Vibration & Precision Engineering Laboratory

The Vibration and Precision Engineering Laboratory (VPEL) is involved with multiple contemporary research projects in ultra-precision technologies, space hardware design, precision vibration control, and smart actuator development.

WORK WITH UNDERGRADUATE AND GRADUATE STUDENTS

Research work with undergraduate and graduate students has been accomplished on many research topics in a variety of environments. I have been involved with the supervision and advising of graduate students, led Senior Design Teams, participated in National Science Foundation (NSF) Research Experiences for Undergraduates (REU) programs, and contributed to special topics programs, many of which were multidisciplinary. A brief summary of select projects is provided.

AgCam

Another remote sensing device is to be placed on the International Space Station (ISS) that will again use digital imagery to assist farmers and ranchers. It will be housed on the ISS utilizing the Window Observations Research Facility (WORF) that provides a portal to view Earth. The Agricultural Camera (AgCam) is currently being developed at UND with direct interactions with NASA. These opportunities have generated substantial increase in undergraduate and graduate student retention and recruitment, as well as an excellent public relations tool for UND. The organization and operational procedures are similar to those used in the AEROCam project. The AgCam fit check at Johnson Space Center is shown in Fig. 1 and the flight and computer models of the system are shown in Fig. 2. Launch of the system is expected in 2006 for analysis of the subsequent three growing season. This will be a major accomplishment for a University sponsored project and will likely be the first non-commercial, non-government payload on the ISS.

Fig. 1. AgCam Fit Check at Johnson Space Center

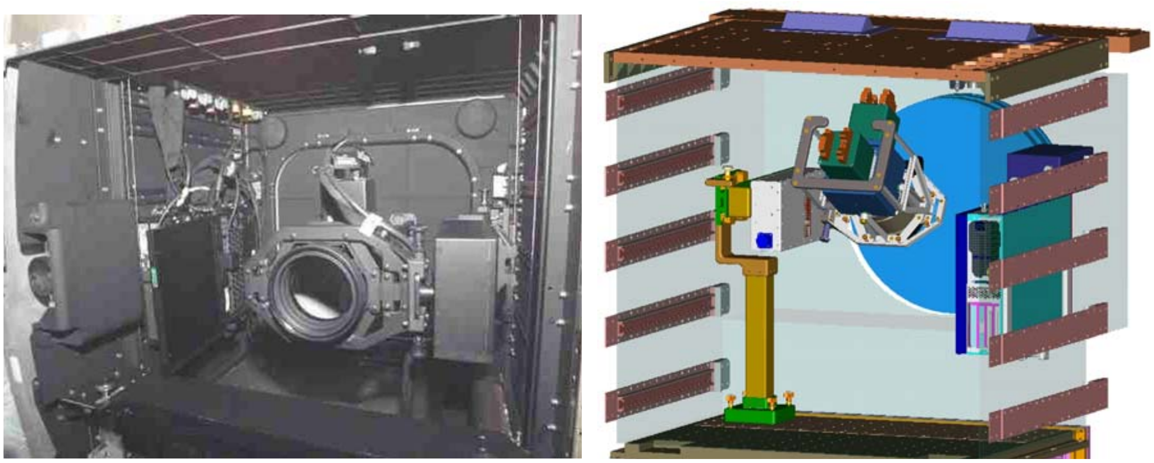

Fig. 2. The AgCam camera system.

AEROCam

The Airborne Environmental Research Observational Camera (AEROCam) is a project that was initiated during the Spring 2001 semester. The objective of the project is to provide multi-spectral aerial imagery to assist farmers and ranchers in improved crop management, natural resource management, and disaster response. During the summer of 2001, nine faculty/staff members from the University of North Dakota (UND) Aerospace, Electrical Engineering, and Mechanical Engineering departments with seven undergraduate students began the design, assembly and integration of AEROCam. Students and faculty members from UND Engineering are developing the electrical and mechanical components of the system, while the Aerospace School is providing program management, funding from the NASA funded Northern Great Plains Center for People and the Environment (NGP CP&E), expertise in remote sensing data analysis and distribution, and flight personnel and support. This complementary team of students, researchers, and faculty permits the unique opportunity to complete the entire task within a single university. All parties are gaining valuable lessons on the needs and requirements of the other groups to develop an optimized system. Interactions among the groups along with end users have been performed in periodic system reviews at critical design phases throughout the development. These activities, as well as the opportunity to work on an operating aerial system that assists the local economy, have been a highly successful public relations and recruitment tool for UND. The AEROCam system is shown in Fig. 3 and the initial team is shown in Fig. 4. The AEROCam system has flown hundreds of missions and undergone several upgrades.

Fig. 3. The AEROCam system.

Fig. 4. Summer 2001 AEROCam team.

