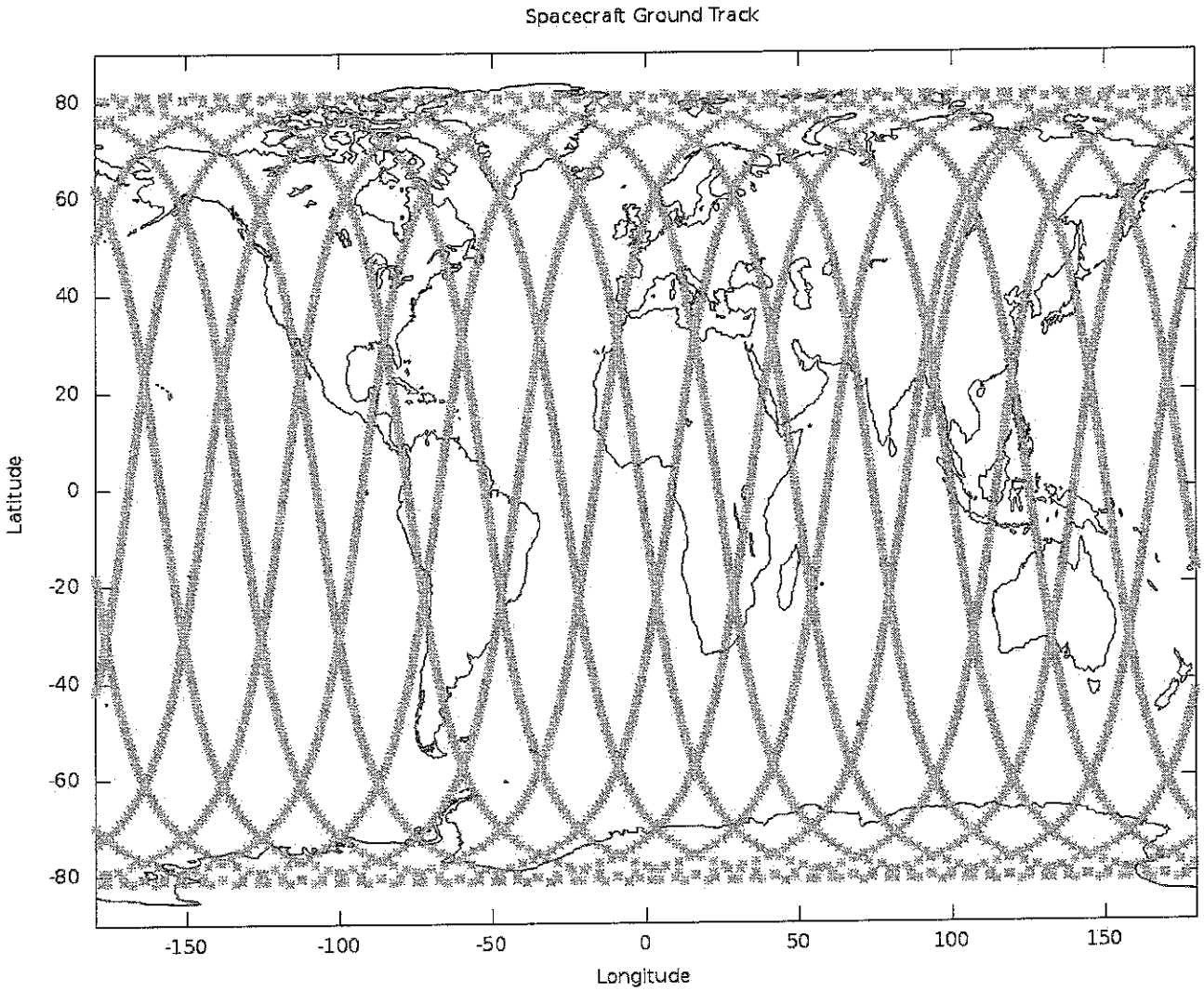

Spacecraft Ground Track
Latitude
80
60
40
20
0
-20
-40
-60
-80
-150
-100
-50
0
50
100
150
Longitude

