A Single Geostationary Satellite for Mobile Terrestrial Transmitter Tracking

By
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This paper will describe the Energetics Satellite Locating Service (ESLS) which is a unique, patented, proprietary satellite based geolocation system. This system called SAT/TRAC for Satellite Tracking, Ranging and Communications may be used to quickly determine the present location within 50 feet of any person, vehicle or object that is equipped with a ESLS low power transmitter. This technology represents a novel approach to radio tracking. The single point location system uses a single satellite with a 165 foot inflatable antenna.

INTRODUCTION

Location of terrestrial mobile transmitters with satellites has traditionally been accomplished by doppler tracking with low earth orbiting satellites or triangulation by geostationary satellites. The unique geolocation system under development by Energetics, Inc. of Englewood, Colorado can use a single geostationary satellite to locate low power terrestrial transmitters. This system called SAT/TRAC that employs a 165 foot diameter antenna will use a single satellite to provide system validation and services for 10,000 users. An additional satellite will expand the service to 6,000,000 users, and improve the response time and location accuracy.

SPACECRAFT GENERAL DESCRIPTION

The spacecraft shown in figure 1 will use a large inflatable antenna. This 165 foot diameter antenna will have RF illuminated spokes that will produce elongated radiation patterns on the earth's surface. The spacecraft will be spinning about the antenna axis and can nutate about an axis normal to the earth. This spinning/nutating action will produce antenna patterns as shown in figure 2. Consideration in the systems engineering is being given to coverage in certain geographic areas with zero nutation. The location of the ground transmitter can be resolved when transmission is received at more than one antenna rotation position.

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OVERVIEW OF SYSTEM OPERATION

The user can be provided full period service or request(demand) service as shown in figure 3. During full period service, the user transmitter will be continuously sending an identification code through the spacecraft transponder to the ground processing station. This will require only a mobile ground transmitter.

Service provided to the request service customers will have a small mobile transceiver. The ground processing station can then activate the mobile transmitter at periodic intervals to meet the response time needs of the users.

The system characteristics are shown in detail in table 1. This table shows both the single satellite validation system and the operational system with two satellites. The response time will decrease from 20 minutes to 1 minute and the resolution distance will go from 1000 feet to 50 feet with the addition of the second satellite in transition from the single satellite validation system to the dual satellite operational system.

The link analysis of the single and dual satellite system is shown in tables 2 and 3. The analysis shows that user transmitters will be required to provide 5 watts EIRP. This operation at 24 GHz will require use of state-of-the-art MIMIC technology.

To provide coverage of the major continents will require three sets of satellites as shown in figure 4.

PROJECT CHALLENGES

The SAT/TRAC project has some major technical challenges. The preliminary payload/satellite characteristics are shown in table 4.

Antenna Tolerance Evaluation

The antenna tolerance evaluation consideration is shown in figure 5. Operating at 24 GHz with an inflatable 165 foot diameter parabolic antenna presents an immense technical challenge in the surface accuracy of the antenna spokes. As noted in figure 5, a mechanical misalignment of 2.0 mm can result in an antenna gain loss of 6 db. Mechanical adjustment of the inflatable antenna be required after deployment in orbit.

Self Generated Interference

Self generated interference comes from the multiple users responses and full period users. The trade off of the measurements/beam response evaluation is shown in figure 6. Better resolution is achieved with more bandwidth and user power. The RF spectrum allocation limits the bandwidth and light weight mobile user transceivers limit the practical power available.

Spacecraft Power Requirement

Considerations of the power requirements of the spacecraft tracking, telemetry and command are shown in table 5. The planned Commander Class satellite will require more solar surface than available on the spacecraft body and any available deployable panels. A structure for this additional power is the use of an inflatable spherical structure from the non nadir pointing end of the satellite using flexible, lower efficiency solar substraits.

CONCLUSION

The space technology being developed by Energetics, Inc. using the new SAT/TRAC concepts has been shown by the preliminary systems engineering analysis to be feasible. There are some technical challenges to provide this new geolocation service, but all are within the proven technology that exists today.

