Emerald Structures and Mechanisms

Design Document, Spring Quarter, 1999. Submitted June 8th, 1999

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1. Overview

The Emerald Structures and Mechanisms team is responsible for the design, buildup, integration, and test of the structure and associated hardware that will support all systems during launch and on orbit operation. In addition, the team is responsible for all spacecraft mechanisms including: the launch vehicle interface, satellite separation system, drag panel mechanisms, and any other deployables such as antennas, solar panels, and booms. The team will deliver a mass budget, CAD drawings, and a FEA of the structure. We will manufacture (or vend out) all spacecraft structures and mechanisms, integrate them, and then perform environmental testing of the spacecraft.

The purpose of this document is two-fold. It is a compilation of the Emerald design achieved by the end of Spring Quarter 1999. Second, it is intended as a “must read” for new members of the structures and mechanisms team. The information contained here should fully brief a new member on the work already performed, the rational for all major design decisions, and the issues that are critical to each system.

2. Team Members/Responsibilities

Name			Phone number		
First	**Last**	**E-mail Address**	**Home**	**Work**	
Stanford:					
Leland	Cheung	blcheung@Stanford.Edu	497-6653		
Eric	Scholten	eric.scholten@stanford.edu	497-2967		
Justin	Bowen	justin.bowen@Lmco.Com	408-270-7046	408-743-0539	742-2540
Campbell	Dinsmore	soup@leland.stanford.edu	367-6028	800-577-6525 ext.2075	408-995-7366
Andy	Noble	andrew.noble@Stanford.Edu	497-2131		
Stephanie	Sours	shayes@leland.Stanford.EDU	497-9925		
Jin	Kang	sjk@leland.Stanford.EDU	328-4010		
Wade	Henning	whenning@Leland.Stanford.edu	497-7041		
Sean	Dougherty	dougherty@stanford.edu	938-6783		
Santa Clara:					
Scott	Crumrine	scrumrine@mailer.scu.edu			
Josh	Heppner	jheppner@mailer.scu.edu			

SubGroups:						
Launch Vehicle Interface:	Justin	Eric	Jin			
Satellite Separation System:	Justin	Eric	Wade	Sean		
Separation Anaylisys:	Justin	Campbell				
Drag Panels:	Wade	Andy	Sean	Scott	Josh	
CAD:	Justin	Andy	Jin	Leland	Eric	(Campbell and Stephanie)
Machining:	Leland	Jin	Justin	Eric	Sean	(others as needed)
Structures:	Jin	Andy	Leland	Stephanie	Campbell	
FEA:	Wade	Campbell	Santa Clara			
Weight/Volume Budgets:	Jin	Stephanie				
Integration/Box design:	Sean	Wade				
Testing:	Stephanie					
VLF/Antennas:	Wade	Campbell				
Elecrical Interfaces:	Campbell	Stephanie				

3. Objectives

Overall

The overall objective of the Structures and Mechanisms team is to support the Emerald project by providing all structures and mechanisms necessary to accomplish the mission. Due to schedule and budget constraints we must provide simple yet elegant design solutions to the challenges imposed by the mission requirements. The Structures and Mechanisms team's goals include:

- Provide structural support to all subsystems throughout the mission life.
- Provide simple and effective mechanisms for executing all mission requirements
- Build two flight structures and two engineering mockups for the lowest possible cost
- Develop easy to use structural interfaces facilitating integration, testing, and subsystem development
- Make everyone's life hell by limiting their mass budget to an unreasonably low number
- K.I.S.S. yet deliver new and innovative designs
- Deliver all hardware on or ahead of schedule
- Sleep more, have fun, see the world, save money, lose weight, workout….

Launch Vehicle Interface

The launch vehicle interface must provide a means of attaching the Emerald spacecraft to the launch vehicle. The launch vehicle interface must also allow the satellites to be separated from the launch vehicle once in orbit. It must be capable of withstanding all launch loads and meet all requirements imposed by the launch vehicle for safety and reliability. In addition, it is desired to have a launch vehicle interface that uses the least possible surface area on the bottom of the spacecraft. This will allow for the mounting of solar panels and other hardware required by Emerald.

Structures and Layout

The objective of the structures and layout group is to provide structural support to all of the subsystems while attempting to design a user friendly interface that will facilitate integration, testing and subsystem development. The structural issues faced by Opal and Sapphire are complicated by the fact that each Emerald satellite is larger than either Opal or Sapphire and we must support one S/C on top of the other during launch. Other challenges include meeting the project milestones for the rapid development pace of Emerald, for example, to complete mass model vibration testing this August.

Inter-satellite separation Interface

Similar to the launch vehicle interface, the satellite separation system must provide a means of attaching the two spacecraft and, once on orbit, separating them. It must be capable of withstanding all launch loads and meet all requirements imposed by the launch vehicle for safety and reliability. In addition, it is desired to have a separation system that uses the least possible surface area on the bottom of the spacecraft. This will allow for the mounting of solar panels and other hardware required by Emerald.

Drag Panels

The drag panels must provide a means of changing the ballistic coefficient of each of the spacecraft in a predictable manner. The use of such mechanisms in space applications can be complicated and unreliable. For this reason, this system will be designed to be as simple as possible, while at the same time, providing the highest possible reliability given our schedule and budget constraints.

Very low frequency Antenna

A VLF antenna of three to five meters will be deployed on each spacecraft. The main objective in this design is to deploy these antennas in a predictable manner and without causing damage to the exterior of the spacecraft. These Antennas must be packaged in an intelligent manner in order to provide a proper deployment, while at the same time, taking up the minimal amount of space and mass.

Communications Antennas

Although smaller than the VLF antennas, the Communications antennas may require stowage and deployment as well. Again, the goal is to deploy these antennas in a manner which minimizes risk to the mission while taking up the minimal amount of space and mass.

Integration Jig

To facilitate integration and testing, the Structures and Mechanisms team would like to build a jig that will hold the spacecraft. The jig will allow the spacecraft to be rotated in any axis providing easy access to all sides of it.

Sensors and Electrical Systems

The sensors and electrical group is responsible for the electrical interfaces to all of the mechanisms on the spacecraft. We are responsible for command of the drag panels and the activation of the separation system and other one-time deployables such as antennas. We are also responsible for choosing what is important to monitor with sensors and designing the appropriate sensors.

4. Requirements

Requirements imposed on Structures & Mechanisms by other systems:

- **High level**
  1. Provide structural support for all systems during launch
  2. Provide structural support for all systems on orbit
  3. Provide a launch vehicle interface that meets STS requirements (safety, redundancy etc.)
  4. Provide adequate radiation shielding to all systems
  5. Separation from launch vehicle
  6. Satellite to Satellite separation
  7. Deployment of VLF antenna
  8. Actuation of drag panels throughout mission life
  9. Modular/Serviceable structure
  10. Provide adequate volume, mass, and surface area for all systems

- **Launch Vehicle Interface**
  These requirements will be further defined once final selection of the launch vehicle has taken place. However, EMERALD is being designed to the following preliminary launch vehicle requirements:
  1. Vibration: 15 g's all axes.
  2. STS Small Payloads integration requirements (see NSTS 07700 Volume XIV).

- **Inter-satellite Separation System**
  1. Two Emerald satellites must be separated.
  2. Tip-off rates should be minimal to aid in early stabilization of each spacecraft.

- **Drag Panels**
  1. 2 Panels located on sides 3 and 5 (numbering clockwise from front panel)
  2. Provide space for solar cells on outer and inner surfaces of panels, and on surface of spacecraft behind panels (panels must be stiff enough not to "pop off" solar cells during launch loads.
  3. Drag panels must be actively controlled.
  4. No structure within 90° cone of colloid thrusters.
  5. Sensors must detect and confirm drag panel deployment.
  6. Clear path for actuator lanyards through middle tray.
  7. Hold-down latch.
  8. Support for panel hinges.
  9. Mass = TBD.
  10. Volume = TBD
  11. Motor and spool location; middle tray.

