University of Colorado
Department of Aerospace Engineering Sciences
ASEN 4018

Project Definition Document (PDD)

FeatherCraft

Approvals

	Name	Affiliation	Approved	Date
Customer	Michael Brown	Surrey Satellite Technology-US	Michael Brown Digitally signed by Michael Brown DN: cn=Michael Brown, o, ou, email=michael_1_brown@yahoo.com, c=US Date: 2015.09.14 09:23:08 -06'00'	
Course Coordinator	James Nabity	CU/AES		

Project Customers

NAME: Michael Brown
ADDRESS: 345 Inverness Dr. S#100, Englewood, CO 20112
Phone: 720-255-0900
Email: MBrown@sst-us.com

Team Members

Larry Burkey 616-724-0121, larry.burkey@colorado.edu	Andrei Iskra 303-443-0588, andrei.iskra@colorado.edu
Jorge Cervantes 720-299-3854, jorge.cervantes@colorado.edu	Taylor Maurer 720-271-5607, taylor.maurer@colorado.edu
Evan Graser 224-622-4642, evan.graser@colorado.edu	Davis Peterson 303-523-0938, davis.peterson@colorado.edu
Lewis Gillis 970-210-1465, lewis.gillis@colorado.edu	Margaret Williams 720-300-7247, margaret.williams@colorado.edu
Megan Howard 303-842-0162, megan.m.howard@colorado.edu	

1.0 Problem or Need

The FeatherCraft project presented by Surrey Satellite Technology-US involves the design, assembly and testing of a lightweight satellite structure to serve as a platform for delivering payloads from the International Space Station (ISS) into low-earth orbit. The high demand for the deployment of economical small satellites, coupled with the rapidly expanding availability of cargo transportation to the ISS, creates an opportunity for the use of the ISS as a launch platform.

Satellites to be launched from the ISS will be transported to the Station onboard commercial cargo transportation vehicles and experience far lower launch loadings than traditional launch vehicles. Upon delivery to the ISS, satellites will be positioned into orbit by the planned NanoRacks Kaber satellite deployment system, onboard the Japanese Experiment Module.

The FeatherCraft structure is a new concept among other small satellites which takes advantage of the unique launch and deployment environment of the ISS by reducing structural weight to provide greater payload mass at a lower cost to the customer[5]. No other satellite structures currently on the market use this environment to their advantage.

The purpose of this project is to design, manufacture, and test a structure for small, ISS launched satellites. The FeatherCraft project will build a structural test model (STM) of the design, design and implement an instrumentation system for vibration tests, and develop a software package that will record and analyze data from the instrumentation system.

A successful FeatherCraft design will provide a 5kg structural platform for 100kg total mass small satellites with a rectangular form factor that will fit within a 19”x30”x30” volume (sized to the internal bay of the Kaber deployment system)[6]. The internal volume of the structure shall be divided into two bays of equal size: a payload bay and an avionics bay.

Three exterior faces shall interface with customer-defined solar panels, one face will be an open aperture to accommodate payload instruments, and one face will act as a radiator for customer-designed avionics. One face of the STM must be able to interface with a third party propulsion plate. The STM shall accommodate multiple payload configurations and survive the combined launch loads experienced by a cargo launch vehicle: as demonstrated by 1.29 GRMS, 3-axis, random vibration test of the combined structure and mass dummies.

A successful FeatherCraft structure will represent 5% of the overall mass of the satellite, reduce Surrey Satellite Technology-US’ standard manufacturing process by greater than 50%, and accommodate a variety of payload and avionics configurations within their respective bays. The benefits of a successful FeatherCraft structure are its ease of construction and low mass, which will improve the small-satellite market and advance the industry of station-launched satellites.

2.0 Previous Work

Initial concept designs for the FeatherCraft structure were developed by Surrey Satellite Technology -US in collaboration with Aerojet Rocketdyne, Inc. and NanoRacks LLC[6]. The FeatherCraft platform is slated to launch from the Kaber launch service (developed by NanoRacks LLC)[1], which is the next step in the progression from the currently available NanoRacks CubeSat Deployer, launched on January 9, 2014 and has since launched several CubeSats for various science missions[4]. The Kaber table can accommodate much larger satellites than the current deployment system[2]. This greatly increases the variety of missions which can be performed from the ISS.

