Form 442 Confirmation Number – EI133779

Form 442 File Number – 0129-EX-PL-2009

Naval Postgraduate School Solar Cell Array Tester

Government Contract Information

The government project is an effort to establish a risk mitigation platform that can test solar cells on a relatively inexpensive spacecraft before they are used on a more complex and critical platform. The project is also an effort by the program sponsor to enhance the educational experience of military officers at the Naval Postgraduate School Space Systems Academic Group before they serve in jobs that support the Department of Defense Space Community. The sponsoring agency is the Secretary of The Air Force. The office designation is SAF/FMBIB-AFOY. The contract number is J448514.

Nature of Research Being Conducted

This project is the result of a research grant to conduct a CubeSat development effort. The project has three aims: 1. Provide hands on satellite design and development experience to student military officers at the Naval Postgraduate School; 2. Establish a baseline for a viable CubeSat program within NPS; 3. Reduce the complexity of a satellite previously funded by the sponsor by taking one of the payloads and integrating it into a dedicated platform (The Solar Cell Array Tester). The actual payload aboard the spacecraft will contain four separate experimental solar cells on a single face of the spacecraft. Also mounted on that face will be a sun sensor. When the experimental face of the spacecraft is in the sun the solar measurement system will sample the voltages produced by the solar cells and correlate the voltages with a sun angle and temperature. As the samples are conducted over a prolonged period of time (the lifetime of the spacecraft) they should allow the principal investigator to understand and quantify the rate of degradation of the solar cells which could provide valuable feedback to the sponsor before they install experimental solar cells on a more expensive and critical spacecraft.

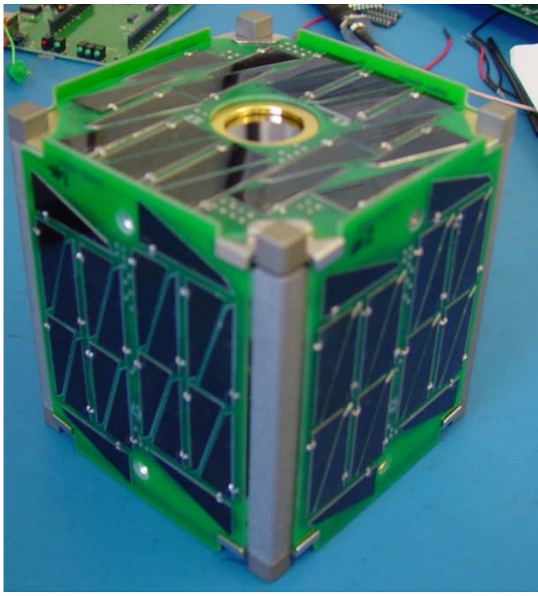

Figure 1. NPS-SCAT Prototype

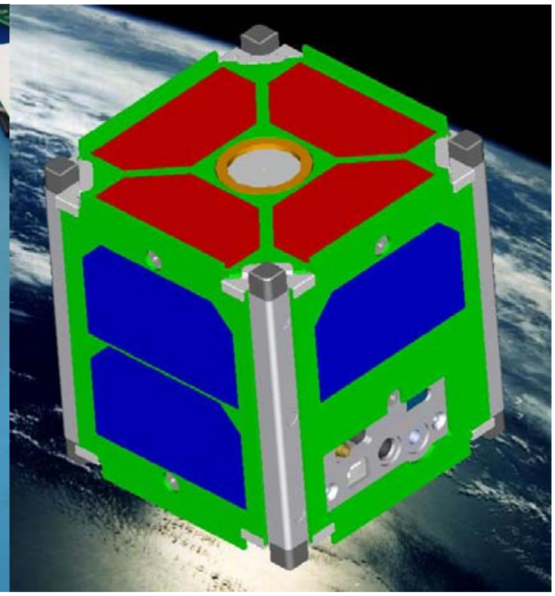

Figure 2. NPS-SCAT Flight Unit

Necessity of Communications Facilities

One of the main thrusts of the research is to develop a baseline COTS satellite sub-system that can be utilized on future CubeSats at the Naval Postgraduate School and simply create a new payload for the next launch. At a fundamental level Pumpkin Inc. has developed the FM430 CubeSat processor to support varying sizes of CubeSats. The FM430 is a flight module processor and has a serial connection that is specifically built to accept the Microhard MHX-2400 series radios. The combination of these two COTS systems presents a rather simple alternative to the development of a communications sub-system that could uniquely support a single satellite. Because this is one of the fundamental goals for the first increment of the program, the Microhard MHX-2400 series is deemed necessary for the research program. Future increments of the program plan to explore the possibility of other transceivers that could support the payload at different frequencies that do not require experimental licenses but instead could operate at frequencies where federal use of the spectrum is authorized for space to Earth communications on a primary basis.