- **Antenna deployments**
  1. Stow antennas in a safe configuration for launch
  2. Deploy antennas as necessary

- **Structures and Layout**
  1. The mass of each Emerald satellite shall not exceed 15 kg
  2. The center of gravity of each satellite shall be within the limits specified by the launch vehicle (Shuttle) requirements. The exact numbers are not currently known, it is currently assumed that 10 inches off of the launch interface is the target.
  3. The satellites shall fit within the required static and dynamic envelopes (also not exactly known). The dynamic envelope for the width of the satellites is believed to be a 18 inch diameter cylinder of unknown height.
  4. The satellite layout shall allow for the easy assembly and disassembly of the satellite, with the anticipation that this will be done many times.

5. The wiring layout will insure that connections are oriented so that all wires travel in the same direction to allow for bundling and ease of layout.

- **Sensors and Electrical Systems**
  1. Standard data and power interfaces

Requirements imposed on other systems by Structures and Mechanisms:

- **High level**
  1. Volume, mass, and surface area constraints
  2. Attitude for separation?
  3. Commanding of all mechanisms
  4. TM for all mechanisms
  5. Power for all mechanisms

- **Launch Vehicle Interface**

- **Inter-satellite Separation System**

- **Drag Panels**

- **Antenna deployments**

- **Structures and Layout**
  1. Each subsystem shall have a mass less than or equal to the mass allotted them in the mass budget.
  2. Each subsystem shall have a volume less than or equal to the volume allotted them in the volume budget.
  3. Only those systems requiring an individual box shall have one. All others will be grouped together by subsystem as much as possible.
  4. External wiring connections shall be placed in such a way as to allow for ease of layout and wiring integration.

- **Sensors and Electrical Systems**
  1. Data Requirements: Deployments – 1000 bits/sec, Drag Panel Ops. – 500 bits/sec, Normal Ops. – 2 bits/sec.
  2. Power Requirements: Deployments – 1 W, Drag Panel Ops. – 4.5 W, Normal Ops. - .5 W

5. Mass Budget

Subsystem	Vol (in^3)	Mass (kg)
Comm	63	0.9
GPS	24	0.5
Power	282	1.5
ADC	48	1
CDH	64	1
VLF	40	0.3
Thrusters (1 satell	256	1
MERIT (1 satellit	84	0.65
Structure	400	5
Intersat Sep Syster	12	1
Drag Panel	100	1
Unaccounted	200	2
Total	**1489**	**15.2**
Total Available	2245	15
Margin	756	-0.2
	33.67%	-1.33%

The current mass budget highlights one of Emerald's biggest constraints, the mass budget. We are over budget by our current rough estimate. There is no Margin available. From experience, we know OPAL used over a kilogram of RTV sealant in final integration, exceeding its mass budget. It is therefore important that all subsystems work hard to reduce the mass estimates of their systems. Note that many smaller features have not been enumerated here, and are therefore lumped into the category "unaccounted", which is separate from Margin. Margin is for emergency use, or the failure of systems to meet their targets. "Unaccounted" items are things like harness cabling, antennas, a matching array, fasteners, tape, RTV, etc..

6. Trade Studies

♦ **Separation System Restraint and Release Mechanisms**

One of first mechanisms that the structures and mechanisms team concerned itself with was the inter-satellite separation system. The typical Marmon clamp, V-band spring separation systems were ruled out for the inter-satellite separation system early in the trade because of high costs and significant weight and volume penalties (however, the satellite/launch vehicle separation system is baselined as the typical Marmon clamp/spring configuration).

Several restraint and release mechanisms were considered for various separation system configurations. The table below presents the release mechanism trade. Paraffin, pyro, nitinol (shape memory alloy), and motor actuated devices were considered. The weighting factors listed in the first row of the trade table can be interpreted as follows: 5 = very important, 4 = important, and 3 = neutral. These weights are based on the reality that EMERALD is student project. Therefore cost is a major factor, whereas mechanical redundancy is less important. The actuators were rated in each category (Weight through Simultaneous Actuation) on the following scale: 5 = superior, 4 = good, 3 = average, 2 = poor, 1 = very poor. The score column lists the sum of each mechanism's ratings multiplied by the appropriate weighting factors. Pyro actuated mechanisms scored poorly in the "safety" and "refurbishable" categories, whereas nitinol activated mechanisms scored poorly in the "Mech. Redundancy", "Speed", and "Simultaneous Activation" categories. The winning mechanisms were of the shape memory alloy and fuse wire separation nut variety. The final mechanism choice is the Starsys Qwknut, a student resetable, shape memory alloy activated separation nut (see the Inter-satellite Separation System section below).

Separation System:

Weighting Factor	5	5	3	3	5	4	4	4	4	3		
Name	Weight	Cost	Mech. Redundancy	Flight History	Refurbishable	Power	Size	Safety	Speed	Simultaneous	Score	Notes
Paraffin Actuated												
Pinpuller	3	4	1	5	5	4	4	5	1	1	137	
Actuator pin (trigger system).	3	4	1	5	5	4	4	5	1	1	137	
Pyro Actuated												
Cable Cutters	3	2	5	5	1	5	2	2	5	5	131	
Bolt Cutters	3	2	5	5	1	5	2	2	5	5	131	
Pinpuller	3	2	1	5	1	5	2	2	4	1	103	
Sep Nut	3	3	1	5	1	5	4	1	5	5	128	
Bolts	3	1	1	5	1	5	3	1	5	5	114	
Nitinol Actuated												
Split Nut/Collar	3	1	1	1	3	5	4	5	1	1	104	
Frangibolt	5	3	1	5	5	5	5	5	1	1	150	
Pinpuller	5	3	1	5	3	5	4	5	1	1	136	
Fuse Wire Sep Nuts (Starsys, NEA)	4	5	1	3	2	4	5	5	5	5	158	
NEA V-Band Clamp	1	3	1	3	3	4	1	3	4	5	110	
Motors	3	2	1	3	3	2	2	5	4	2	110	

♦ **Drag Panel Designs**

Several drag panel system designs were evaluated in the table below. The weighting and scoring system for the trade is similar to that shown in the Separation System Release and Restraint Mechanism trade above. The poorest scoring designs here included lead screw and two-way pin-puller systems. These scored poorest in the weight, volume, and cost categories. The Stepper Motor/Lanyard/Spool System scored well because of its relatively low cost (we can convert a COTS stepper into flight hardware fairly easily) and its design flexibility. The simplicity and manufacturability of the Stepper/Lanyard/Spool System was also very desirable.