The largest challenge facing the team is the mass requirement for our structure. With a mass limit of 5kg, the structure represents only 5% of the total mass of the 100kg satellite. A team from Los Alamos National Laboratory and Composite Optics Inc. was successful in achieving a 33% mass savings by using flat stock panels of graphite/epoxy composite material over a more traditional aluminum alloy when designing the FORTE satellite[3].

3.0 Specific Objectives

Levels of success were developed to define the meaning of success for the FeatherCraft team. Although the team will design to the highest level (level 3) of success, if there are unforeseen challenges achieving aspects of level 1 or level 2 still delivers a successful final product. Level 1 represents the achievement of the base requirements determined by Surrey Satellite Technology –US. Level 3 represents fulfilling those base requirements in a way which is most convenient for the user.

Table 3.1: Levels of Success

	Structure:	**Vibration Testing:**	**Accelerometers:**	**Data Acquisition System:**	**Software:**
Level 1	Less than or equal to 5 kg Structural Test Model (STM) fits into ISS Kaber volume (30"x19"x30") Partitioned for an avionics bay and payload bay. Supports a total 100kg satellite through operating conditions and vibration testing.	STM maintains structural integrity in a 1.29grms ± 10% (per GSFC-STD-7000A) 3-axis random vibration test	Capability of supporting a suite of TBD tri-axial and TBD axial accelerometers (5kHz, ± 5g range, and TBD g resolution). Test TBD points on the structure to validate FEM analysis	Able to measure data from accelerometer suite for up to 1 hour. USB transferable Real time plotting of g loading	Software organizes and stores data into CSV file(s), where the user then manually imports into MS Excel which converts data to PSD form
Level 2	>50 % reduction to Surrey Satellite Technology-US's conventional manufacturing process (exact time/cost metric TBD)	STM has vibration modes above a TBD Hz	-	-	Software imports raw data, outputs MS Excel compatible post-processed data package
Level 3	-	-	Perform vibration test with full suite of accelerometers	Real time plotting of power spectral density (PSD)	GUI developed to allow user control over analysis settings

4.0 Functional Requirements

Due to of the restricting dimensions required by the Kaber deployment system, the structure shall be a rectangular shape not to exceed the maximum envelope of 30"x19"x30". On three on the faces (in the TBD direction), the structure must allow mounting of solar panels. On the nadir-pointing side, the structure shall allow payload and antenna mounting and no obstruction to these elements. On one of the sides facing deep space, thermal dissipation must occur with a heat dissipation system TBD. Finally, on the TBD side, a propulsion plate shall be mounted. After all these elements are integrated, the structure must withstand a 1.29 grms (with an added factor of safety TBD) vibration test from frequencies between 50 and 2000 Hz with a realistic mass load within the structure. Finally, the structure shall be bubble-wrapped upon testing and prior to integration with the resupply vessel, so the designed structure must support this wrapping.

These elements are integrated into the FeatherCraft structure shown below and tested with a data acquisition system of our own design. This system is show in Figure 4.1.

