PRATHAM

IIT BOMBAY STUDENT SATELLITE

Preliminary Design Report

Quality Sub-System

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Requirements Capture

1. Reliability of Satellite as a whole should be maintained high.
Hence, critical points should be identified and redundancy measures should be taken, wherever required.
2. All processes, storage handling should be controlled as required.
3. Tests will be designed together with each sub-system and records of all tests and NCs will be maintained.

Following will NOT be covered as a part of QA but will be looked into by Project Manager/ Core group.

1. Organization chart
2. Criteria for selection of members, including requirements of Knowledge and skills
3. Define Roles, responsibilities & interactions of sub-groups and members
4. Budget planning
5. Design plan to include
    a. Activities and time plan
    b. Interaction of sub-groups (Output of one group becomes input for other.)
    c. Stages of design reviews

Manufacturing under controlled conditions
Use of qualified operators where required.
Records to be kept , including those for failures
Process environment has to be maintained.
    Clean Room will be setup.
    ESD protective workspace will be used for all electrical subsystem work, testing, transport and storage.
Testing as per testing plan
Special process(es) like soldering to be validated.
Appropriate storage, handling and transport arrangements.
Software scheduler will be designed to have enough safety margins.
Code walkthroughs will be conducted

Hardware (Mechanical):

For Mechanical sub-systems reliability is assumed to be 1.0000. However, reliability analysis can be done qualitatively. The method of FMEA was found to be most suitable for our purpose. Hence, FMEA for deployment mechanism and main structure was done. Since, deployment is a very crucial node, very high reliability is required. Hence, multiple redundancy measures are incorporated in the design of Deployment mechanism.

Hardware (EEE Components):

Materials Selection

Outgassing requirements will be met by all subsystems and/or components through proper selection of materials and appropriate vacuum bakeout of parts, components, and subsystems if necessary.
Bulk materials will be chosen with low outgassing property with guidance from ISRO.
Such materials are
Wires
Connectors
PCB material
Fasteners, adhesives
Wire used in Deployment mechanism.
Body material
Solar panel substrate, and cover glass

Materials other than this will be assumed not be harmful as they are present in small amount. Plastic and rubber like materials will be avoided. In case they must be used, vacuum bakeout will be carried.

Other than this all material selection will be done by each subsystem and they will have to accepted by QA based on compatibility.

CLEAN ROOM

Assembly of the spacecraft will take place in a cleanroom.

1. It will have enamel paint (Steridex)
2. It will have air conditioner unit.
3. Grounding provided to room for ESD purposes will have less than 2 ohm of resistance. Anti-static mats will be used allover the room, connected to ground.
4. One/two laminar flow bench(es) will be installed with air flow rate more than 100 cfm. It will have size greater than 4x2 ft^2, with provision of light and electricity plug-points and ground points for ESD protection.
   All electronic soldering will be done on clean bench. All electronic circuitrary will be packed before it is taken away.
5. The room will not have any steps where dust can accumulate.
6. Entry to clean room will be restricted to maximum 5 people.

During all fabrication and assembly phases and associated storage/transportation periods, contamination control measures will be instituted. Surfaces will be kept clean. For all mechanical parts Gross cleaning will be done as per MIL-STD-1246. During assembly, mating surfaces will be cleaned to visibly clean sensitive prior to attachment.
Spacecraft subsystems will be maintained at a visibly clean level throughout the fabrication process. When not in a class 100,000 environment the spacecraft must be bagged. Regular monitoring of the cleanroom will be accomplished. The spacecraft will remain bagged whenever operations permit.

ESD SAFETY MEASURES

ESD control will be practiced in all EEE parts storage and fabrication areas and in the assembly and integration clean room. All fabrication involving ESD sensitive parts will be carried out only in ESD protected areas. Bagging materials and drapes must be contamination and electrostatic discharge (ESD) approved. To prevent electrostatic discharge (ESD) damage to any of the electronic components, precautions beyond contamination control measures may be required. ESD safe mats, workstation will be used at workspace. Wrist straps will be used every time while handling the electronics. Additionally the temperature and humidity of the work environment will be controlled. ESD sensitive components will be identified and accordingly care will be taken while handling them.
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The following are some of the major ESD guidelines for ESD control.