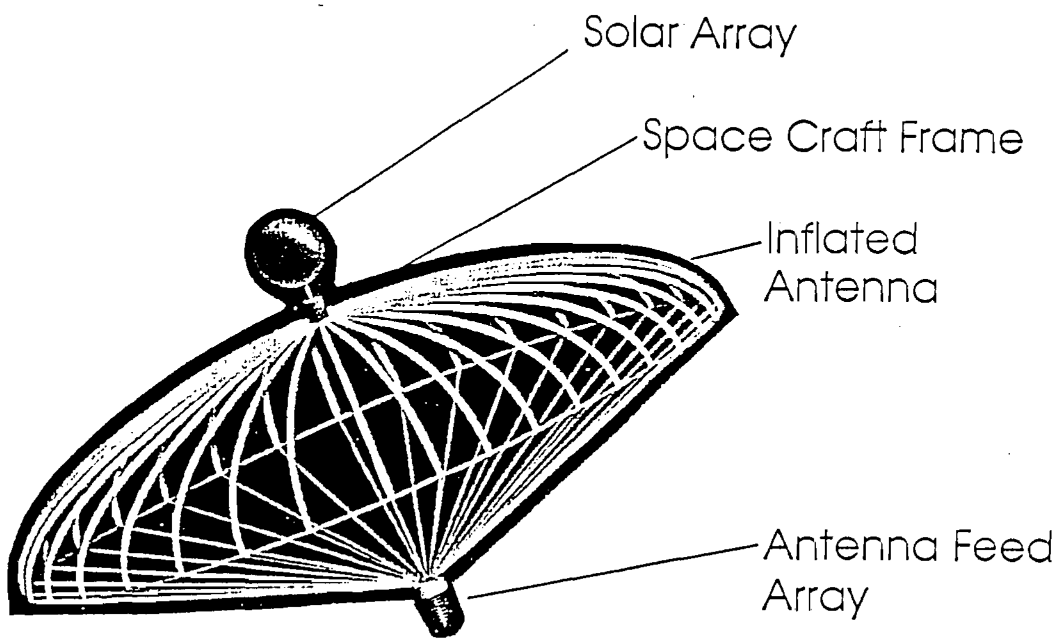


Figure 1 SPACE CRAFT

HOW SAT/TRAC WORKS

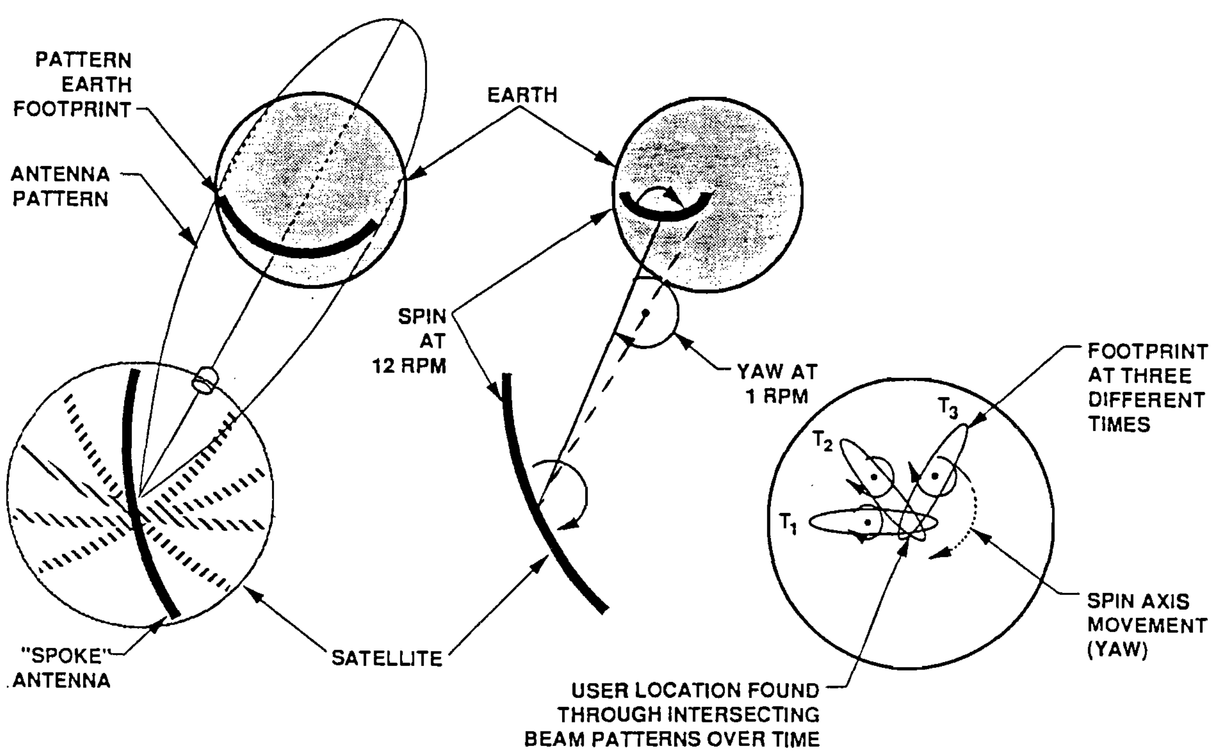
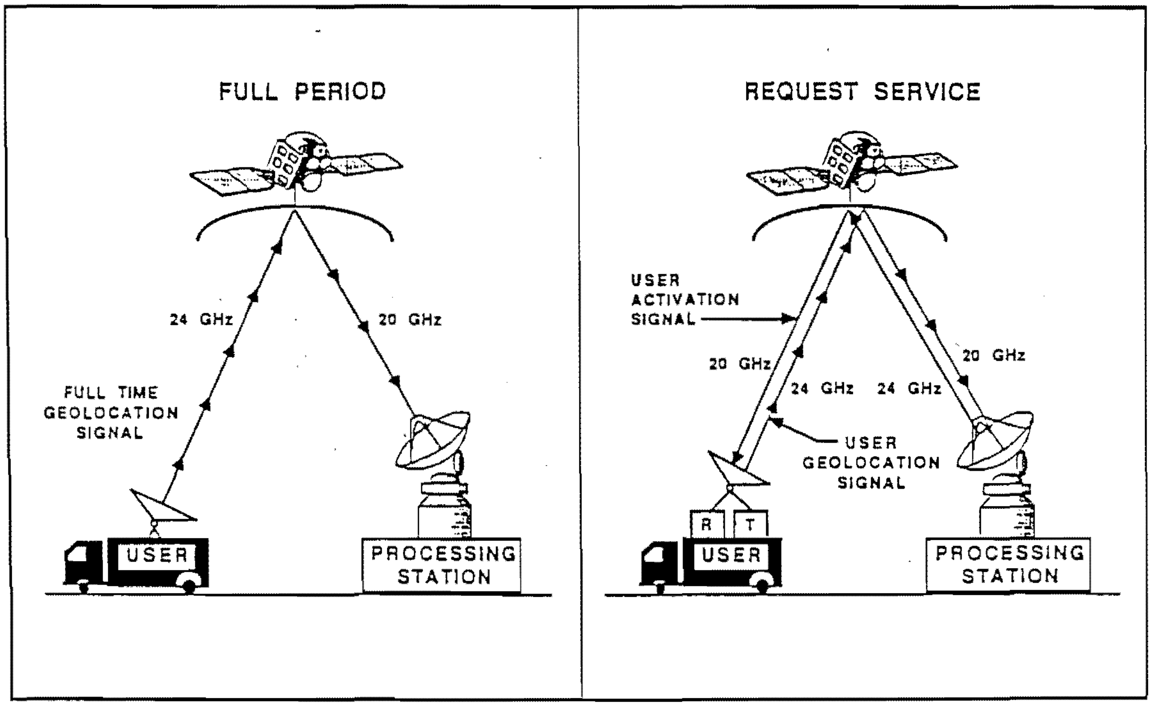


Figure 2