Inadequacy of Current Communications Facilities

The satellite is schedule to be launched aboard STS-133 after it departs from the International Space Station. The satellite will deploy from the Space Shuttle from the Space Shuttle Payload Launcher at an altitude 20 Kilometers under the International Space Station. Due to the altitude of the spacecraft, the relatively low EIRP of the spacecraft communications system (~32 dBm), the fact that the spacecraft is tumbling, the margin in the link budget is below the desired 10 dB to account for fading at elevation angles below 80 degrees . This would not allow the program to receive or transmit enough useful data over the lifetime of the satellite. By installing an HPA/LNA assembly on the parabolic antenna that will serve as the primary uplink/downlink the ground station will be able to close the link with sufficient margin at elevation angles above 30 degrees. This will allow approximately 170 seconds of contact between the satellite and the ground station once a week which will allow the downlink of the experimental data and the uplink of any commands that the satellite requires. A representative link budget is below. The budget shows that the communications system as it operates now is not sufficient to downlink data to the ground station and accomplish the fundamental goals of the program.

NPS SCAT 2.4GHz DownLink Budget

Item	Symbol	Units	Source	DL	DL	DL	DL	DL	DL
Orbit Altitude (km)		km		410	410	410	410	410	410
Elevation Angle		deg		**5**	**30**	**40**	**60**	**80**	**90**
Frequency	f	GHz	Input parameter	2.4	2.4	2.4	2.4	2.4	2.4
Transmitter Power	P	Watts	Input parameter	1	1	1	1	1	1
Transmitter Power	P	dBW	10log(P)	0	0	0	0	0	0
Transmitter Line Loss	Ll	dBW	Input parameter	-1	-1	-1	-1	-1	-1
Avg Transmit Antenna Gain	Gpt	dBi	Input parameter	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**
Transmit Total Gain	Gt	dB	Gpt+Lpt	1.0	1.0	1.0	1.0	1.0	1.0
Eq. Isotropic Radiated Power	EIRP	dBW	P+Ll+Gpt	1.00	1.00	1.00	1.00	1.00	1.00
Propagation Path Length	S	km	From Alt. and El.	**1833.066**	**756.603**	**612.582**	**468.754**	**415.935**	**410.000**
Space Loss	Ls	dB	Eq (13-23b)	-165.3	-157.6	-155.8	-153.5	-152.4	-152.3
Propagation and Polarization Loss	La	dB	Fig. 13-10	-3	-3	-3	-3	-3	-3
Receive Antenna Diameter	D	M	Input parameter	3.02	3.02	3.02	3.02	3.02	3.02
Receive Antenna Eff	Eta		Input parameter	0.55	0.55	0.55	0.55	0.55	0.55
Peak Receive Antenna Gain	Grp	dBi	Eq (13-18a)	35.02	35.02	35.02	35.02	35.02	35.02
Receive Antenna Line Loss	Lr	dB	Input parameter	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Receive Antenna Beamwidth*	Theta	deg	Eq (13-19)	2.90	2.90	2.90	2.90	2.90	2.90
Receive Antenna Pointing Error	E	deg	Input parameter	2.00	2.00	2.00	2.00	2.00	2.00
RX Antenna Pointing Error Loss	L_theta	dB	Eq (13-21)	-5.72	-5.72	-5.72	-5.72	-5.72	-5.72
Receive Antenna Gain with pointing error	Gr	dB	Grp+Lpr+L_theta	28.8	28.8	28.8	28.8	28.8	28.8
System Noise Temperature **	Ts	K	Table 13-10	585	585	585	585	585	585
Data Rate	**R**	bps	Input parameter	**172000**	**172000**	**172000**	**172000**	**172000**	**172000**
Eb/No (1)	Eb/No	dB	Eq (13-13)	10.1	17.7	19.6	21.9	22.9	23.1
Bit Error Rate	BER		Input parameter	10-5	10-5	10-5	10-5	10-5	10-5
Required Eb/No (2)	Req Eb/No	dB-Hz	Fig. 13-9	13.5	13.5	13.5	13.5	13.5	13.5
Implementation Loss (3)		dB	Estimated	-2	-2	-2	-2	-2	-2
Margin		dB	(1)-(2)+(3)	**-5.4**	**2.2**	**4.1**	**6.4**	**7.4**	**7.6**
Max Nadir Angle	Eta Max	deg	Eq (5-36)	69.39	54.46	46.04	28.02	9.39	0.00
Max Earth Central Angle	Lambda Max	deg	Eq (5-37)	15.61	5.54	3.96	1.98	0.61	0.00
Max Range	Dmax	km	Eq (5-38)	1833	757	613	469	416	-6378
Min Earth Central Angle	Lambda Min	deg	Eq (5-43)	0	0	0	0	0	0
Time in View	T	min	Eq (5-49)	**8.042558**	**2.854705**	**2.042915**	**1.019733**	**0.314187**	**0**
	T	sec		**482.5535**	**171.2823**	**122.5749**	**61.18395**	**18.85125**	**0**
Kilo Bits Per Pas		Kbs		**82999.2**	**29460.6**	**21082.9**	**10523.6**	**3242.4**	**0.0**