Drag Panels:

System Type	Weight	Cost	Complexity	Reliability of Components (Mech.)	Flight History (Components)	Failure Modes Rating of System	Power	Volume	Accuracy in Flight (only need open/closed)	Flexibility in Design Placement	Manufacturability (students at Stanford)	**Score**	Notes
Weighting Factor	5	5	5	5	3	5	4	4	2	5	5		
Drag Panel Actuation Systems:													
Stepper/Linkage System	2	4	4	4	4	4	3	3	5	2	4	166	
Stepper/Lanyard/Spool System (Kevlar)	3	5	4	3	3	3	3	4	3	5	5	183	
Motor/Lead Screw System	2	2	3	4	4	4	3	3	5	2	4	151	
Two-way Pinpuller system	2	1	4	4	3	4	3	3	4	3	4	151	
Solenoid/Linkage Actuated System	4	2	3	4	4	4	4	4	4	5	4	182	
Hinges:													
Stanley Tape Measure	5	5	5	4	2	4	-	5	-	5	5	191	
Torsional Spring Hinges	3	3	4	4	5	4	-	4	-	5	3	161	

7. Detailed Design

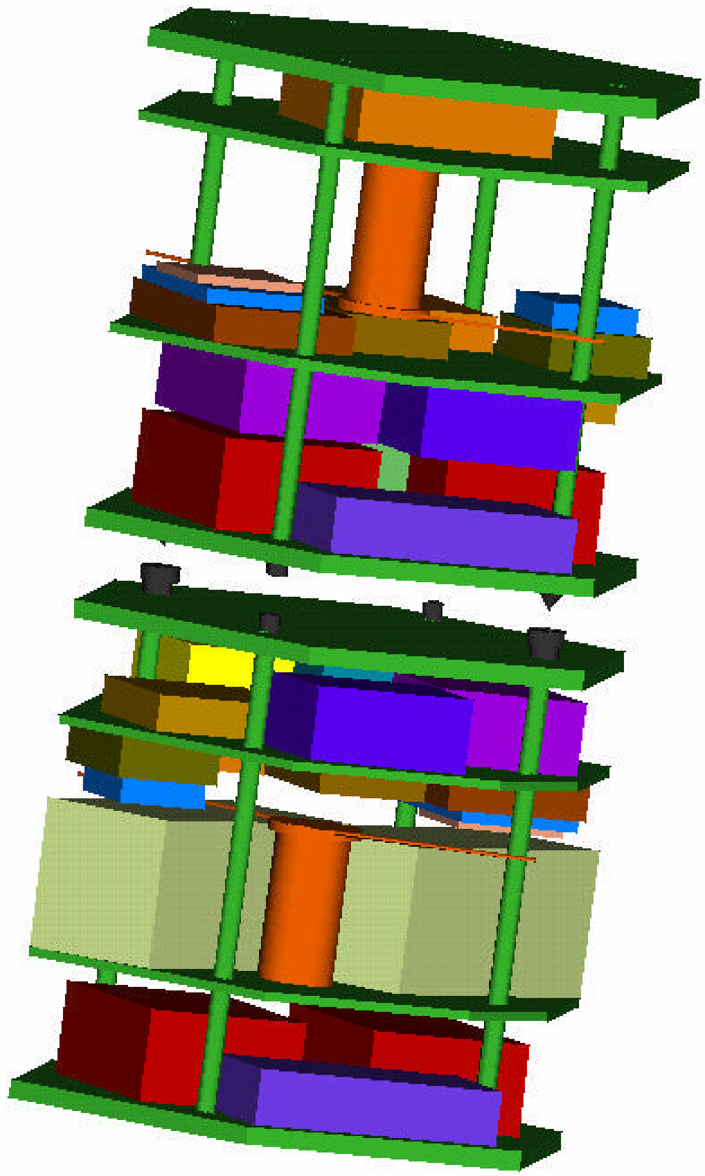
7.1 Launch Vehicle Interface

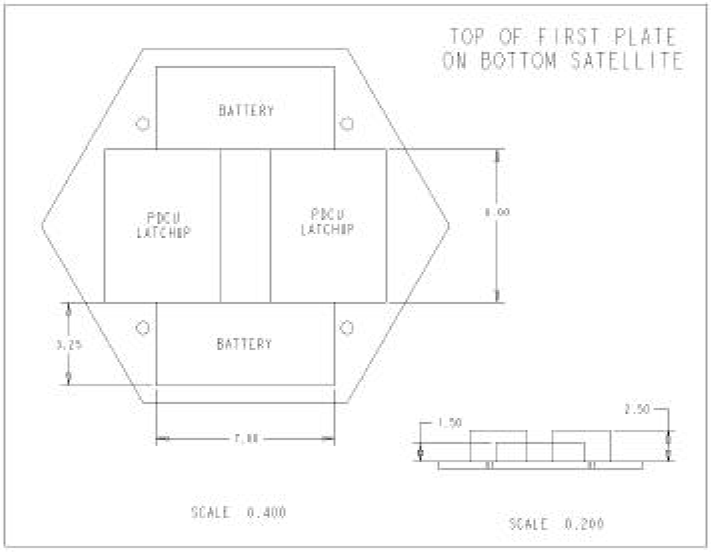
Emerald will be launched from the payload bay of the Space Shuttle from a SHELS (Hitchhiker Program) adapter pallet. Our interface to the shuttle is slated to be a Marmon Clamp/V-band system, a standard commonly used for STS small payloads, which should give us few problems meeting shuttle interface requirements. A Marmon clamp system utilizes a split “V” band that is tightened around clamps to hold two mating rings together. As more detailed requirements are made available, the launch vehicle interface design will evolve.

The Emerald launch interface adapter ring will cover most of the bottom face of the lower Emerald vehicle, and will thus leave little or no surface area for solar cells. Similarly, the bottom surface of the top Emerald vehicle will retain the separation bolt and springs of the inter-satellite separation system, thus leaving little area for solar cells.

7.2 Structures and Layout

All trays and panels are made of aluminum honeycomb. The top and the bottom plates are one half inch thick and the rest of the structure is a quarter inch thick. The structure is held together using four threaded rods with standoffs for separating the plates as shown below. There is a requirement to keep the center of gravity near the launch interface to reduce bending moments during launch. Most systems for the top satellite were therefore kept towards the bottom to aid in this requirement. The batteries and power systems were located at the bottom tray of each satellite to further aid in this requirement. Separation system designs may require that the power conditioning unit be split in two halves or mounted off center. Also shown below are the layouts of each component for both the top and the bottom satellites. A corner of each internal tray was notched to allow for ease of cabling. Each electronic component was placed on its side rather than its edge to ensure a secure attachment to the tray. It is expected that each component box will be mounted on rails for ease of installation and removal during testing and integration.





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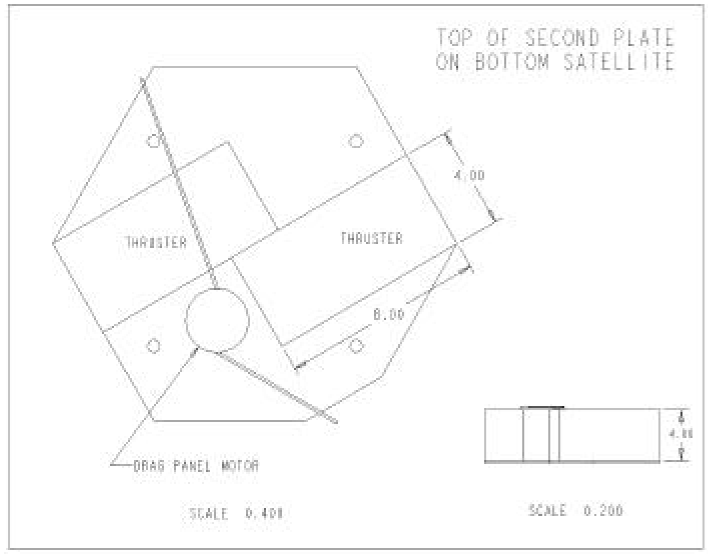

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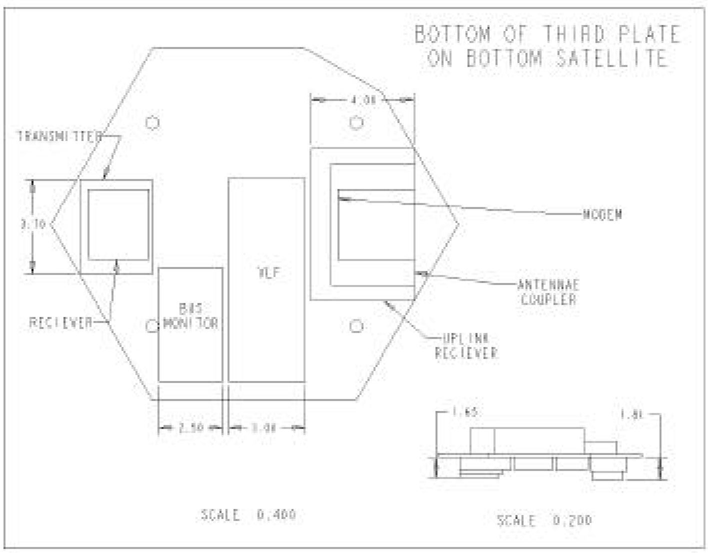