Figure 1

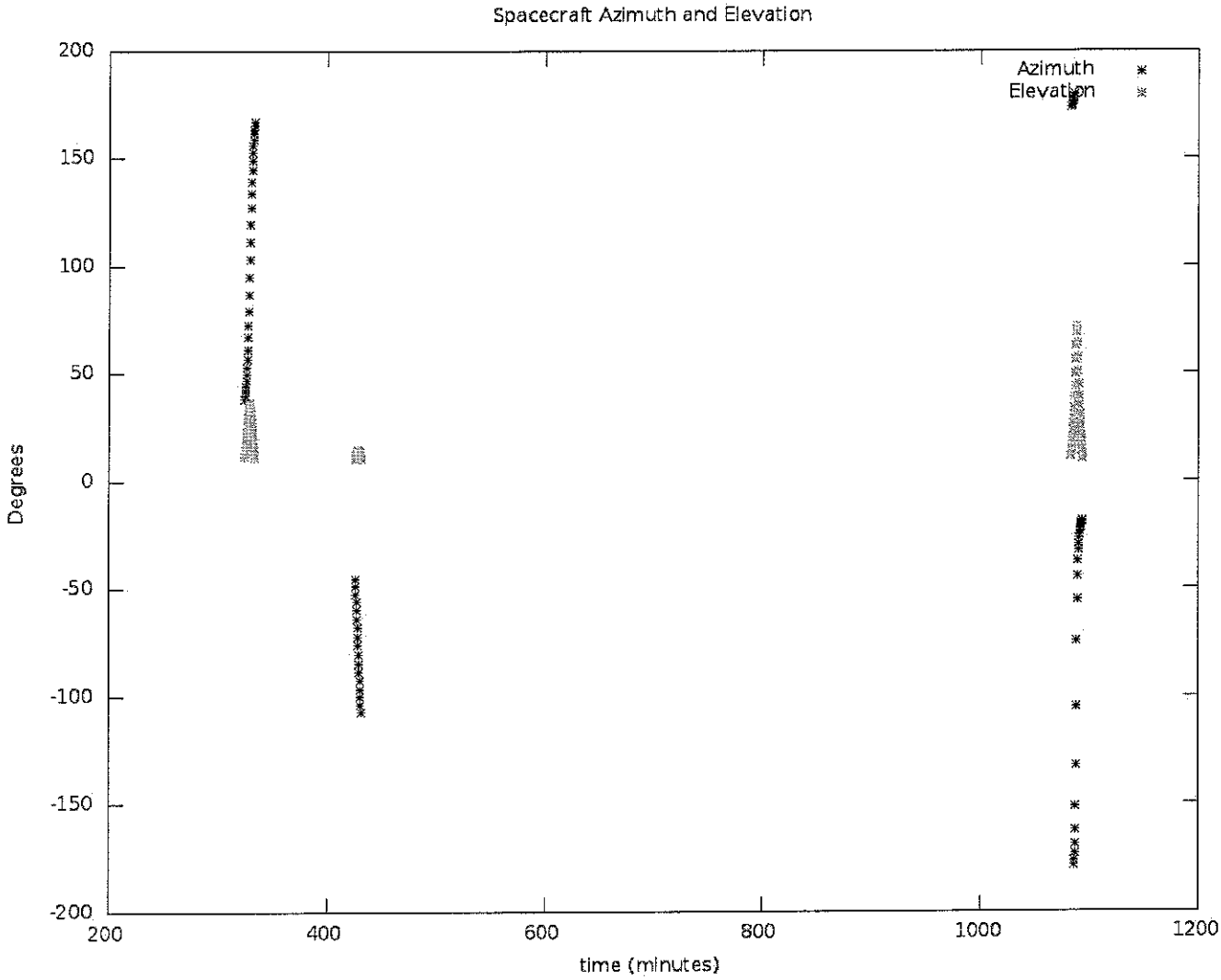

Spacecraft Azimuth and Elevation
Azimuth
Elevation
Degrees
time (minutes)
200
150
100
50
0
-50
-100
-150
-200
200
400
600
800
1000
1200

