PACE 2012

Reliability

14 – 18 May, 2012

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Subsystem Overview

- **Class C Mission per NPR 8705.4**
  - Baselines a single string design with selective redundancy to bolster critical areas
- **Out of house (RSDO) spacecraft for 3 years required and 5 years desired mission**
  - Spacecraft vendor needs to come up with the appropriate design to meet this
    - Single string with selective redundancy to meet mission life requirements and EOM deorbit requirements per NASA-STD 8719.14 Rev. A

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Subsystem Description

Redundancies

- **ACS**
  - Northrop Grumman SIRU is internally redundant
  - 4 reaction wheels (3 required)
  - 8 Coarse Sun Sensors (6 required)
  - 2 Magnetometers (1 required)
  - 3 Torquer Bars (3 of 3 required)
    - Redundant coils on each
- **Avionics**
  - Single string flight avionics
- **Power**
  - 60 solar cell strings (~59 required at 5 years)
  - 8 Battery Cells (7 required)
  - Power System Electronics are single string
- **Propulsion**
  - 4 22N Thrusters (3 Required in order to have a minimum of 2 available on opposite corners of spacecraft—mostly used for controlled deorbit)

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Subsystem Description (cont)

- **Thermal**
  - 60 heaters (Assumed 75%/25% split between Operational/Survival)
    - 45 operational heaters (40 required—10% loss)
    - 15 survival heaters (13 required—10% loss)
  - 60 thermostat pairs (120 thermostats)
    - Same splits as heaters
  - 75 Thermistors
    - 67 required (loss of 10% is assumed to be acceptable—unknown at this time which ones are used as control inputs, etc.)
- **Communications**
  - X band system
    - 2 Transmitters; 1 of 2 for operation
    - Antenna—1 Omni
  - S band system
    - 2 Transponders 1 of 2 for operation
    - 2 Diplexers 1 of 2 for operation
    - Antenna—2 Omnis (both required)
  - GPS receiver
    - Single String Receiver
    - Single Antenna

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Subsystem Description (cont)

Duty Cycles

- Propulsion
  - Thrusters- 50% (conservative estimate; amount of fuel through thruster/rated total flow)
  - Latch valve- 1% (small number of actuations)
- Thermal
  - Operational heaters-70% (Typical MDL estimate)
  - Survival heaters-10% (Typical MDL estimate)
- X-band Communication System- 50% (conservative duty cycle)
- S-band Communication System- 7% (max 1.5 hours per day)

- All other systems assumed to have 100% duty cycle

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De-Orbit Reliability

PACE 2012---DEORBIT RELIABILITY

Mission Duration (years)	
Requirement:	3
Goal:	5
Extended Lifetime:	5

Master Duty Cycle:	100%

	Mission Duration (years)						
	Baseline Design				**Single String Design**		
	3		**5**		**3**		**5**
ACS	0.998824		0.997447		0.984351		0.974055
Avionics	0.975139		0.95891		0.975139		0.95891
Power	0.987954		0.980004		0.987953		0.980002
Propulsion	0.987731		0.979436		0.982388		0.970818
Thermal	0.999998		0.999977		0.991358		0.985638
Communications	0.991379		0.985673		0.990006		0.983399
Deorbit Reliability	**0.942259**		**0.904887**		**0.914333**		**0.861338**

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Conclusions

- **Baseline spacecraft configuration will be adequate for controlled deorbit out to 5 years**

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Backup Material

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ACS for Deorbit

ACS

Subsystem / Component Name	Qty	Model	MTTF/ Char Life / Lognormal Mean	Failure Rate / Shape / Lognormal Std Dev	Relative Duty Cycle	Component Reliability (for time in years) 3	5	5	Redundancy Configuration	Subsytem Reliability (for time in years) 3	5	5
Gyro	1				100%	0.999399278	0.998998997	0.998998997	Single String	0.999399278	0.998998997	0.998998997
NG Scalable SIRU	1	E	43734201.02	2.28654E-08		0.999399278	0.998998997	0.998998997	Single String	0.999399278	0.998998997	0.998998997
										6	of	8
Coarse Sun Sensor	1				100%	0.994801252	0.991350444	0.991350444	K of N (Hot)	0.999992284	0.999964921	0.999964921
Coarse Sun Sensor	1	E	5041912	1.98337E-07		0.994801252	0.991350444	0.991350444	Single String	0.994801252	0.991350444	0.991350444
Magnetic Torquers	3				100%	0.999989	0.999981667	0.999981667	Single String	0.999967	0.999945001	0.999945001
MTA Torque rod	1	E	2389077769	4.18572E-10		0.999989	0.999981667	0.999981667	Single String	0.999967	0.999945001	0.999945001
Magnetometers	1				100%	0.999619203	0.999365419	0.999365419	Cold Standby	0.999999927	0.999999799	0.999999799
Magnetometer	1	E	69000000	1.44928E-08		0.999619203	0.999365419	0.999365419	Single String	0.999619203	0.999365419	0.999365419
										3	of	4
Reaction Wheels	1				100%	0.9905	0.984216859	0.984216859	K of N (Hot)	0.999465335	0.998536622	0.998536622
RWA	1	E	2753154.885	3.6322E-07		0.9905	0.984216859	0.984216859	Single String	0.9905	0.984216859	0.984216859
										2	of	3
Horizon Sensor					100%	0.994801252	0.991350444	0.991350444	K of N (Hot)	1	1	1
Earth Sensor (Coarse Sun Sensor form library)	1	E	5041912	1.98337E-07		0.994801252	0.991350444	0.991350444	Single String	1	1	1