- While entering ESD-protected areas, personnel will wear anti-static garments.
- Relative humidity in ESD protected areas shall be more than 30%.
- Non-essential static generating materials will not be kept in the ESD-protected areas.
- Static dissipative floor mats, and table mats having surface resistivity between 10^6 and 10^{12} ohms/square, shall be used in ESD protected areas.

- Personnel shall wear grounded ESD wrist straps, with approximately 1 M-ohm series resistance, while working with ESD sensitive devices.
- Resistance between the contact of AC-powered tools, such as strippers and soldering irons, with ESD sensitive parts and the third wire ground shall be less than 20 ohms.
- ESD ground point to earth path shall have very low resistance.
- Anti-static connector dust caps will be used on packages.
- While moving ESD sensitive items from one ESD-protected area to another area, metalized static shielding bags will be used.

TEST PHASE

Sub-system level testing:
Hardware(EEE):
On Sub-system level for systems involving electronic circuitry, following tests will be conducted.

Sl. no.	Description of test	Applicability to:		
		FM	PFM	QM
1	Initial functional test	Yes	Yes	Yes
2	ESD test	No	No	Yes
3	EMI/EMC test	No	No	Yes
4	Hot and cold soak	No[2]	One cycle, with 24 hr. dwell[2]	One cycle, with 24 hr. dwell[2]
5	Sine Vibration test	No	No	Yes
6	Random Vibration test	No	No	Yes
7	Mechanical shock	No	No	Yes
8	Thermovac cycling test	5 cycles with 2 hr. dwells	5 cycles with 2 hr. dwells[1]	5 cycles with 2 hr. dwells[1]

1. ESD test will not be done for FM/PFM as LEO orbits do not face problems due to Van-Allen belt, which is a major cause of ESD damage.
2. EMI test will be designed with due consultation of experts.
3. Vibration tests will be done only on System level for FM and PFM.
4. Thermovac tests will be designed as per MIL-STD-883B
5. Note 1. Thermovac testing for PFM OR QM may be skipped in case of lack of access to corresponding facilities. All other tests will be mandatory.
6. Note 2. Hot and cold soak chamber test will be designed as per impact on each sub-system. For system level, maximum of all of them will apply.
7. Burn-in and acceptance tests will be designed as per MIL-STD-883D.

Software:
As explained in the software section.

System Level Testing:

Following tests will be conducted to check the overall functioning of all sub-systems.

Sl. no.	Description of test	Applicability to:		
		FM	PFM	QM
1	Initial functional test	Yes	Yes	Yes
2	Hot and cold soak	No[2]	One cycle, with 24 hr. dwell[2]	One cycle, with 24 hr. dwell[2]
3	Sine Vibration test	No	No	Yes
4	Random Vibration test	No	No	Yes
5	Mechanical shock	No	No	Yes
6	EMI/EMC	No	No	Yes
7	Alignment Test	Yes	Yes	Yes

8	Mass Properties Testing	Yes	Yes	Yes, but not critically
9	Thermovac cycling test	5 cycles with 2 hr. dwells	5 cycles with 2 hr. dwells[1]	5 cycles with 2 hr. dwells[1]

On Board Computer In Loop Simulation (OILS)

Introduction

OILS (On-board computer In-Loop Simulation), as the name suggests is a setup for simulating the on-board computer with inputs similar to those that it may experience in the satellite. It is part of the second level testing and will help identify bugs and shortcomings of the hardware and software of the On-Board Computer. In short, the objective is as follows:

To setup an arrangement to do hardware in loop simulation of the onboard computer with the exact inputs and outputs it is supposed to receive in space, and thus verify its performance.

Approach

The problem consists of the following parts:

1. Hardware interfacing with the computer.
2. Generation of sensor data to be fed in as input to the OBC and verification of the response of the system against the expected response.

Implementation

The connectivity diagram of the Satellite is shown in the chapter on Wires and Connectors. The connectivity and block diagrams for OILS are as follows.