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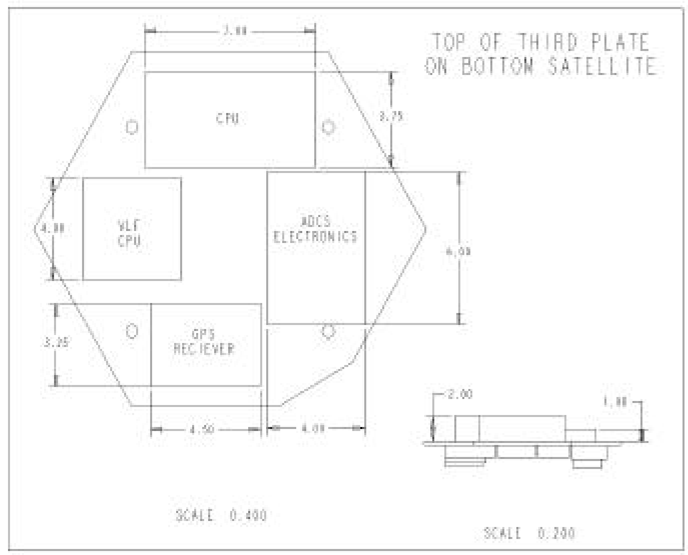

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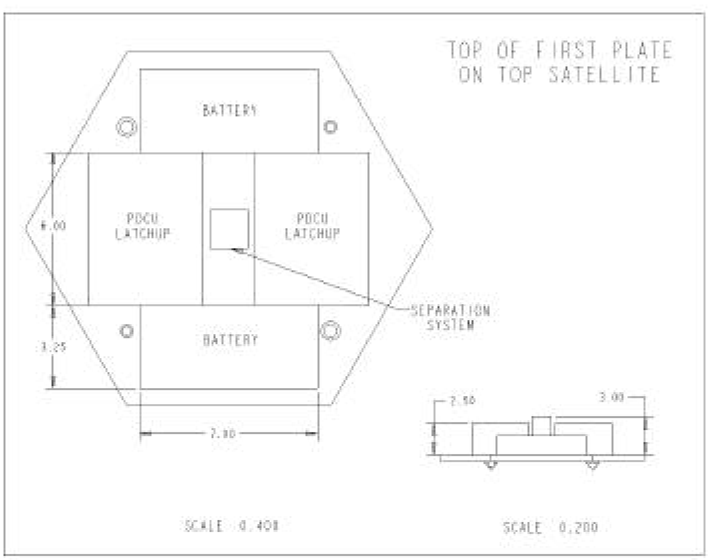

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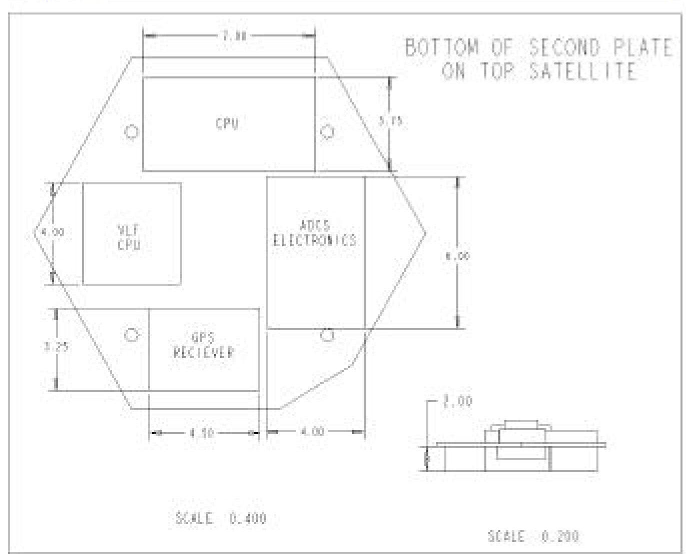

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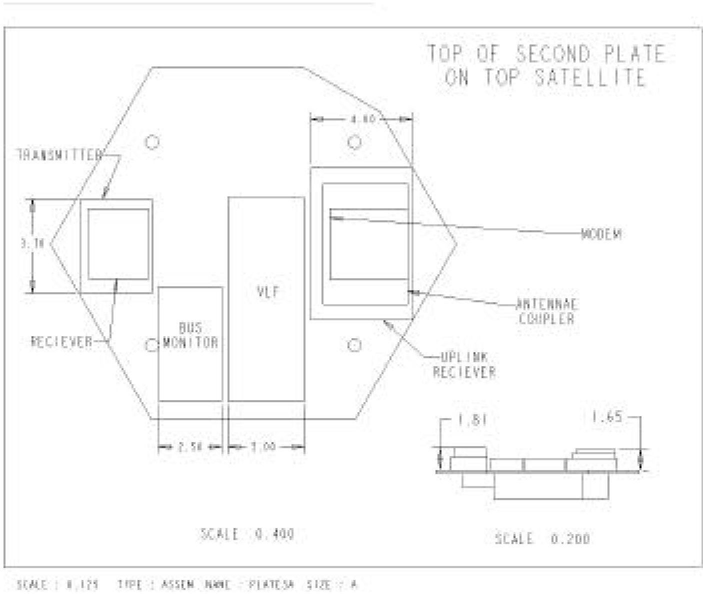
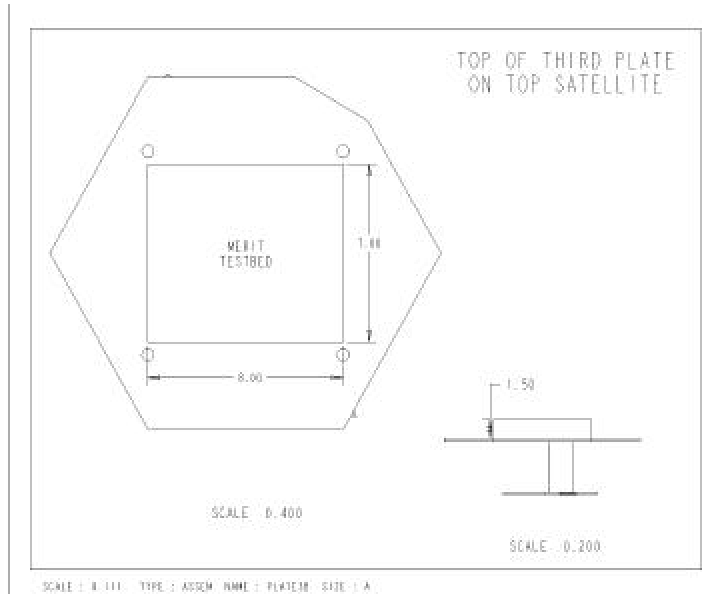
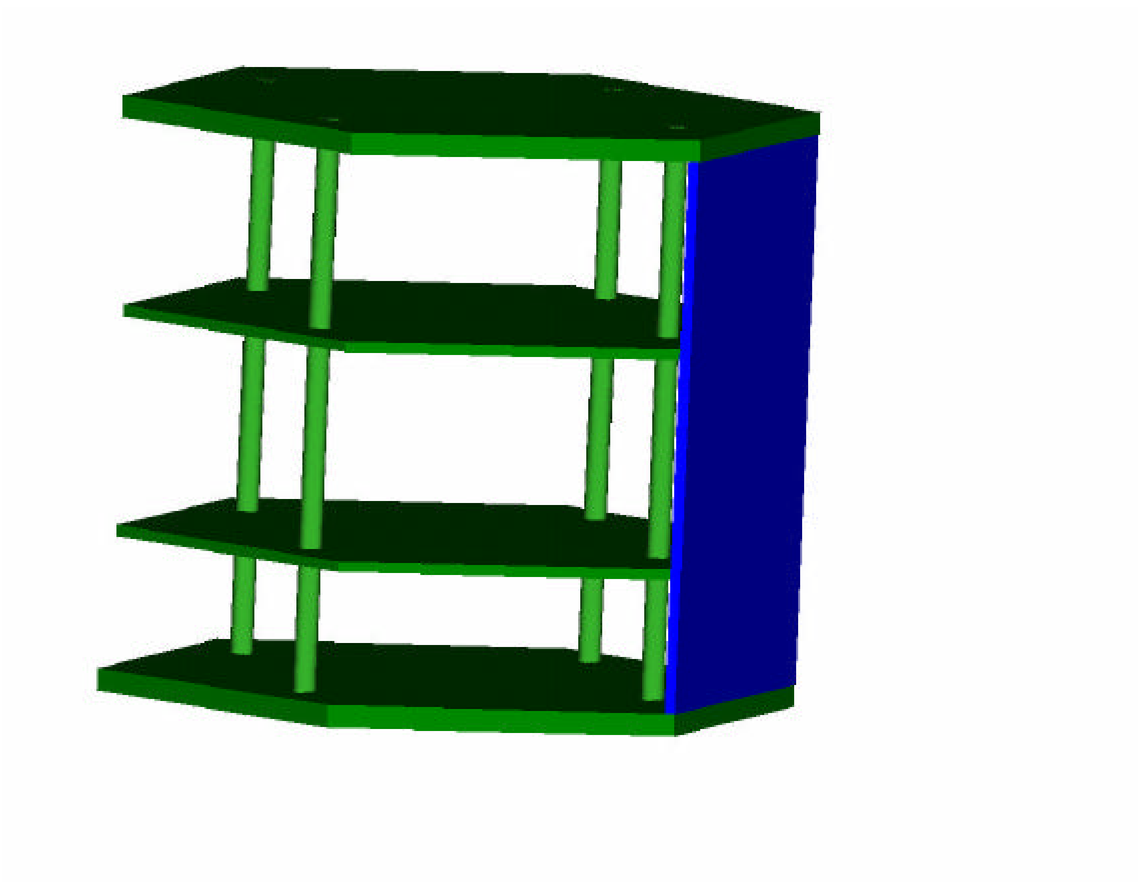