	ACS Total		
	3 years	5 years	5 years
Max Redundancy	0.998824192	0.997447029	0.997447029
Min Redundancy	0.984351241	0.974055019	0.974055019

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Avionics for Deorbit

Avionics

Subsystem / Component Name	Qty	Model	MTTF/ Char Life / Lognormal Mean	Failure Rate / Shape / Lognormal Std Dev	Relative Duty Cycle	Component Reliability (for time in years)			Redundancy Configuration	Subsytem Reliability (for time in years)		
						3	5	5		3	5	5
Integrated Avionics Unit	1				100%	0.975139133	0.958909546	0.958909546	Single String	0.975139133	0.958909546	0.958909546
input/output controller (IOC)	1	E	5139789.979	1.9456E-07		0.9949	0.991514458	0.991514458	Single String	0.975139133	0.958909546	0.958909546
power controller 2 (PC)	1	E	2843361.498	3.51696E-07		0.9908	0.984713737	0.984713737				
relay-driver	3	E	7286852.102	1.37233E-07		0.989238833	0.982129134	0.982129134				

	Avionics Total		
	3 years	5 years	5 years
Max Redundancy	0.975139133	0.958909546	0.958909546
Min Redundancy	0.975139133	0.958909546	0.958909546

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Power Systems for Deorbit

Power												
Subsystem / Component Name	Qty	Model	MTTF/ Char Life / Lognormal Mean	Failure Rate / Shape / Lognormal Std Dev	Relative Duty Cycle	Component Reliability (for time in years)			Redundancy Configuration	Subsytem Reliability (for time in years)		
						3	5	5		3	5	5
										30	of	60
Solar Arrays	1				100%	0.9999987	0.999997833	0.999997833	K of N (Hot)	1	1	1
Solar array panel/strings	1	E	20215371476	4.94673E-11		0.9999987	0.999997833	0.999997833	Single String	0.9999987	0.999997833	0.999997833
Battery Lithium Ion	1				100%	0.993712649	0.989543058	0.989543058	Single String	0.993712649	0.989543058	0.989543058
Battery in LEO (the entire battery; not technology specific)	1	E	4166666.667	0.00000024		0.993712649	0.989543058	0.989543058	Single String	0.993712649	0.989543058	0.989543058
Power System Electronics	1				100%	0.994354334	0.990608275	0.990608275	Single String	0.994354334	0.990608275	0.990608275
Power control circuit	3	E	420466859.9	2.37831E-09		0.999812512	0.999687539	0.999687539	Single String	0.994354334	0.990608275	0.990608275
Power control circuit	1	E	420466859.9	2.37831E-09		0.9999375	0.999895836	0.999895836				
PSE Board	1	E	4865292.2	2.05538E-07		0.994613036	0.991037859	0.991037859				
Primary power bus	1	E	2627986860	3.80519E-10		0.99999	0.999983333	0.999983333				
Back harness connector	1	E	2.02154E+11	4.94673E-12		0.99999987	0.999999783	0.999999783				
Solar Array Drive	1				100%	0.99985	0.999750013	0.999750013	Single String	0.99985	0.999750013	0.999750013
Deployable drive assembly (DDA)	1	E	175186859.7	5.70819E-09		0.99985	0.999750013	0.999750013	Single String	0.99985	0.999750013	0.999750013

	Power Total		
	3 years	5 years	5 years
Max Redundancy	0.987954263	0.980004491	0.980004491
Min Redundancy	0.987952979	0.980002368	0.980002368