Unmanned Aerial Vehicle

During the summer of 2004, eight students and two high school teachers were summoned from various parts of the United States of America to participate in the Research Experience for Undergraduates (REU), sponsored by the National Science Foundation (NSF). Upon arrival in early June, the students met with Electrical Engineering, Space Studies, and Mechanical Engineering professors to determine the objectives of the summer REU: the students were to develop an Unmanned Aerial Vehicle (UAV) with multiple payload capabilities.

The team was divided into subgroups to make development more efficient. An electronics group, payload group, and plane assembly group were formed. At the end of the summer the students had successfully built and flown the UAV, named the Albatross. The student team is shown in Fig. 5 and Fig 6 shows the inaugural flight. Many payloads were developed including an air quality sampling device in cooperation with the Environmental and Energy Research Center (EERC) and an in-flight mosquito catcher to assess the spread of mosquito borne illnesses.

Fig. 5. Summer 2004 REU UAV team

Fig. 6. First flight of the Albatros

CubeSat

ZAMBONI, the Zippy Aerospace Module Broadcasting Observed Not-so-bad Images, is a CubeSat that will contain many of the same components as a commercial satellite, but it will be developed at a much lower cost (under $10,000) and with a significantly lower risk than its larger counterparts. Although size and weight must be carefully conserved on a CubeSat mission, important experiments are possible with this picosatellite spacecraft bus. The ZAMBONI package will be double the size and mass of a standard CubeSat, with a mass of 2 kg and a size of 10 cm x 10 cm x 20 cm. The UND CubeSat will contain two payloads: two commercial-off-the-shelf digital cameras and reserved space (approximately 30%) for a DoD, NASA, or industry-sponsored scientific payload. Figure 7 is the UND Zamboni team logo and Fig. 8 shows a CAD image of the satellite.

Fig. 7. UND Zamboni team logo.

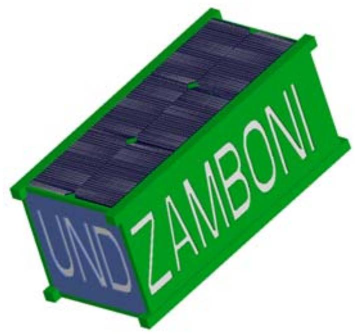

Fig. 8. Cad graphic of UND CubeSat.

Scorpio Alpha Balloon Project

The Scorpio Alpha project was the first aerospace related project with the intent of building our infrastructure and expertise. This multidisciplinary design project emphasized the systems engineering approach, in which extensive documentation is created prior to any construction or testing. Fourteen undergraduate and three graduate students designed and tested the second build of a spacecraft, known as Scorpio II, to be launched using a zero-pressure balloon during the 2000-2001 academic year. This project sent a 10-kg spacecraft to an elevation to collect and transmit real-time sensor and digital image data. The large-scale scope of this project, coupled with the group size, led to many new experiences for the students, including an appreciation for true teamwork and the positive and negative aspects of group dynamics. Final preparations to the spacecraft can be seen in Fig. 9 and Fig. 10 shows the liftoff of Scorpio Alpha II.

Fig. 9. Final touches on Scorpio Alpha

Fig. 10. Liftoff in the spring of 2001

Mars Lander Solar Array

Other aerospace related research was conducted on a lightweight deployable solar array to be used in future Mars Lander projects. This work was conducted with a graduate student and in cooperation with the Jet Propulsion Laboratory (JPL) and AEC-Able Engineering Company, Inc, a major supplier. A design of experiments methodology was used to characterize the dynamic behavior of the deployed solar array. The Mars Lander and the first polar symmetric mode shape are shown in Figs. 11 & 12, respectively.

Fig. 11. 2001 Mars Surveyor

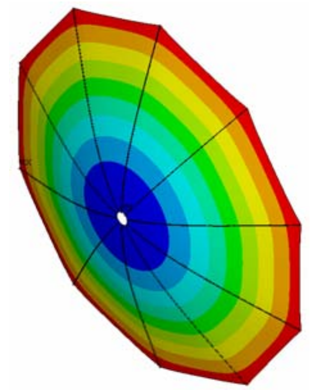

Fig. 12. First polar-symmetric mode

Pipe Flange Vibration

Another area of activity was the dynamic analysis of bolted flanges with Drs. Bibel and Jerath along with two graduate students. Experimental and numerical (finite element) analyses were done to investigate the vibrational response of a bolted flange connection and the effect of a gasket. The testing setup is shown in Fig. 13 and Fig. 14 shows an accelerometer time history resulting from an impact load.