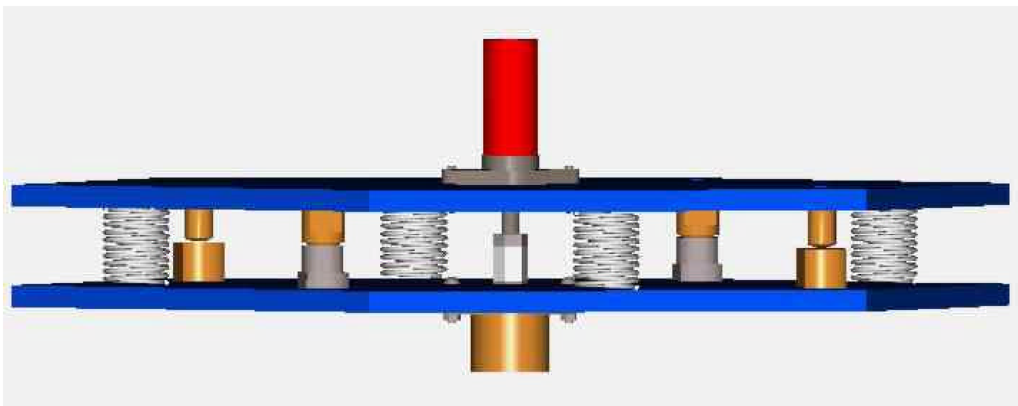


The side panels will be placed between the top and the bottom panels of each satellite to provide more shear support. The setup is shown below. The side panels will be attached using L-brackets.



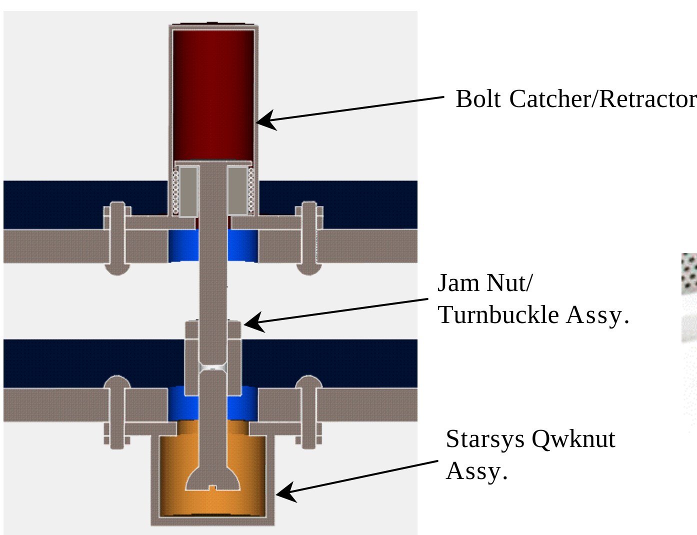
7.3 Inter-satellite Separation System

The baseline inter-satellite separation system for the EMERALD mission makes use of heritage (OPAL and SAPPHIRE) components while introducing new, more student/project friendly components. The Starsys Qwknut restraint and release mechanism can be reset in 1 min., thus enabling the design team to perform multiple tests on the separation system. A bolt catcher/retractor has been implemented in the design per Starsys recommendation to insure proper bolt retraction. Cup/cone and button post interfaces are included in the design to react torsion and shear loads during launch. To insure minimal tip-off rate, a multiple rather than single spring system was designed (a single spring system must be positioned through the satellites c.g.'s fairly accurately to insure a small tip-off rate—a challenging task, whereas with multiple, similarly sized springs the consequences of positioning inaccuracies are diminished).



Separation System Design Features:

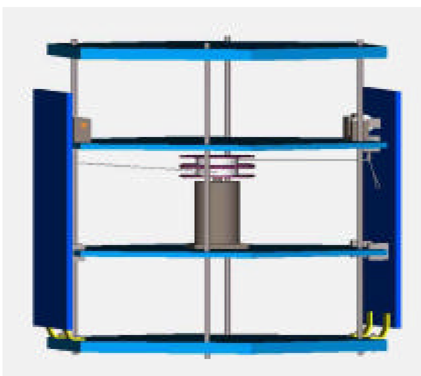
- Starsys Qwknut Actuator (1 min. re-settable)
- Bolt Catcher/Retractor (student built)
- 2 cup/cone interfaces (torsion, shear)
- 2 spherical button/post interfaces (compression, bending)

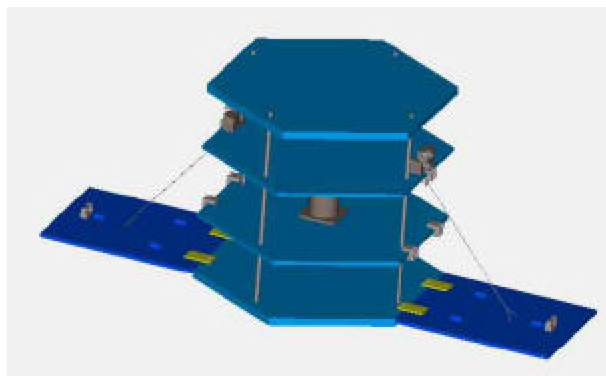


7.4 Drag Panels

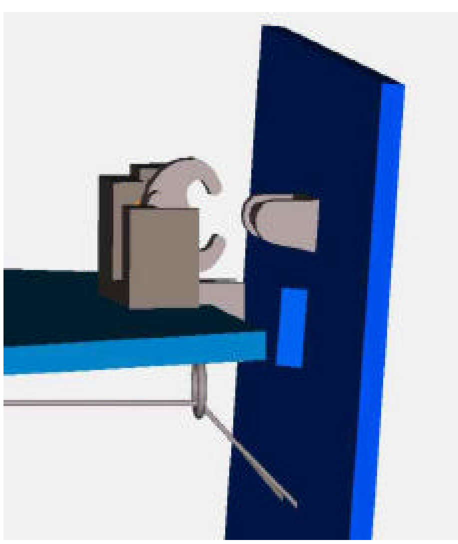
The drag panels are designed to unfold to change the ballistic coefficient of an Emerald vehicle. The attitude control group has determined that the flight configuration of Emerald dictates that two side panels on each bus should unfold outward. We have selected a stepper motor with a winding spool that connects to two lanyards that actuate the panels. The panels will be hinged with carpenter's tape to provide a spring force that tends to open the panels fully. The lanyards will pull against this light force.