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Propulsion for Deorbit

Propulsion

Subsystem / Component Name	Qty	Model	MTTF/ Char Life / Lognormal Mean	Failure Rate / Shape / Lognormal Std Dev	Relative Duty Cycle	Component Reliability (for time in years) 3	5	5	Redundancy Configuration	Subsytem Reliability (for time in years) 3	5	5
Tank	1				100%	0.9956	0.992677427	0.992677427	Single String	0.9956	0.992677427	0.992677427
Tank (leakage or rupture)	1	E	5959577.615	1.67797E-07		0.9956	0.992677427	0.992677427	Single String	0.9956	0.992677427	0.992677427
Filter	1				100%	0.99974	0.999566704	0.999566704	Single String	0.99974	0.999566704	0.999566704
liquid filter	1	E	101063782.5	9.89474E-09		0.99974	0.999566704	0.999566704	Single String	0.99974	0.999566704	0.999566704
Latch Valve	1				1%	0.999925866	0.999876446	0.999876446	Single String	0.999925866	0.999876446	0.999876446
Latch Valve Coil	1	E	7089554.585	1.41053E-07		0.999962932	0.999938221	0.999938221	Single String	0.999925866	0.999876446	0.999876446
Thruster Valve	1	E	7089554.5	1.41053E-07		0.999962932	0.999938221	0.999938221				
Fill and drain valves	2				100%	0.9963	0.993840942	0.993840942	Single String	0.99261369	0.987719818	0.987719818
Isovalve	1	E	7089554.585	1.41053E-07		0.9963	0.993840942	0.993840942	Single String	0.99261369	0.987719818	0.987719818
Pressure Transducer	1				100%	0.999999495	0.999997662	0.999997662	Single String	0.999999495	0.999997662	0.999997662
Pressure Transducer	1	W	3300000	3		0.999999495	0.999997662	0.999997662	Single String	0.999999495	0.999997662	0.999997662
										3	of	4
Thrusters	1				50%	0.994405228	0.990692781	0.990692781	K of N (Hot)	0.999813589	0.999486681	0.999486681
Thruster primary	1	E	6902641.136	1.44872E-07		0.998098192	0.996832329	0.996832329	Single String	0.994405228	0.990692781	0.990692781
Thruster Valve	1	E	7089554.5	1.41053E-07		0.998148286	0.996915715	0.996915715				
Cat bed heater in the thruster assembly	1	E	7089554.585	1.41053E-07		0.998148286	0.996915715	0.996915715				

	Propulsion Total		
	3 years	5 years	5 years
Max Redundancy	0.987731345	0.979435924	0.979435924
Min Redundancy	0.982388341	0.970818438	0.970818438

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Thermal for Deorbit

Thermal

Subsystem / Component Name	Qty	Model	MTTF/ Char Life / Lognormal Mean	Failure Rate / Shape / Lognormal Std Dev	Relative Duty Cycle	Component Reliability (for time in years)			Redundancy Configuration	Subsytem Reliability (for time in years)		
						3	5	5		3	5	5
										40	of	45
Operational Heaters	1				70%	0.992483841	0.98750448	0.98750448	K of N (Hot)	0.999998858	0.99997959	0.99997959
Heater	1	E	2530883.726	3.95119E-07		0.992757745	0.987958738	0.987958738	Single String	0.992483841	0.98750448	0.98750448
Thermostat Pair	1	E	66666666.67	0.000000015		0.999724098	0.999540206	0.999540206				
										13	of	15
Survival Heaters	1				10%	0.998922788	0.998205292	0.998205292	K of N (Hot)	0.999999437	0.999997412	0.999997412
Heater	1	E	2530883.726	3.95119E-07		0.998962166	0.998270876	0.998270876	Single String	0.998922788	0.998205292	0.998205292
Thermostat Pair	1	E	66666666.67	0.000000015		0.999960581	0.999934302	0.999934302				
										67	of	75
Thermistors	1				100%	0.9999429	0.999904835	0.999904835	K of N (Hot)	1	1	1
thermistor	1	E	460232043.8	2.17282E-09		0.9999429	0.999904835	0.999904835	Single String	0.9999429	0.999904835	0.999904835

	Thermal Total		
	3 years	5 years	5 years
Max Redundancy	0.999998295	0.999977002	0.999977002
Min Redundancy	0.991358116	0.98563839	0.98563839

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Communications for Deorbit

Communications

Subsystem / Component Name	Qty	Model	MTTF/ Char Life / Lognormal Mean	Failure Rate / Shape / Lognormal Std Dev	Relative Duty Cycle	Component Reliability (for time in years)			Redundancy Configuration	Subsytem Reliability (for time in years)		
						3	5	5		3	5	5
S-Band Single String Components	1				7%	0.999863105	0.999771852	0.999771852	Single String	0.999863105	0.999771852	0.999771852
Antenna-- 2 Omnis need both	2	E	33252681.05	3.00728E-08		0.999897265	0.99982878	0.99982878	Single String	0.999863105	0.999771852	0.999771852
hybrid	1	E	50000000	0.00000002		0.999965837	0.999943062	0.999943062				
S-Band Redundant Components	1				7%	0.99861382	0.997690768	0.997690768	Cold Standby	0.999999039	0.999997332	0.999997332
diplexer	1	E	50000000	0.00000002		0.999965837	0.999943062	0.999943062	Single String	0.99861382	0.997690768	0.997690768
transmitter	1	E	2008369.805	4.97916E-07		0.999149821	0.998583437	0.998583437				
Receiver	1	E	3399830.085	2.94132E-07		0.999497689	0.999162956	0.999162956				
GPS System	1				100%	0.991516083	0.985900163	0.985900163	Single String	0.991516083	0.985900163	0.985900163
Antenna	1	E	33252681.05	3.00728E-08		0.99921	0.99868368	0.99868368	Single String	0.991516083	0.985900163	0.985900163
Receiver	1	E	3399830.085	2.94132E-07		0.9923	0.987199634	0.987199634				

	Communications Total		
	3 years	5 years	5 years
Max Redundancy	0.991379396	0.985672602	0.985672602
Min Redundancy	0.990006118	0.983399079	0.983399079

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