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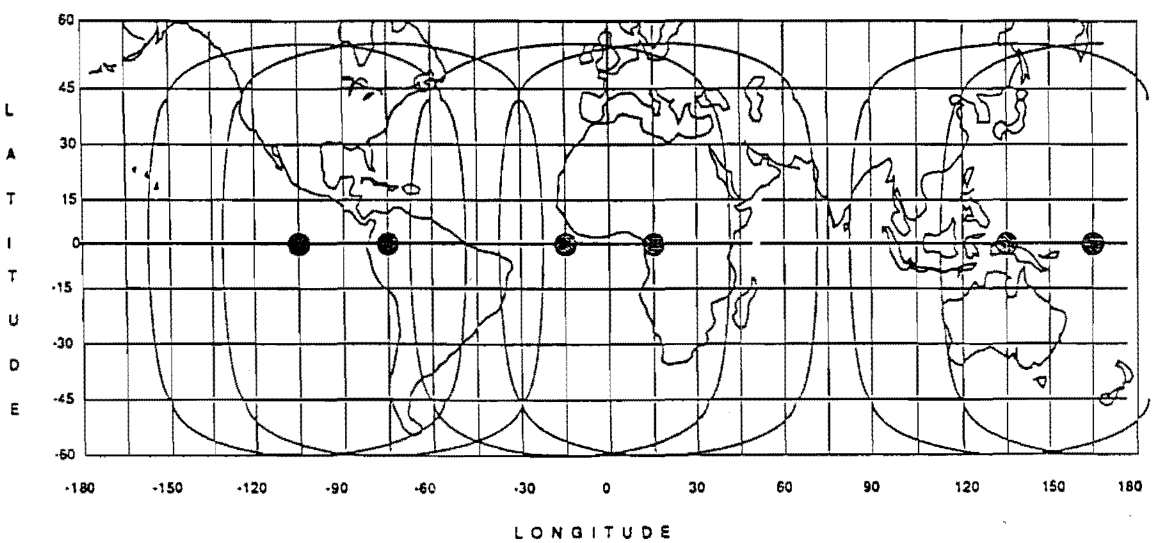
Comparision of Full Period User Transmission V.S. Request (Demand) Service