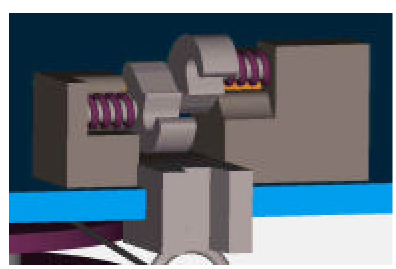
A motor was chose in a configuration that allowed one actuator to move both panels. Information is available on how to use a commercial off the shelf motor for space by cleaning off the lubrication and replacing it with space rated materials. A lanyard was chosen over a rigid linkage for many reasons. A rigid link would require several delicate hinges, which are vulnerable to thermal jamming, vibration, breakage, and would require lubrication. A link would also present difficulties in getting around the complex internal geometry of the bus, whereas the flexible lanyards present no such challenges. The figures below show one configuration of the drag panel design stowed and deployed.

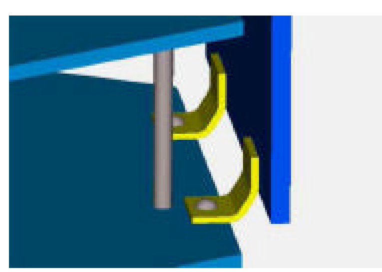




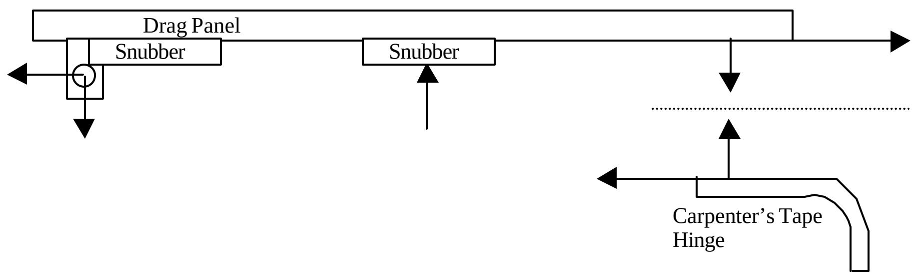
The restraint and release system for the drag panels is somewhat akin to a car door latch. Two hand shaped latches hold the panel in a pre-loaded condition via a dowel/claw interface. The latches are mounted on a common structure and are torsion spring loaded. A solenoid pin holds the latch system closed. Upon actuation of the solenoid, the torsion springs act on the latches and the "thumb"-shaped ends of the latches push the dowel and panel outward as shown below.



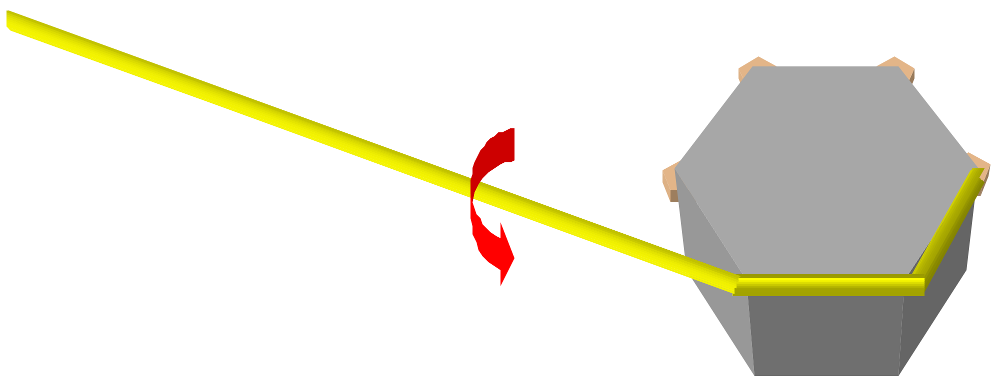




The carpenter's tape hinges can be used in a clever way to support the STS launch loads. The diagram below shows how the system can be loaded such that the carpenter's tape is preloaded at launch. The lateral loads are supported by snubbers which are seated in mating structures on the satellite. The snubbers could even be cup/cone interfaces to react loads in all six degrees of freedom. Notice that proper initial stowage of the drag panel system can place the carpenter's tape hinges in a preloaded, load capable configuration.



7.5 Very Low Frequency Antenna (VLFA)



The VLF lightning experiment requires a long antenna, preferably at least 3 meters, oriented perpendicular to the surface of the Earth. This antenna will be stowed for launch and deployed after spacecraft separation.

Critical issues with the VLF antenna deployment include:

- Scraping against solar cells during launch
- Dynamic effects after deployment
  - Colloid microthruster spin up effect (issue for one sat only)
  - Will antenna wrap around bus, reach steady state bending, or contact the S/C bus in any way?
  - Magnetic stabilizers effects (what axis will vibration/bending be induced)
  - S/C separation (VLF will be deployed which emerald's are still together, and will bend
  - Failure to detumble
  - During the impulse of intersatelite separation. (pending ops plan)
- Stepper motor inertial effect
- deployment out of plane for wrapping spiral (nice if it doesn't, but hard to assess outside vomit comet test)
- Nichrome wire failure to burn through risk
- How to tension the wrapped antenna: nichrome may be too stiff to overlay the antenna
- tangling with comm antennas (4 sets, 9in long, 2 of which share vicinity with VLF)

- Tangling with other VLF antenna (current soln is to but one antenna on bottom panel of bottom sat, and other on top panel of top sat. VLFA's face same direction, but mutual distance is maximized)
- Shadowing of solar cells (will occur when S/C is approaching eclipse, traveling away from sun) Not an issue for max power point in orbit as S/C are departing eclipse, and VLFA is trailing
- Solar cell space: power must fit 1 entire string per panel: if VLF stowage across panels is thus prohibited, brackets may allow hexagonal stowage around top panel off the side panels

Comprehensive stowage plan:

Antenna

Stanley tape measure. dimensions: ½ inch wide. 3 meters free length. 1 inch root
Rational:

Stowed Orientation

Wrapped around hex bus
Rational: minimum stored potential energy to be released into antenna velocity during deployment. We want as predictable motion as possible. No explosive deployments.

Deployed Orientation

Straight away from the aft panel of the S/C bus, at the top(bottom) of the panel for the top(bottom) S/C in the STS stack configuration. This points the VLFA directly opposite the intended velocity vector of the S/C
Rational

Brackets

Anchor

Charge isolation:

Plastic material heritage from OPAL comm will be used for the VLF anchor

Tension

Hold Down

Deployment

Deployment Electronics

Harness

The VLF antenna will require a slot in the rear panel of the S/C large enough to accommodate the entire head of the connector to the VLFA anchor

Testing

A wrapped hex configuration has been prototyped and tested. Zero gravity conditions were approximated by deploying the antenna in free fall by dropping the rig off a balcony. The antenna unfolded smoothly in an outward spiral a very low speed, and reached fully open form before reaching the ground. The hex bus was modeled by Styrofoam for low weight.

