NSTRF Quarterly Report for **NASA Grant #NNX11AM61H** Modeling Cable-Harness Effects on Spacecraft Structures Virginia Polytechnic Institute & State University	
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Goal

The goal of this research is to develop a scientific basis for characterizing the effect of power and signal cables attached to lightweight, flexible spacecraft structures in order to develop models of such systems to gain understanding of the important physical effects that affect their dynamic response. Goals of the project have been narrowed down to a combination of testing cabled-beam systems to provide an experimental validation for models developed, as well as provide experimental data to determine the extent of damping to the system, developing one or more models to predict the vibration characteristics (natural frequencies) of the cabled-beam system, and possibly investigating a statistical method to evaluate the success of the predictability of the system response by the model, which would tie in to studies being performed at JPL currently. The student's next advisor visit is March 15th, at which time these goals will be further refined and evaluated.

Summary of Quarterly Activities, Accomplishments, Impacts

Since the submission of my training plan, I have read a lot more literature about different methods of vibration system response solutions, information about cable properties and dynamics, and have gone through the existing research more carefully, and I am currently working on model development. In this quarter, I also began my on-site experience at the Jet Propulsion Laboratory NASA Center. I brought the data from the experiments that I had performed at the CIMSS Lab at Virginia Tech to take a look at with my NASA mentor. The consensus between my mentor, advisor and I was that while the data was valuable in terms of developing the experimental set-up, learning how to use the equipment, and getting an overall idea of the system response and influence of damping, we are going to want data that is more reliable in the low-frequency area. Figure 1 (on the next page) shows typical results from my Virginia Tech data, where the area circled in red shows the evident noise in the low frequency range. Since this low frequency range is the area where the approximate models I am developing will be most accurate, we agreed that I will want to spend some time at JPL in the ALPS lab to run similar experiments under more controlled conditions. I have spent a little bit of time in the lab learning about the experiments that are currently being run, and have looked over the existing test fixtures and manufacturing facilities at JPL. I have also attended several of the lectures and

presentations that occur almost daily at JPL to attempt to fully immerse myself in the NASA program here.

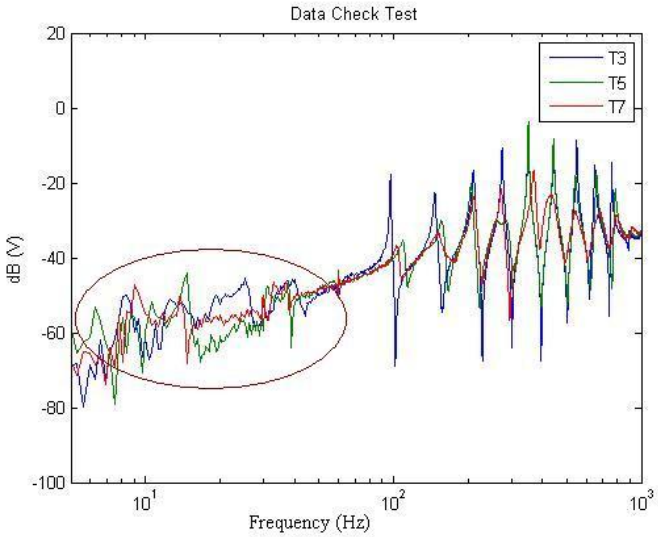

Figure 1. A typical response for cabled-beam testing run at Virginia Tech CIMSS lab, showing good agreement at higher frequency ranges, but too much noise at lower frequencies, which will likely lead to difficulties in validating models that are more accurate at lower frequencies.

We also agreed that, before running more experiments, I should put some time and effort into investigating model types and developing a reasonable model. I started with the three methods outlined in my initial proposal; I began by reading about the homogenization method and contacting experts only to find that homogenization may not be the best method for this case and my expertise. I decided (on the advice of my advisor) to start with methods that I know. I developed equations of motion for the cabled beam system using Hamilton's Variational method, and then wrote code to use the Rayleigh-Ritz method to determine the natural frequencies for the cabled beam system. My code works for known bare-beam systems, so I am currently using different trial functions to find the function that can yield the most accurate results for the least computational time. I have also been looking into the Distributed Transfer Function Method (DTFM), which can be used with the Combined Dynamical Systems method from my initial proposal. At this point, there are other students in my lab working on the finite element model updating method, so I will endeavor to support their research by providing experimental data, but will not myself continue with the model updating method. Instead, I will continue with my use of the Rayleigh-Ritz and DTFM methods. The group I am working in at JPL has an individual with expertise in the DTFM method as well as many knowledgeable members who have given me good advice on how to proceed with my investigations.