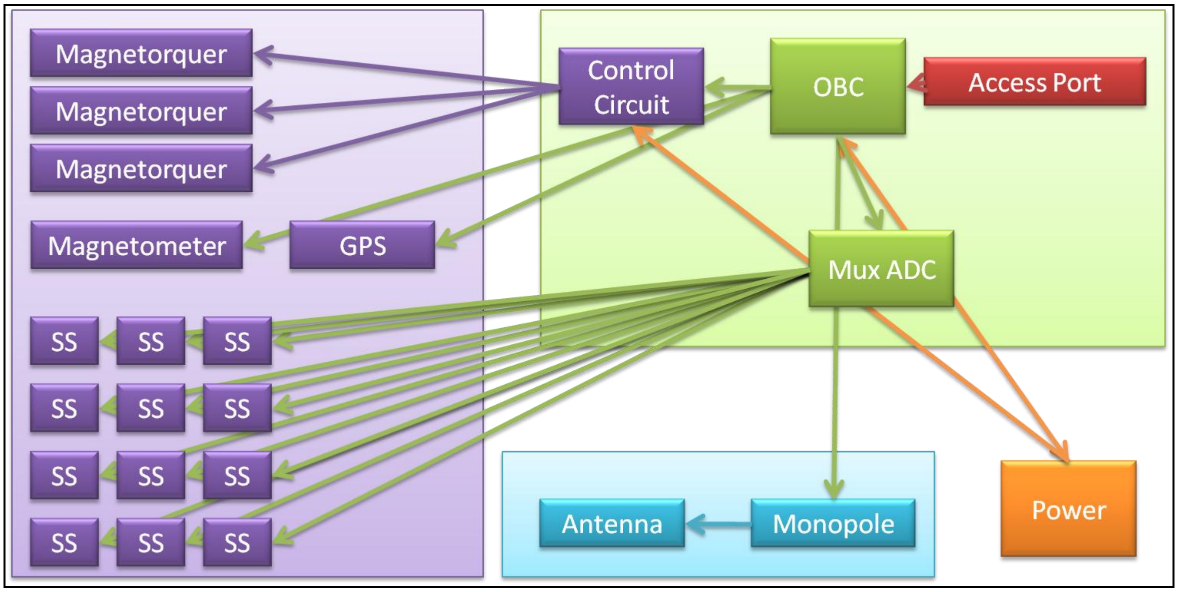

Figure 1: Connectivity Diagram for OILS

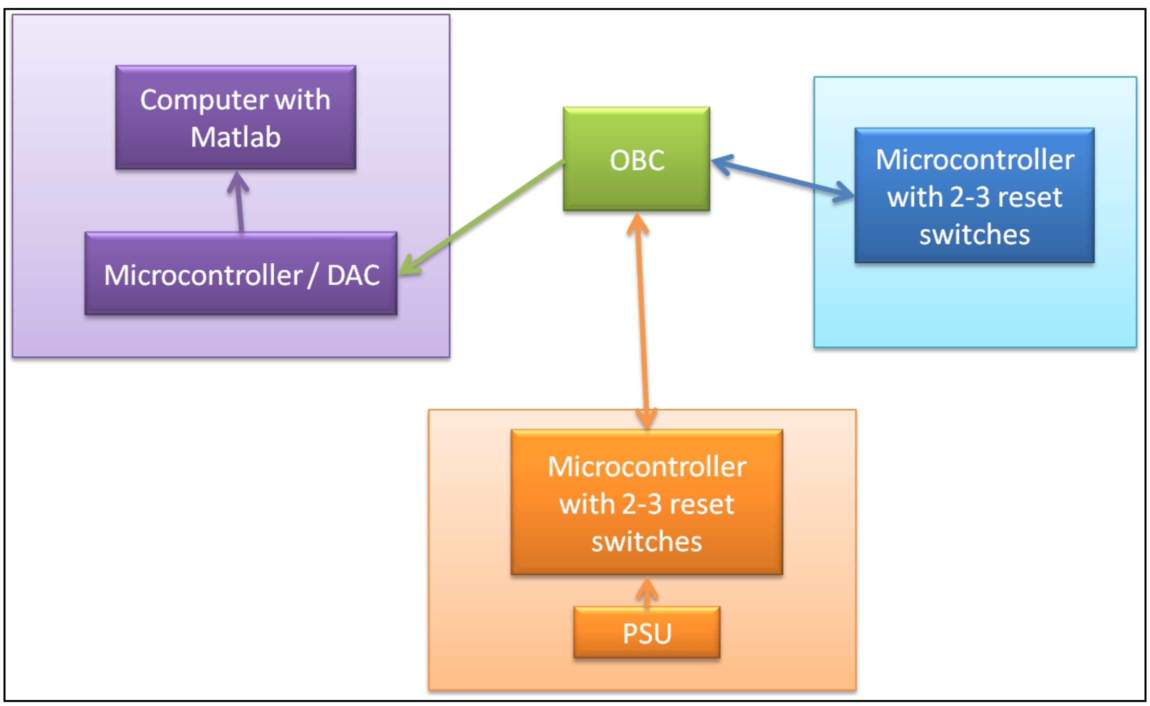

Figure: Block Diagram for OILS

As can be seen from the block diagrams, the following modifications were made for OILS:

1. The solar panels were replaced by a Power Supply Unit (PSU).
2. The control components (magnetometer, GPS, magneto-torquer and sun-sensors) were replaced by a computer with matlab and a microcontroller/DAC.
3. The power board has been replaced by a PIC microcontroller giving out a constant health monitoring message instead of sensor dependent health monitoring that the actual power board does.
4. The access port and the umbilical cord are not part of the OILS setup. However they may be added later.

RELIABILITY ALLOCATION & ANALYSIS

Reliability figures will be allocated to each sub-system. After a sub-system is designed, its reliability analysis will be done. If a sub-system overshoots its limit allocated by allocation, possibilities of adding redundancy to critical components will be considered. Reliability figures from datasheet(Example) will be preferred followed by empirical values from MIL-STD-217. Else values used by other satellites will be used. Reliability analysis of Power System is done and attached in Appendix 2.

Reliability prediction is based on the following general assumptions.

- Infant mortalities have been removed through screening.
- All parts are under the constant failure rate regime. The failure rates are computed based on MIL-HDBK-217F, notice 2.
- Components are in their useful life period and the wear out phase is not reached.
- Reliability of mechanical connections and mechanical parts is unity.

Following table is a rough set of values for reliability allocation. These values are determined from data available from other satellites, modified for Lifetime of Pratham.

Mission life of Pratham is 4 months. The spacecraft reliability targeted for this mission life is minimum 0.95.

Subsystem	**Apportioned reliability**
Payload	0.9990
Power	0.9920
Controls	0.9990
On Board Computer	0.9900
Thermal	0.9995
Structure and Mechanisms	1.0000
Integration	0.9990

ROLES AND RESPONSIBILITIES

The Systems Engineer, Integration Team and Quality Assurance Engineer will be responsible for ensuring that control measures are implemented throughout the design, fabrication, assembly, integration, testing, storage and transportation, and all other phases.

QUALITY AWARENESS AND TRAINING

All people handling flight model hardware will be made aware of quality standards.
Two to three lectures/presentations will be held from experts/professors about Quality assurance and various military standards, PCB design guidelines etc.

SOFTWARE

On Board Computer sub-system has a major role to play in implementing the control law as required by Controls sub-system. The four life cycle phases included in on-board software implementation are: requirement analysis, design, coding, and testing. The major aspects of on-board software assurance are

- Documentation
- Reviews
- Testing
- Code walkthroughs
- Configuration management and non-conformance control

Documentation The documents listed in the following table will be prepared by the software designers.

Table: Documentation for Software Quality Assurance

Sl. No.	Name of the document	Phase
1	Software requirement specifications document	Requirements phase
2	Software description document (To include all flowcharts)	Design phase
3	Code document (To include explanations of all functions)	Coding phase
4	Software test report	Test phase

Reviews Reviews of the work products will be conducted at the end of each of the four life cycle phases mentioned before using the in-house generated guidelines and checklists.

Testing : The primary issues that shall be addressed during testing are logic testing, computational algorithmic testing, input/output testing, interface testing, boundary value testing, and negative logic testing. During all the levels of testing care will be taken to ensure coverage, load testing, stress testing, regression testing, etc.

Code Walkthroughs: In Code Walkthroughs a designer or programmer leads members of the development team and other interested parties through a software product, and the participants ask questions and make comments about possible errors, violation of development standards, and other problems. An internally constituted committee or a competent external agency will conduct code walkthroughs to check compliance to recommended coding styles and standards.

APPENDICES:

1. CONTAMINATION SOURCES FOR SPACECRAFT

Possible sources of contamination must be identified in order to protect the spacecraft from contamination and to effectively clean contaminated components. Table 3-1 is a listing of possible contamination sources at the various development stages.