Other stowage configurations have been tested, including explosive options, and packing arrangements. The antenna is difficult to pack by folding end over end because of the curvature, and would require a large volume box for this low stored energy alternative. Wrapping a coil for an explosive deployment was found to depend strongly on where the antenna was anchored: either from the outside or the inside of the coil. Inside anchors led to complete tangles. Outside anchoring led to much better performance, but still chaotic.

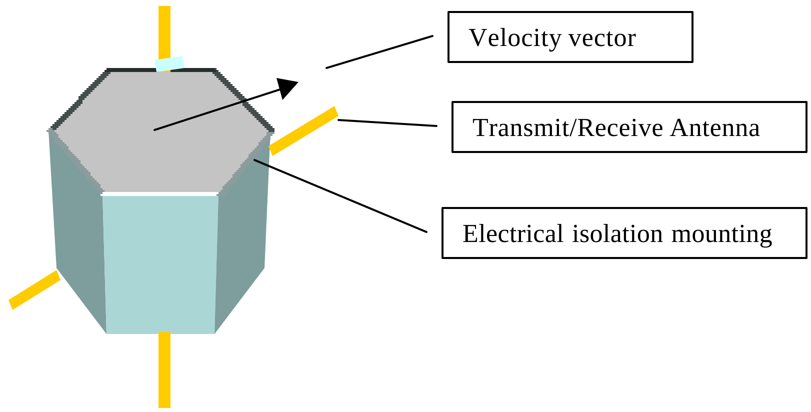
Proposed Work

Literature search on previous antenna issues. Carpenters tape is a very common material for spacecraft antennas and has been used may times before. Most of the issues we are facing have probably been addressed in the past, and should be locatable in the literature

7.6 Comm Antennas

The communications antennas will hopefully not require deployment or mechanisms. They are of issue to the structures and mechanisms team because they are very important to the STS stacked configuration and the Emerald clearance envelope

Communications will require four antennas per spacecraft. These will consist of 9 inch long sections of carpenter's tape protruding from the seams between the top (bottom) and side panels at an angle; nominally 45 degrees



The arrangement of antennas will maximize field of view

The antennas will need to interleave during stacking. Because the interleaved antennas can be on opposite sides of the stack, this is not expected to be a problem at separation. Please see the design document for the Communications team for more details on the antennas.

7.7 Integration Jig

The structures team recommends the early fabrication of a jig for the manufacture of the Emerald spacecraft. This is based on the experience of Jamie Cutler in final fabrication of OPAL. The jig should have the following essential functions/features:

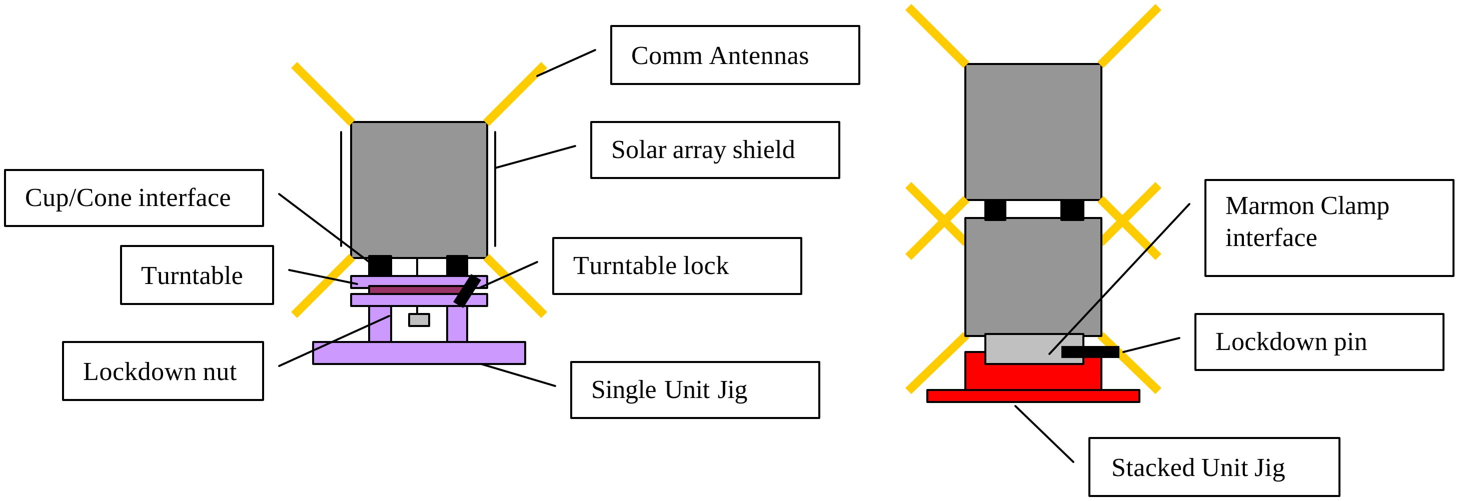
- ability to lock S/C to jig with a hand turned nut
- cup cone interface matching S/C and intersatellite interface
- Handles for easy transport around the clean room, and into and out of transportation boxes
- Provide table clearance for all antennas that project down for S/C

In addition, the jig would ideally have the following secondary features:

- Ability to rotate the S/C freely on a turntable
- Ability to lock this turntable for work at a fixed position using a hand turned nut / dial.

The stacked Emerald's should be able to sit on a flat surface on the face of the STS Marmon interface. There must be no protruding objects that prevent full flush contact with the table top (antennas, separation switches, etc). This requires either the Marmon interface on the emerald bus have sufficient height to provide clearance for the antennas, or that a jig consisting of a mating radius detent be provided on the working surface.

These assembly jigs are depicted below



7.8. Sensors and Electrical Interface

During the first quarter, we have focused on the sensing aspect of our group. We have chosen to detect the following things using the following sensors.

Separation Detection Sensors

There are two methods to confirm separation under consideration. The first is the use of a microswitch mounted between the emerald vehicles which sends a one bit signal (ON/OFF) when polled right after the separation command has been given.

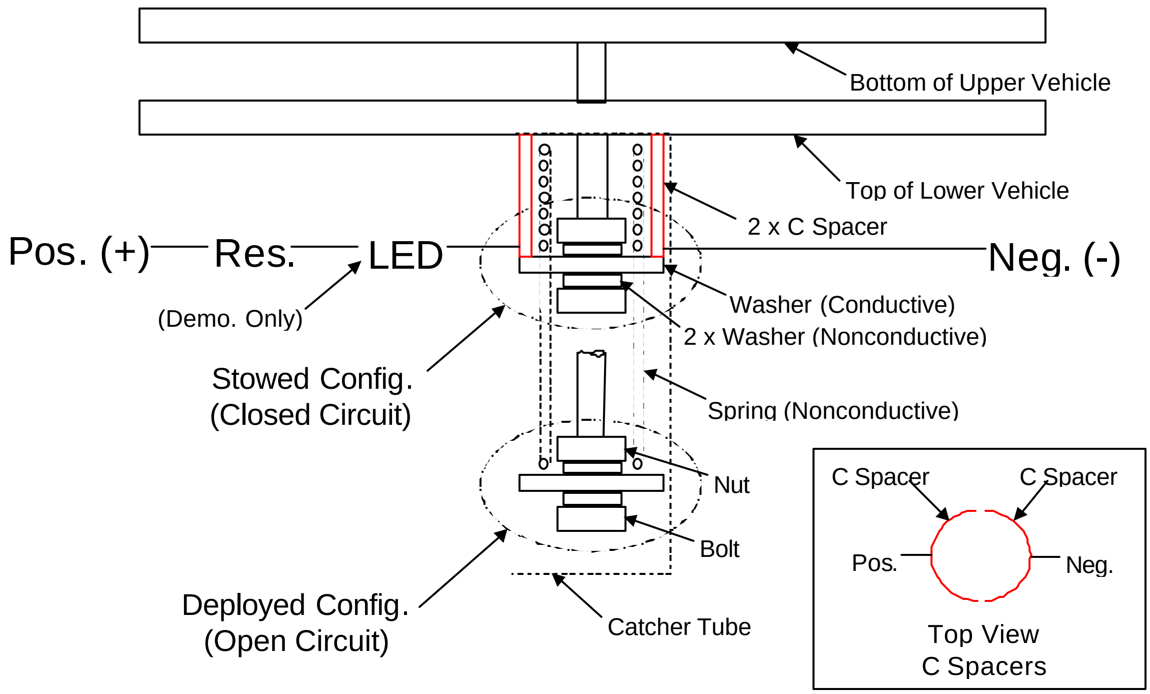
We could also use GPS or attitude telemetry to confirm separation, because after separation the two satellites should have different attitudes from one another, different spin rates, and also different absolute positions. Therefore, the actual separation event should be easy to confirm from preexisting telemetry and may not require a separate sensor.