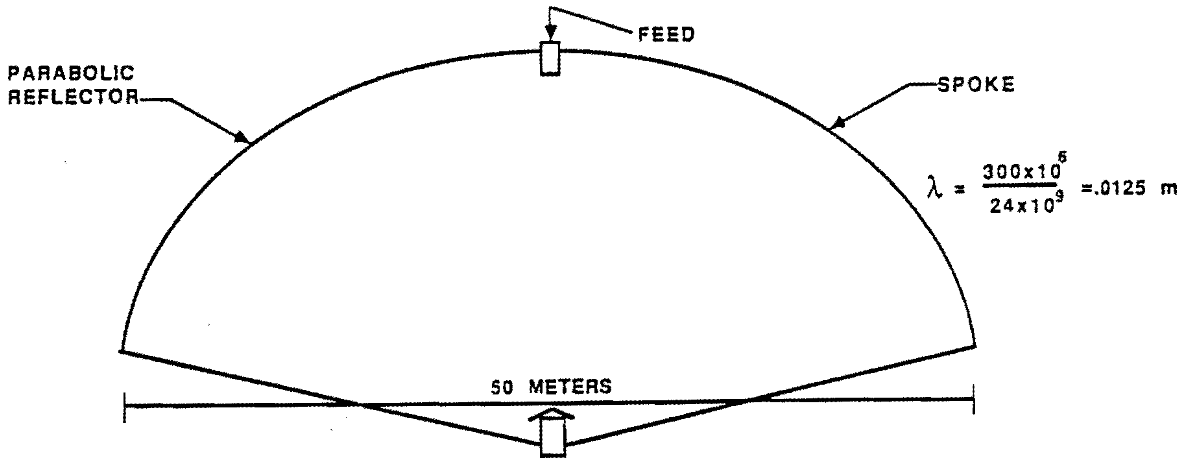
Figure 3



SAT/TRAC Dual Satellite Coverage

Figure 4

ANTENNA TOLERANCE EVALUATION

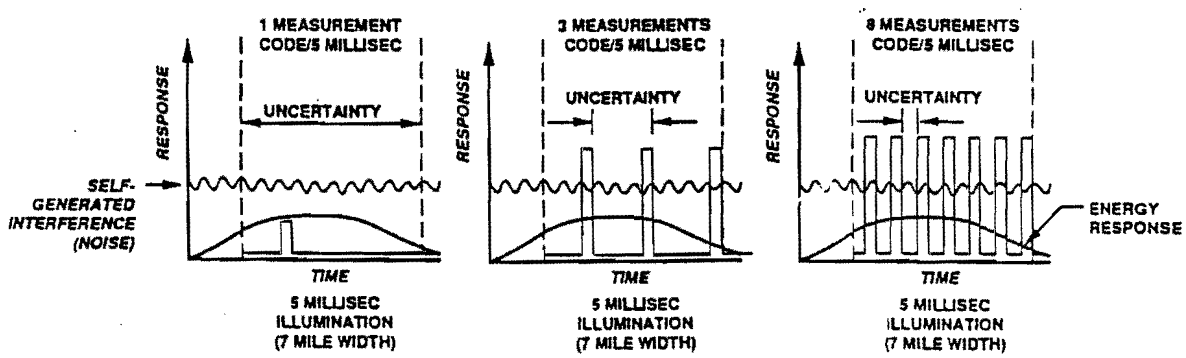


ANTENNA GAIN CHARACTERISTICS ARE HIGHLY DEPENDENT ON ACHIEVING EXCELLENT SURFACE TOLERANCE (ROUGHNESS) AND ADHERENCE TO PARABOLIC SHAPE OVER ENTIRE SPAN UNDER DYNAMIC AND THERMAL STRESS.