Table: Contamination Sources for Spacecraft

Mission Phase	**Molecular**	**Particulate**
Fabrication	materials outgassing, machining oils, fingerprints, air fallout	,shedding, flaking, metal chips, filings, air fallout, personnel
Assembly & Integration	Air fallout, outgassing, personnel, cleaning, solvents, soldering, lubricants, bagging material	air fallout, personnel, soldering, drilling, bagging material, shedding, flaking
Test	Air fallout, outgassing, personnel, test facilities, purges	air fallout, personnel, test facilities, purges, shedding, flaking, redistribution
Storage	Bagging material, outgassing, purges, containers	bagging material, purges, containers, shedding, flaking
Transport	Bagging material, outgassing, purges, containers	bagging material, purges, containers, vibration, shedding, flaking
Launch Site	Bagging material, air fallout, outgassing, personnel, purges	bagging material, air fallout, personnel, shedding, flaking, checkout activities, other payload activities
Launch/Ascent	outgassing, venting, engines, companion payloads separation maneuvers	vibration and/or redistribution, venting, shedding, flaking
On-Orbit	outgassing, UV interactions, atomic oxygen, propulsion systems	spacecraft cloud, micrometeoroid & debris impingement, material erosion, redistribution, shedding, flaking, operational events

2. Reliability Analysis of Power sub-system

Reliability analysis of Power system was done as a representative. Infant mortality rate and MTBF are calculated independently. Reliability values of standard components were taken from datasheets if mentioned. Else values form Military standard MIL-STD-217F were used. Failure of any one component implies failure of the system. In case redundant component is used, failure of both components implies failure of the system. For solar panels, failure of 2 or more panels was considered as failure.
Infant mortality rate was found to be 700ppm or 0.07%.
Reliability of the complete power system was calculated to be 0.9977

Reliability Analysis: Nominal Mode

Component	Base MTBF	Lambda	Infant Mortality	Corr. Factor	Environment Factor	Net Lambda	Net MTBF	Reliability
Unit	*10^6 hours	/10^6hours	Parts per million					
Diode Schottkey	250.00	0.00400	10	1.00	0.50	0.00200	500.00	0.99999
2 pin Connector(Power)	142.86	0.00700	0	1.50	0.50	0.00525	190.48	0.99998
2 pin Connector(data)	1000.00	0.00100	0	2.49	0.50	0.00125	801.95	1.00000
UCC3911, series 5 caps, 2res(lp), 30 pin soldering	278.00	0.00360	229	1.00	1.00	0.00360	278.00	0.99996
TPS203x, series 3 caps, 2res(lp), 20 solder joints	2080.00	0.00048	42	1.00	0.50	0.00024	4160.00	0.99997
PTH08080, series 2 tantalum caps, 2 res(lp)	48.00	0.02083	100	1.00	1.00	0.02083	48.00	0.99992
PTR08060, series 2 tantalum caps, 2 res(lp)	13.70	0.07299	100	1.00	1.00	0.07299	13.70	0.99976
Resistor(Low Current)	416.67	0.00240	0	0.14	0.50	0.00016	6127.45	0.99999
Resistor(High Current)	416.67	0.00240	0	0.46	0.50	0.00056	1795.98	0.99999
Tantalum Capacitor	2500.00	0.00040	0	3.30	0.50	0.00066	1515.15	1.00000
Ceramic Capacitor	1000.00	0.00100	0	4.30	0.50	0.00215	465.12	1.00000
PCB with PTH	90.91	0.01100	0	2183.51	0.50	12.00930	0.08	0.99997
Each soldering joint	14285.71	0.00007	100	1.00	0.50	0.00004	28571.43	1.00000
PIC16C77 series 7805, 5 caps, 50pin solder	300.00	0.00333	100	1.00	1.00	0.00333	300.00	0.99996
Sensors	1000.00	0.00100	10	1.00	1.00	0.00100	1000.00	1.00000
UA7805	737	0.00136	10	1.00	1.00	0.00136	737.00	1.00000
Battery	1.54	0.65000		1.00	1.00	0.65000	1.54	0.99806
Solar Panel	0.17	6.00000		1.00	1.00	6.00000	0.17	0.98221

Reliability from Panel + connectors+diode assuming 3of 4 must work	Reliability from Panel + connectors+diode	UCC series battery	UCC series battery one of two must work	pth series diode	pth series diode one of two must work
0.99814	0.98218	0.99798	1.00000	0.99991	1.00000

tps203x series two pin connector	6 tps in series	If redundant tps is used	PCB,uC,sensor in series	Net for circuit
0.99995	0.99970	1.00000	0.99991	0.99771

Conclusion: There is 0.24% probability that the circuit will fail before 4 months

Where the correction factor takes care of following considerations:
Power stress factor for resistors, Series resistance factor for capacitors and complexity factor for Printed circuit boards.
Numbers in red are not justified.