Figure 2

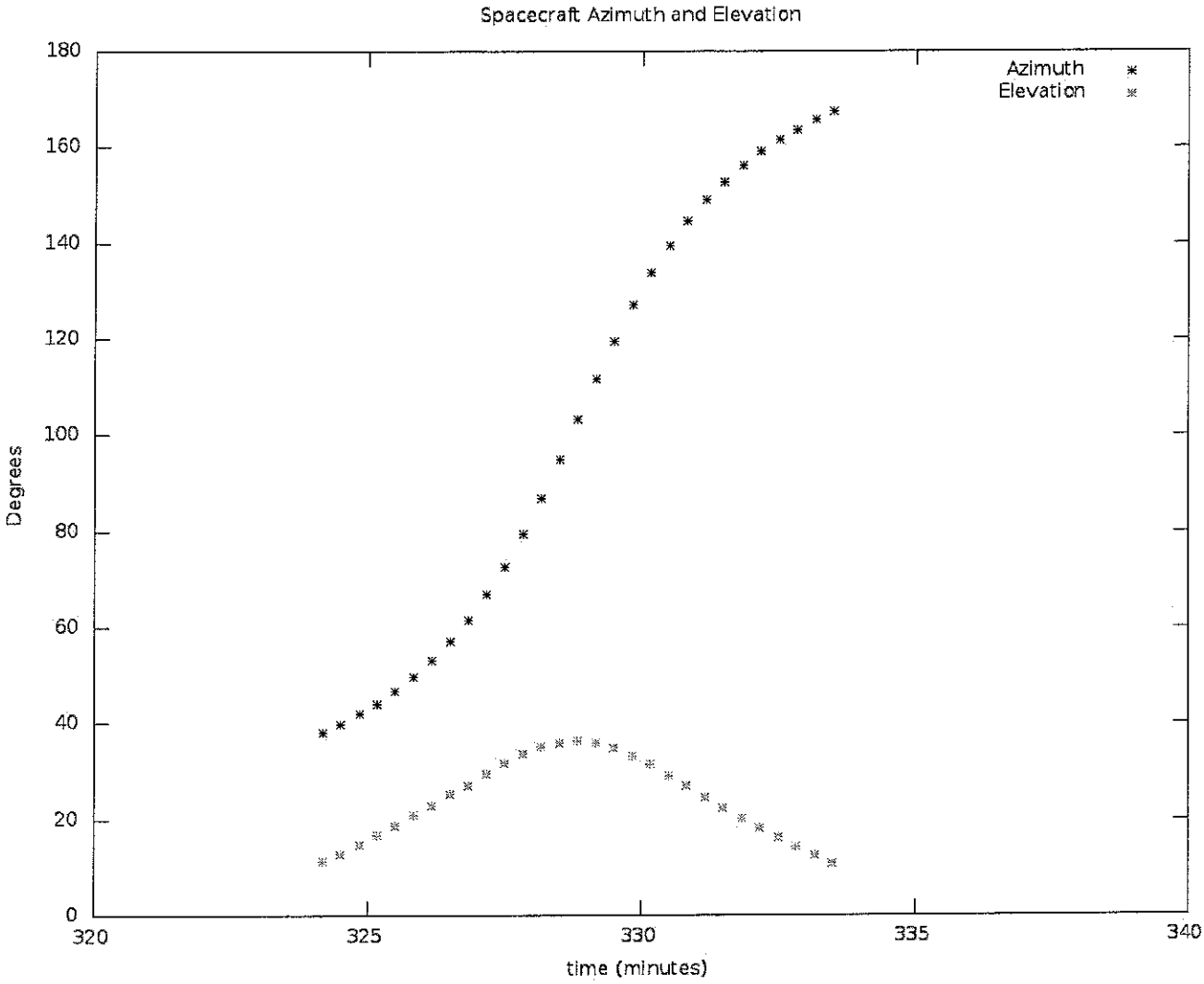

Spacecraft Azimuth and Elevation
Azimuth
Elevation
Degrees
time (minutes)
0
20
40
60
80
100
120
140
160
180
320
325
330
335
340