ANTENNA MECHANICAL ACCURACY	APPROXIMATE LOSS IN GAIN
0.0 mm	0.0 dB
1.0 mm	1.2 dB
1.5 mm	3.0 dB
2.0 mm	6.0 dB

Figure 5

MEASUREMENTS/BEAM RESPONSE EVALUATION



- ENERGY LEVEL DETECTION NOT POSSIBLE BECAUSE OF HIGH LEVEL OF SELF INTERFERENCE. RESPONSE DOES NOT EXCEED NOISE LEVEL.
- USER UNIQUE CODE DETECTION PERMITS DISCRIMINATION AGAINST OTHER USERS
- TOTAL CODE MUST BE RECEIVED IN 5 MILLISECONDS, THE BEAM ILLUMINATION TIME.
- THE HIGHER THE NUMBER OF MEASUREMENTS PER ILLUMINATION, THE BETTER THE LOCATION PRECISION (RESOLUTION).

BETTER RESOLUTION = MORE BANDWIDTH = MORE USER POWER

Figure 6

LINK ANALYSIS

Dual Satellite (Operational System)

PARAMETER	GEO UPLINK	GEO DOWNLINK	COMM DOWNLINK	UNITS
BOLTZMANN'S CONSTANT	-198.6	-198.6	198.6	dBm/Hz/K°
noise temp	30.0 9 (SAT)	26.2 (CPF)	28.2	dB-K°
RESPONSE BANDWIDTH	0.2	0.2	0.2	dB-Hz
RESOLUTION BANDWIDTH	28.5 (50FT)	28.5 (50FT)	-	dB-Hz
E_b/N_o @10^{-3} BER	7.0	7.0	9.6	dB
INTERFERENCE/NOISE	3.0	3.0	-	
MINIMUM SIGNAL ATENNA	-129.9 (SAT)	-133.7 (CPF)	-157.6 (USER)	dBm
ANTENNA LOSS	-49.3 (SAT)	-72.5	-2.1	dBi
BEAM EDGE LOSS	3.0	0.5	3.0	dB
SIGNAL AT APERATURE	-176/2 (SAT)	-205.7 (CPF)	-156.7 (USER)	dBm
PROPAGATION LOSS	211.5	210.3	210.3	dB
H_2O ABSORPTION	1.5	1.2	1.2	dB
EIRP RQ'D	36.9 (USER)	5.8 (SAT)	54.8 (SAT)	dBm
ANTENNA LOSS	-2.1	-20.0 (SAT)	-20.0 (SAT)	dBi
ANTENNA/HPA LOSS	1.5	2.0	2.0	dB
BEAM EDGE LOSS	1.0	3.0	3.0	dB
SIGNAL USER HPA	37.2 (USER)	-9.2 (SAT)	39.8 (SAT)	dBm
NUMBER OF ACTIVE SWITCHES	-	35.5 (3600)	-	dB
BACKOFF	-	3.0	3.0	dB
HPA RQ'D	37.2 (USER)	29.3 (SAT)	42.8 (SAT)	dBm
HPA	5 WATTS (USER)	20 WATTS (SAT)		

Table 3

PAYLOAD/SATELLITE CHARACTERISTICS

The SAT/TRAC satellite has the following preliminary characteristics:

Geolocation Antenna Diameter (length)	165 feet
Geolocation Antenna Width	0.15 feet
Yaw axis offset from Earth center	0.0 degrees
Spin rate	0.02 RPM
On-axis 25 GHz geolocation antenna gain	49 dBi
Geolocation LNA temperature (total of Earth,satellite)	1000 degrees K
Power Amplifier at 20 GHz	30 watts
20 GHZ Earth Coverage antenna gain	20 dBi
Transponder bandwidth (uplink)	1.5 MHz
Transponder bandwidth (downlink)	36 MHz
TT&C system.	S-Band (primary) Ku-Band (secondary)