Reliability Analysis in Launch condition

Component	Base Factor	Base MTBF	Environment	Other	Corresponding	Lambda	MTBF	Reliability
			factor	Considerations	Factor			
Diode Schottkey	0.0040	250.00	33		1.00	0.1320	7.5758	0.999999
2 pin Connector(Power)	0.0070	142.86	36	No. of pins	1.50	0.3780	2.6455	0.999996
2 pin Connector(data)	0.0010	1000.00	36	No. of pins	2.49	0.0898	11.1382	0.999999
UCC3911	0.0036	278.00	50		1.00	0.1799	5.5600	0.999998
TPS203x	0.0005	2080.00	67		1.00	0.0322	31.0448	1.000000
PTH08080	0.0208	48.00	34		1.00	0.7083	1.4118	0.999993
PTR08060	0.0730	13.70	34		1.00	2.4818	0.4029	0.999975
Resistor(Low Current)	0.0024	416.67	87	Power dessipation^0.40, stress factor	0.14	0.0284	35.2152	1.000000
Resistor(High Current, sense)	0.0024	416.67	87	Power dessipation^0.40, stress factor	0.46	0.0969	10.3217	0.999999
Tantalum Capacitor	0.0004	2500.00	50	Series resistance factor, capacitance factor	3.30	0.0660	15.1515	0.999999
Ceramic Capacitor	0.0010	1000.00	50	Series resistance factor, capacitance factor	4.30	0.2150	4.6512	0.999998
PCB with PTH	0.0000	58823.53	27	Complexity, No. of pth to be hand soldered	2183.51	1.0022	0.9978	0.999990
Each soldering joint	0.0001	14285.71	50		1.00	0.0035	285.7143	1.000000
PIC16C77	0.0033	300.00	50		1.00	0.1667	6.0000	0.999998
Sensors	0.0010	1000.00	50		1.00	0.0500	20.0000	1.000000
UA7805	0.0013569	737	50		1.00	0.0678	14.7400	0.999999
Battery	0.6500	1.54	50		1.00	32.5000	0.0308	0.999676
Solar Panel	6.0000	0.17	50		1.00	300.0000	0.0033	0.997014
Reliability from Panel	Rel. Panel +	UCC series	UCC series battery	pth series diode	pth series diode	tps203x series	6 tps in	If redun-dant
+ connectors+diode	connectors	battery	one of two		one of two	two pin	series	tps is used
assuming 3of 4 must work	+ diode		must work		must work	connector		
0.99995	0.99701	0.99967	1.00000	0.99999	1.00000	1.00000	0.99998	1.00000
100 soldering	PCB,uC,	Net for circuit						
Joints	sensor in							

	series							
1.00000	0.99998	0.99990						

Conclusion: There is 0.01% probability that the circuit will fail while in launch

3. FMEA for main structure:

Failure Modes and Causes	Mission Phase / Operational Mode	Occurrence	Failure Effects: Local Effects	Failure Effects: Next Higher Effects	Failure Effects: End Effects	Compensating Provisions	Severity	RPN	Remarks
Resonance due to external excitation	Launch	1			Mission failure	Mass concentration is high => high stiffness and high damping	10	10	Not a big issue as occurrence is rare.
Fatigue	Launch	2				Short Launch time	10		
Fatigue	Nominal mode	1				Short design life	10	10	Not a big issue as occurrence is rare.
Thermal distortions	Nominal mode	6	Breaking of solar panels	Lack of power, control law ineffective	Lower mission life	TBD	8	48	Needs to be taken care, will not be a big issue as far as homogeneous materials are concerned.
Buckling	0	0					0	0	Does not matter in case on sheet structures and lack of compressive loading
Random Vibrations	Launch	Not Known	Structure disintegrates		Mission failure		10		
Harmonic Failure	Launch								

Reference:

FED-STD-209 Clean Room and Work Station Requirements, Controlled Environment

MIL-STD-883D Test Method Standard for Microcircuits

MIL-STD-217F Reliability data for EEE parts

MIL-STD- 1246 Product Cleanliness Levels and Contamination Control

Contamination Control Plan for Midshipman Space Technology Applications Research (MidSTAR)-1 Spacecraft

Quality Assurance Document of GSAT-6.