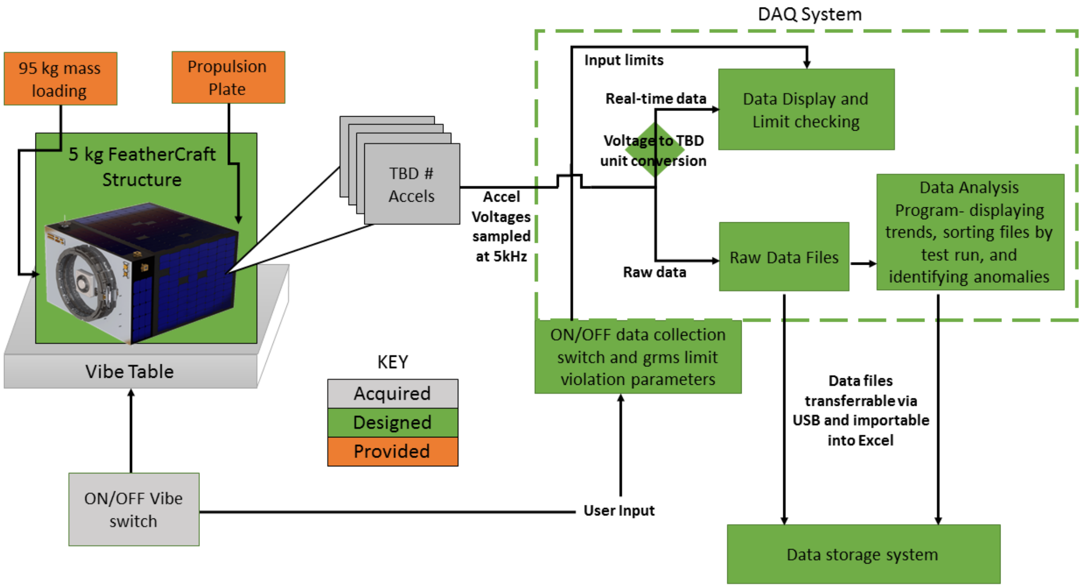

Figure 4.1: Function Block Diagram of Test Instrumentation

The design, fabrication, and testing aspect of the project all contribute to the final implementation of the FeatherCraft system on an ISS-deployable mission. The trade studies performed for the structure will influence the final structure design and perform the mission outlined in the ConOps diagram in Figure 4.2.

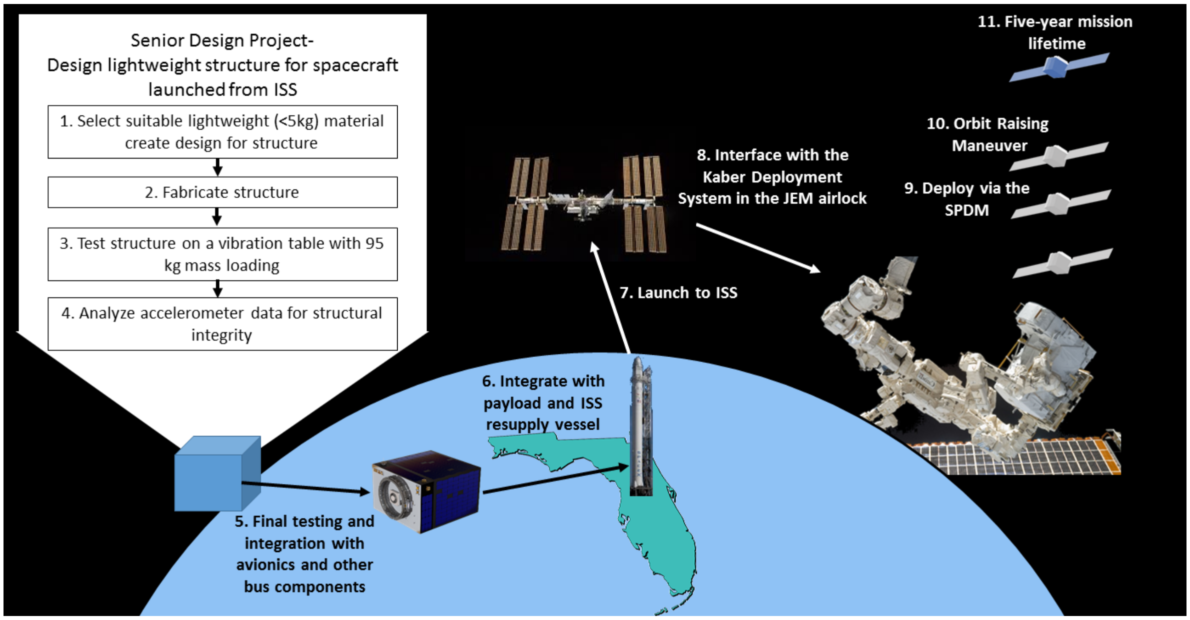

Figure 4.2: ConOps diagram for FeatherCraft Structure

5.0 Critical Project Elements

5.1 Maintaining rigidity with 5 kg structural mass

The structure shall experience no permanent deformation during random and frequency sweep vibration testing, as defined by TBD vibration test plan based on customer ICD and NASA standards. This will be performed while the 5 kg or less structure supports the 100 kg FeatherCraft satellite. This critical design requirement poses challenging and innovative means in material selection, mass reduction design, and structural analysis.