Table 4

SYSTEM CHARACTERISTICS

FEATURE	VAILDATION SYSTEM	OPERATIONAL SYSTEM
USER ANTENNA	HEMISPHERICAL	HEMISPHERICAL
USER RECEIVER	YES-DEMAND ROST	YES-DEMAND ROST
USER RF AMPLIFIER	5 WATTS	5 WATTS
USER "CHIPPING"	1.5 MC/S	1.5 MC/S
SATELLITES/REGION	1	2
CONSTELLATION SIZE	4-5	6-7
SATELLITE ANTENNA	USE 1 OF 24 SPOKES	24 SPOKES
SATELLITE SPIN	0.6 RPM	.02 RPM
SATELLITE YAW	.05 RPM	NONE
TRANSPONDERS	USE 1 OF 24	24
SATELLITE POWER	30 WATTS	30 WATTS
CPF ANTENNAS (NO.)	1	2
CPF ANTENNA SIZE	50 FEET	90 FEET
CPF DEMODULATORS	1000	60,000-100,000

SYSTEM CHARACTERISTICS (CON'T)

FEATURE	VAILDATION SYSTEM	OPERATIONAL SYSTEM
CUSTOMERS SERVED	10,000 (EXPANDABLE TO 6,000,000)	6,000,000
RESPONSE TIME	20 MINUTES	1 MINUTE
AVE SERVICE RESPONSES/DAY	SELECTABLE	3
UPLINK BANDWIDTH	1.5 MHZ	1.5 MHZ
DOWNLINK BANDWIDTH	1.5 MHZ	36 MHZ
DISTANCE RESOLUTION	1000 FEET	50 FEET

Table 1

LINK ANALYSIS

Single Satellite (Validation System)

PARAMETER	GEO UPLINK	GEO DOWNLINK	COMM DOWNLINK	UNITS
BOLTZMANN'S CONSTANT	-198.6	-198.6	-198.6	dBm/Hz/K°
NOISE TEMP	30.0 (SAT)	26.2 (CPF)	28.2	dB-K°
RESPONSE BANDWIDTH	11.9 (16 HZ)	11.9 (16 HZ	0.0 (1 HZ)	dB-Hz
RESOLUTION BANDWIDTH	15.7 (1000FT)	15.7 (1000FT)	-	dB-Hz
E_b/N_o @ 10^{-3} BER	7.0	7.0	9.6	dB
INTERPENDENCE/NOISE	3.0	3.0	-	
MIN SIGNAL AT LNA	-131.0 (SAT)	-134.8 (CPF)	-160.8 (USER)	dBm
ANTENNA LOSS	-52.5 (SAT)	-72.5	-2.1	dBI
BEAM EDGE LOSS	3.0	0.5	3.0	dB
SIGNAL AT APERATURE	-180.5 (SAT)	-206.8 (CPF)	-159.9 (USER)	dBm
PROPAGATION LOSS	211.5	210.3	210.3	dB
H_2O ABSORPTION	1.5	1.2	1.2	dB
EIRP RQ'D	32.5 (USER)	4.7 (SAT)	51.6 (SAT)	dBm
ANTENNA LOSS	-2.1	-20.0	-20.0	dBi
ANTENNA-HPA LOSS	1.5	2.0	2.0	dB
BEAM EDGE	1.0	3.0	3.0	dB
SINGLE USUR HPA	32.9	-10.3 (SAT)	36.6 (SAT)	dBm
NUMBER OF ACTIVE SIGNALS	0.0	14.0	-	
BACKOFF	0.0	3.0	3.0	
HPA RQ'D	32.9 (USER)	6.7 (SAT)	39.6 (SAT)	
HPA	2 WATTS (USER)	10 WATTS (SAT)		

Table 2

POWER SUMMARY

SUBSYSTEM	POWER WATTS	DUTY CYCLE	AVERAGE POWER
EPS (Regulator loss @ 75% efficiency)	8.50	1.00	8.50
C & DH			
Processor	10.00	1.00	10.00
Mass Storage	10.00	0.65	6.50
GPS Receiver	8.00	0.50	4.00
RF SYSTEM			
CMD Receiver	2.30	1.00	2.30
Xmitter S-Band	22.40	0.12	2.70
ACS			
RWA (2)	14.00	0.25	3.50
Magnetometer	1.00	0.10	0.10
Rate Gyro (3)	2.70	1.00	2.70
Earth Sensor	1.00	1.00	1.00
Momentary Controls (eg. Torquers)	120.00	0.01	1.20
PAYLOAD			
TOTAL LOAD (Orbit Average)			115.00
BATTERY LOSS (Orbit Average)			16.00
TOTAL POWER (Orbit Average)			131.00

SPACE CRAFT
EPS

Table 5