Figure 3

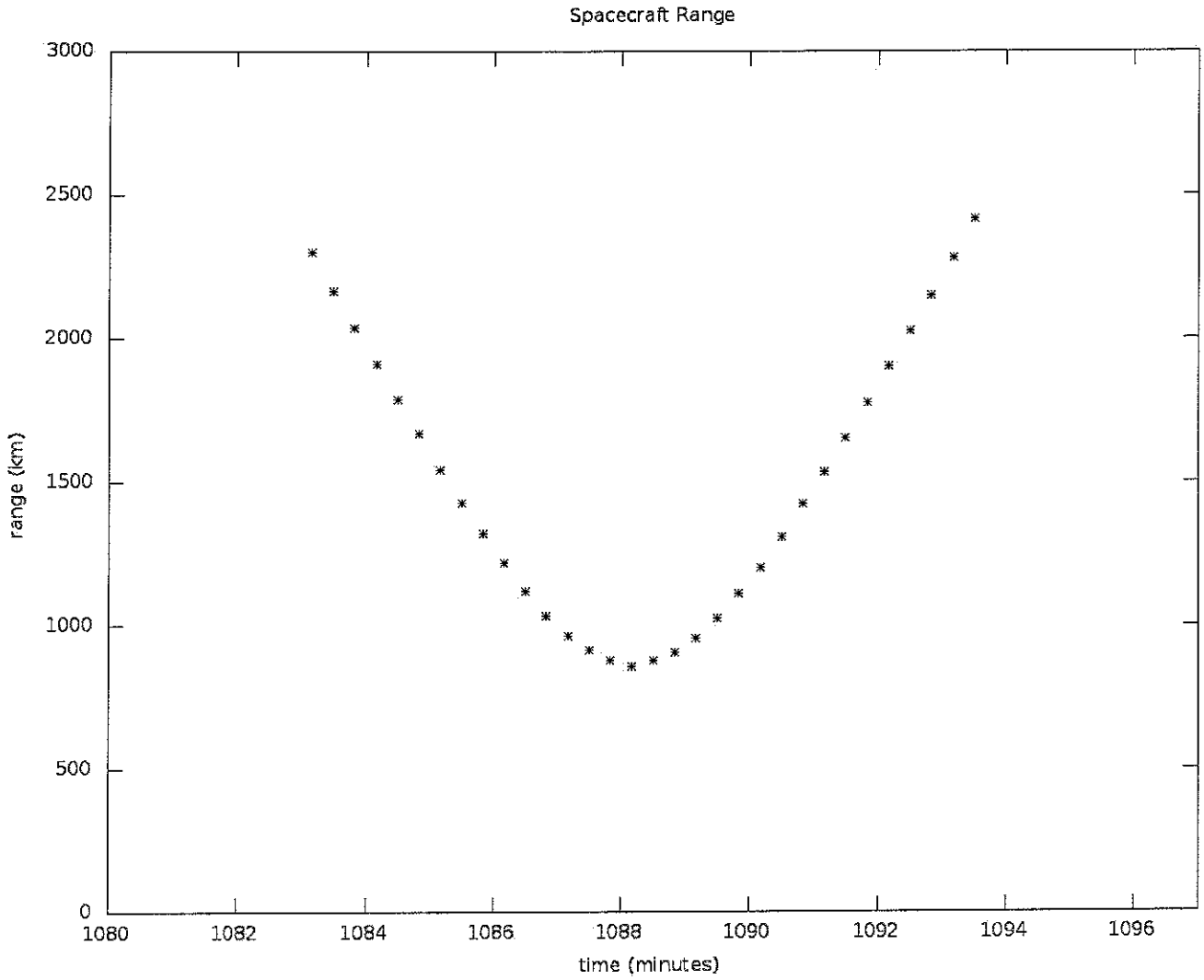

Spacecraft Range
range (km)
time (minutes)
3000
2500
2000
1500
1000
500
0
1080
1082
1084
1086
1088
1090
1092
1094
1096