Another possible separation verification technique was suggested after the preliminary design review. This was to use an IR reflectance sensor, similar to the system that was used by Opal, in order to determine the presence of the adjacent satellite. Since this suggestion was made fairly recently, we have not had a chance to investigate this option at this time but that would be a good investigation for the future.

Bolt Retraction Sensors

However, in the event that the spacecraft do not separate, we want to sense whether the Qwknut has fired or not so that we can determine if there is some chance that we could try again to fire the system or if the spacecraft are simply tangled together. Although no formal trades were done, several alternatives were considered for the design of the Qwknut bolt firing detector. Two basic ideas were considered. The first was using an IR reflectance sensor to see if the bolt had moved, similar to the system that was used by Opal to detect if the picosats had fired or not. The second was to use a washer on the retraction bolt itself to complete a circuit which would then be off when the bolt had fired. We chose to develop the second idea because it seemed that it would be easier to incorporate into the separation system design and would take up less space. Also, it would not require the purchasing of any specialized components. We also considered a few variations of the bolt as switch idea, using the retraction spring and a surrounding circular spacer as the two ends of the switch, and using a split spacer. It was decided that the split spacer would be easier to wire and to isolate electrically. This split spacer concept is shown in the figure below. Using a microswitch pressed down by the bolt instead of a washer on the bolt itself to complete the circuit was also suggested to us after the preliminary design review, but we have not yet examined that possibility.

If bolt retraction did not occur, we want to monitor the temperature of the Qwknut to determine if it cannot fire because it has fallen outside of its operational range. The temperature sensor we plan to use is the Dallas DS1820 which works with the Dallas 1-wire system.



Drag Panel Monitoring Sensors

In order to know what position the drag panels are currently in and also whether or not they are changing in response to a command, we want to monitor the drag panel position using a potentiometer connected to the drag panel drive motor shaft. If this potentiometer is placed in a voltage divider circuit, the voltage around it can be measured and will be proportional to the angle of the motor shaft. This, in turn, will be related to the drag panel position. This voltage will then be fed into an I2C compatible A/D converter which will output this voltage as digital bits; a data form which can be handled by the C&DH subsystem. We may also want to be able to detect the fully open or fully closed position of the drag panels so that we can calibrate the potentiometer and perhaps recalibrate in flight if it develops problems. This can be done by using some limit switches that will be activated at the extremes of the panels travel.

In order to help detect a problem with the motor while it is operating, both the temperature of the motor and the current drawing by motor will be monitored. Both of these parameters should help indicate an increase in the motor load. If the motor starts to deal with an increased load, such as an increase in motor friction or a snagged lanyard, its temperature and its current consumption should increase. Like the potentiometer voltage, these parameters will be fed into an A/D converter and the sent on to the C&DH system. A current limiter on the motor is probably also desirable, although we have not given it much consideration yet.

Electrical System

Even though our primary focus has been on the sensors, there have been some discussions about the electrical system. The most important of these discussions involves providing power to the various deployment systems located around the spacecraft. The problem is that these deployment systems, at first glance, appear to require larger currents than can be provided at any one time by the power subsystem. Since this is the case, there must be some way for our subsystem to store enough current in order to drive these actuators. The first and most promising concept for doing this would be to have a capacitor bank which could be used to store charge before firing the actuator. During firing, the current would be drawn from these capacitors in addition to what will be provided by the power system. These capacitors would have to be sized to supply the additional required current and any associated circuitry would have to be designed, but from a conceptual perspective, this idea would seem to be feasible.

One of the things to keep in mind when designing the rest of this circuit would be to place a buffer between it and the rest of the power system. This could be done by placing an inductor on the upstream side of the capacitor bank. This would keep the current being drawn from the power system at a relatively constant level and would assist in preventing firing transients from disturbing the rest of the spacecraft. One problem that would have to be avoided when using an inductor in this fashion is the possibility introducing resonant frequencies in the firing circuitry. Nonetheless, this seems like something which merits further consideration.

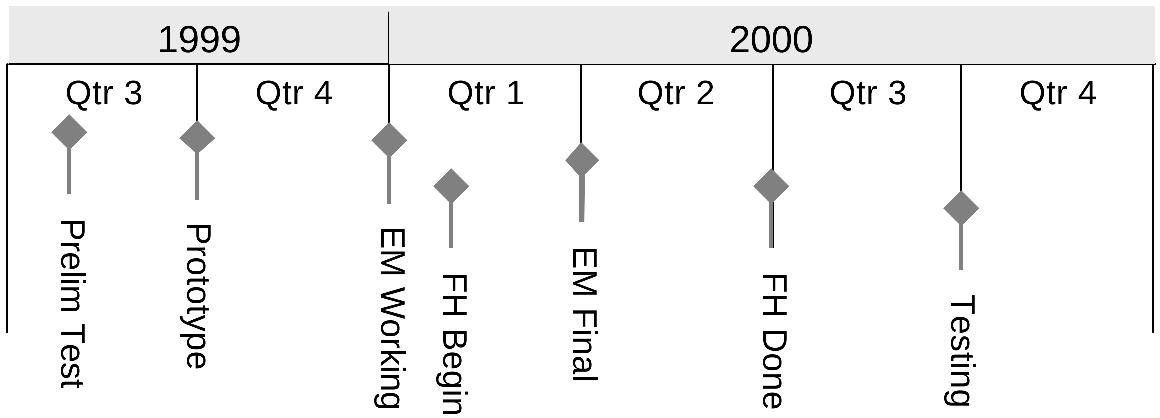
One final note, there has been some discussion of the actual power requirements for these actuators. At this time, we have not been successful in locating any documentation about the actual power requirements. This documentation would be of great value before spending a large amount of time pursuing this design.

Future Sensors/Electrical Tasks

Beyond the obvious tasks of continuing to develop the designs which have been mentioned above, there are at least two other major tasks which must be worked. The first is developing the power supply for the drag panel motor. This should be fairly interesting because it has the potential for drawing relatively large amounts of power for finite periods of time. The second major task is developing a means by which to command the various systems. Some of the commands which must be generated are deployment commands, drag panel open/close commands, and drag panel intermediate position commands. Others may also be required, but this is the list we have to date.

8. Future Work

All future work to be done by the Structures and Mechanisms team is outlined below.



- Finish manufacturing the separation system 6/26/99
- Prototype the drag panel mechanism 6/8/99
- Prototype the VLF deploy mechanism 6/8/99
- Prototype electrical interfaces 6/8/99
- Finalize layout and mass budget 7/1/99
- Test all mechanisms 8/1/99
- Finite Element Analysis 8/1/99
- Mass model vibration testing 8/5/99
- Initial Thermal-Vac Testing 9/1/99