5.2 > 50% reduction to the Surrey Satellite Technology-US's structure manufacturing process

The FeatherCraft structure shall assemble quickly and easily without a large part count. For complete success the design will have reduced the conventional manufacturing process time and cost by more than 50%. This critical design requirement poses difficulties in machining tolerances, alternative bonding techniques such as adhesives or welding, and an understanding of standard manufacturing practices.

5.3 Vibration table and test space acquisition

A vibration table and suitable space for vibration testing will be required to validate the structure and vibration sensor suite. The TBD vibration test plan requires a vibration test of the structure loaded to 100 kg at high frequencies. A vibration table capable of such a test may require expensive outsourcing. This will pose a challenge to the budget and schedule with preliminary cost estimates of one fifth the project budget.

5.4 Accelerometer count and associated hardware

The data acquisition system shall provide the capability of operating a sufficient number of accelerometers to validate the structure and FEM analysis under TBD vibration test plan defined frequency sweep and random vibration testing. Preliminary estimates indicate approximately TBD accelerometers and their associated hardware will be needed. Determining the exact number and quality will require critical vibrations testing and structural analysis knowledge. Also, the number of accelerometers and their quality will greatly affect the cost to the team.

6.0 Team Skills and Interests

Table 6.1: Team Member Skills and Critical Elements

Critical Project Elements:	Skills Necessary:	Team Members:
Maintaining Rigidity with 5 kg Structural Mass	• SolidWorks and FEM Modeling • Material Knowledge	Lewis Gillis, Evan Graser, Megan Howard, Davis Peterson, Andrei Iskra
> 50% Reduction to the Conventional Structure Manufacturing Process	• Manufacturing and bonding knowledge • CAD/CAM experience	Lewis Gillis, Megan Howard, Andrei Iskra,
Vibration Table and Test Space Acquisition	• Testing knowledge • Financial Planning	Maggie Williams, Taylor Maurer, Evan Graser, Larry Burkey, Davis Peterson
Accelerometer Count and Associated Hardware	• Sensor calibration knowledge • Signal Processing Knowledge	Evan Graser, Larry Burkey, Jorge Cervantes, Taylor Maurer, Maggie Williams

7.0 Resources

Table 7.1: Critical Project Elements and Resources

Critical Project Elements:	Resource:	Source:
Maintaining Rigidity with 5 kg Structural Mass	• Material database / knowledge • Computer modeling	• Matt Rhode, Bobby Hodgkinson, Kurt Maute, Mahmoud Hussein • SolidWorks • ANSYS Workbench • OnlineMetals.com
> 50% Reduction to the Conventional Structure Manufacturing Process	• Machine shop • Composites Lab • Computer modeling	• Aerospace/ITLL Shop • Aerospace Composites Lab • SolidWorks
Vibration Table and Test Space Acquisition	• Funding for Vibration Table • Student Discounts • Table Rentals	• Trudy Schwartz • Surrey Sattelite Technology • CascadeTek
Accelerometer Count and Associated Hardware	• Funding for Sensor Hardware • Student Discounts	• Trudy Schwartz • Digi-Key Electronics • Mouser Electronics

8.0 References

[1] "Kaber Small Satellite Deployment System." *Nano Racks ISS Workshop*. < http://nanoracks.com/wp-content/uploads/Kaber-Small-Satellite-Deployment-System-Presentation.pdf> N.p., 17 Feb. 2015. Web. 30 Aug. 2015.

[2] Foust, Jeff. "Companies Offer Larger Satellite System For ISS Deployment - SpaceNews.com." *SpaceNews.com*. N.p., 08 Apr. 2015. Web. 30 Aug. 2015.

[3] Grastataro, C.I. et al. "Development of a Composite Satellite Structure for FORTE." United States: N. p., 1995. Web. 2 Sep 2015.

[4] "NanoRacks Successfully Deploys After On-Orbit Repairs." *NanoRacks*. N.p., 27 Feb. 2015. Web. 30 Aug. 2015.

[5] "Surrey Satellite, NanoRacks to Make Possible Larger Satellite Deployment from the ISS." *Space Digest*. N.p., 9 Apr. 2015. Web. 30 Aug. 2015.

[6] Thorpe, Carol. "Surrey Satellite US Joins Aerojet Rocketdyne and NanoRacks for FeatherCraft Development." *NanoRacks*. N.p., 8 Apr. 2015. Web. 30 Aug. 2015.