Figure 4

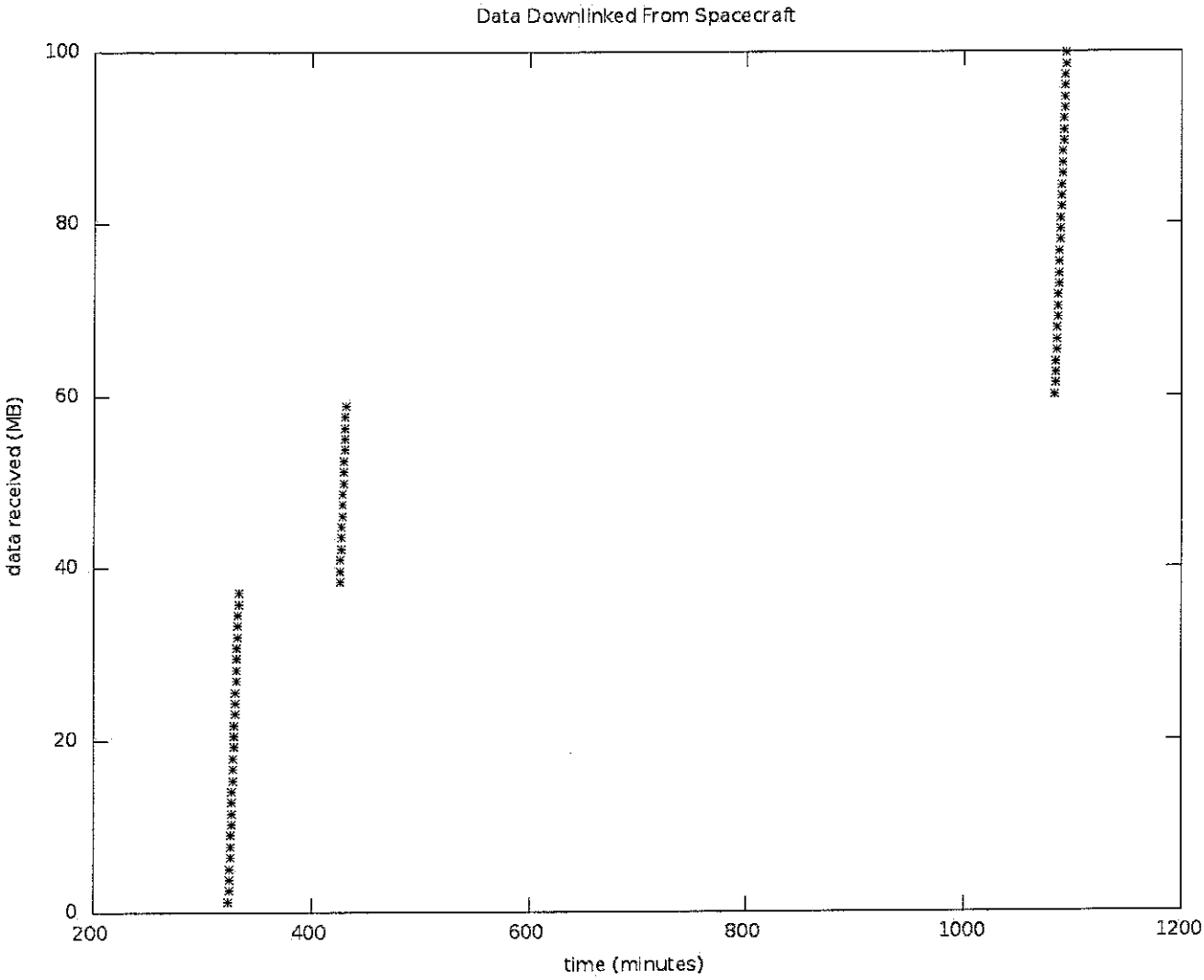

Data Downlinked From Spacecraft
data received (MB)
time (minutes)
0
20
40
60
80
100
200
400
600
800
1000
1200

Figure 5