As far as my milestone achievements, I am quite happy with the background reading I completed in this quarter, and since I switched the experimental and modeling tasks to develop models in February and then begin testing in March, I am well on track. My advisor visit had to be moved

back, but I have been in regular contact with him and am able to meet with my mentor weekly, so I still feel well-guided. My first conference in April is scheduled, and my advisor and mentor have recommended that I visit NASA Langley while I am there, which should be beneficial.

Milestone or Activity	Estimated Date	Change Notes	Completed?
Began graduate degree coursework at VT	August 2010		YES
Passed Ph.D. Qualifying Exam	March 2011		YES
Preliminary experiments at Virginia Tech	June-August 2011		YES
Completed degree-required coursework	December 2011		YES
Background reading of contact mechanics, prior research, AFRL research, and beam-cable interactions. Determine areas of greatest concern and interest, identify challenges and strategies to overcome obstacles.	November 2011-Jan/Feb 2012	Reading will, of course, be ongoing throughout the project, but background reading is complete.	YES
On-site experience at JPL, Pasadena, CA	Jan-August 2012		IN PROGRESS
Meeting with advisor and mentor at JPL to finalize project direction, goals, and deliverables. Determine specific goal and research question to be answered.	**Early February 2012**	**Changed to March 15th, 2012 due to advisor travel requirements**	**Scheduled**
Design of experiments to be conducted	February 2012	Experiments and modeling were switched to develop model first	Switch to begin after model development, in March 2012
Conduct experiments, develop model	Feb -Mar 2012	Developing Rayleigh-Ritz and DTFM (Combined Dyn. Sys. Models)	IN PROGRESS
Data analysis and model validation	March 2012-April 2012	Contingent on experiment completion	Future Work
Consider committee meeting for research update	March 2012	Instead of committee meeting, will develop presentation for JPL work group for input and advice	Future Work
Technical presentation at VSGC conference, Williamsburg, Virginia	April 2012	April 5th, 2010 – Will also plan on visiting NASA Langley Facility!	Scheduled
Attend AIAA Conference	April 2012		Future Work
Determine further experiments needed, etc	May 2012		Future Work
Conduct experiments, improve model	June-August 2012		Future Work
Data analysis and model validation, etc	Sept-Oct 2012		Future Work
Preliminary thesis defense	November 2012		Future Work
Finish any outstanding work, thesis	Dec ‘12-Jan ‘13		Future Work
Degree conferred, graduation	May 2013		Future Work

Planned Activities for Next Quarter

My next quarter includes a presentation of my work at my first conference, a visit to an additional NASA center, continuation of model development to predict the response of cabled-beams, and setting up cabled-beam experiments to validate my model and investigate damping effects. My advisor's visit in March will be very important to refine our goals and consider whether I should turn to a more statistical route for data analysis or go for an exact comparison of experimental data and model output. JPL has a "Cognizant Engineer" training class for cable fabrication that I would like to attend in April, and JPL also has an actual cable group that I am hoping to speak with when I begin my next experimental phase so that I can get expert opinions on my materials and test setup.

My immediate work includes completing my simple Euler-Bernoulli Rayleigh-Ritz model and adding complexity by using a Timoshenko beam model for the cable and including damping as a non-conventional work term. I will also be learning how to apply the DTFM method to my specific system of interest, but I am sure I will able to get help from the experts here at JPL if I get stuck.

We have discussed running my experimental testing in the March-April-May months, since the summer months (June-August) tend to be busier with more students at the facility and thus, testing areas are under greater demand. This coincides with my milestone plan, so I will work hard to have models developed enough to begin testing, and will make sure not to postpone testing too long if modeling does not go as well as hoped.

My next quarterly report should have information on the outcome of my modeling efforts, status updates on my experimental testing, and summaries of my visit to NASA Langley and first conference presentation, as well as further lessons learned from my experience at JPL.

Issues and Concerns

I am really enjoying my time and training at JPL, and am looking forward to visiting another NASA center in April. I have gained a greater interest in my research and am looking forward to talking with my advisor about what I should aim for in terms of publishable results.

I was a little bit surprised by the quarterly report deadline (thinking that I was supposed to submit my second report 90 days from the submission of my training plan), so please excuse the delay in your receipt of this update. Thank you again for the opportunity!