Fig. 13. Experimental testing setup

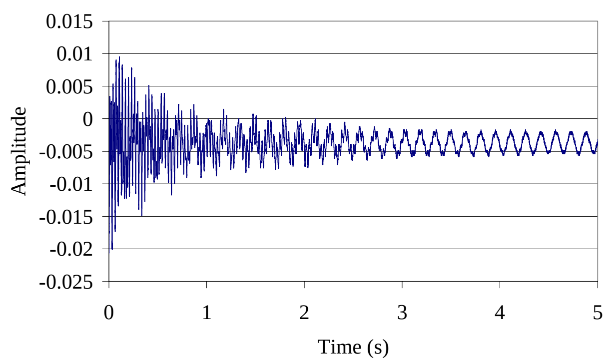

Fig. 14. Accelerometer time history data

Smart Actuator Technology

My previous work on nanopositioning mechanical flexure stages is ideally suited to provide an excellent starting point for advancement and innovations in ultraprecision positioning equipment. Nanopositioning flexure stages are used in many settings, including surface metrology, precision machining, optics, and biotechnology devices. Current stages are made of an aluminum alloy that has been precision machined. This is a costly procedure and has limited performance. Recent and future investigations will include the analysis of new and innovative flexure designs. The primary investigations involve the use of composites with bonded piezoelectric actuators to create a "smart actuator" to control the motion. The replacement of the flexure hinges with smart actuators/sensors will have many benefits including the utilization of advantageous composite properties, the increase of the resonant frequency of the stage system, the simplification of the manufacturing procedure, and an increased range of motion. The current experimental setup is shown in Fig. 15 and close up of the prototype is shown in Fig. 16. This work has been done with cooperation with Sioux Manufacturing in Fort Totten, ND and Cirrus Designs in Grand Forks, ND.

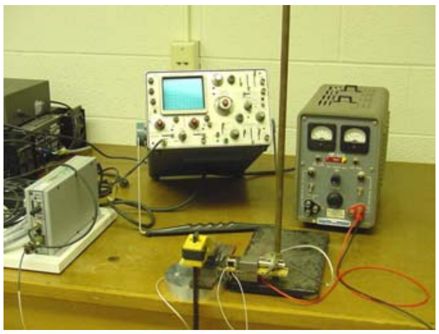

Fig. 15. Current experimental setup

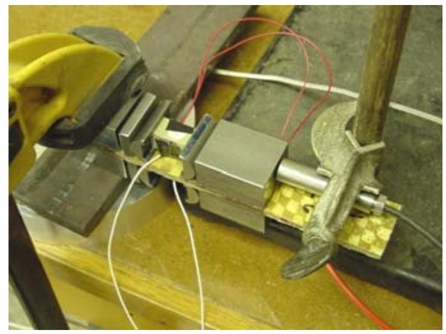

Fig. 16. Smart material actuator

Imation Non-Contact Measurement System

The Imation Senior Design project focuses on non-contact sensor technologies that will evaluate tape transport spools used in the production of data tape cartridges at the Imation production facility at Wahpeton, ND. The design is to be incorporated into an automated production line to acquire data to be used to increase yield, for performance tracking, as well as defect detection. Therefore, the design must have high throughput along with excellent accuracy and repeatability. Team members are evaluating several non-contact sensor technologies including laser and optical methods. A test procedure has been developed to evaluate the efficacy of each method and recommend the most effective technology. The test station can be seen in Fig. 17 and preliminary results are shown in Fig. 18. The final apparatus will be built and installed on the Imation production line during spring semester. Data will be obtained and evaluated during production use.

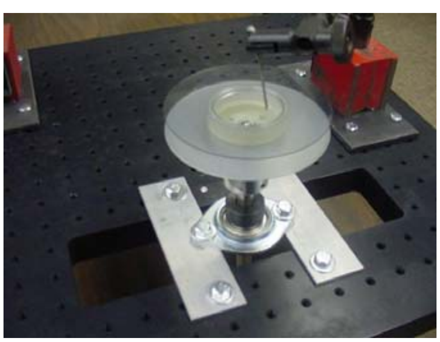

Fig. 17. Current experimental spool test station

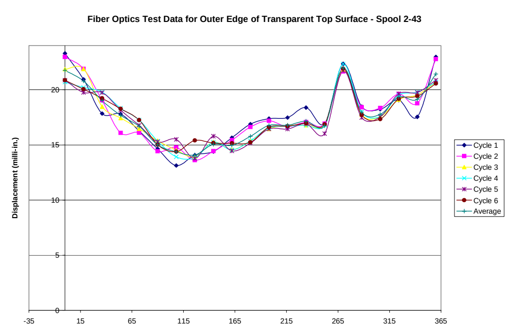

Fig. 18. Repeatability data obtained

Modal Mapping Tool – Scan-O-Matic

A scanning contour mapping device, named the Scan-O-Matic, was designed and built by a Senior Design team that I advised my first year at UND. It is a cost-effective positioning system capable of translating a measuring device in linear motion about two axes for the purpose of computerized, real-time data acquisition. The device is used to map the surface of a structure as it is excited at one of its resonant frequencies. In this manner, the structural mode shapes are visualized using computer simulations of the experimentally obtained data. These are compared, correlated, and verified with those found using mathematical methods, including finite element analysis. The CAD model designed and the final build of the system are shown in Figs. 19 & 20respectively.

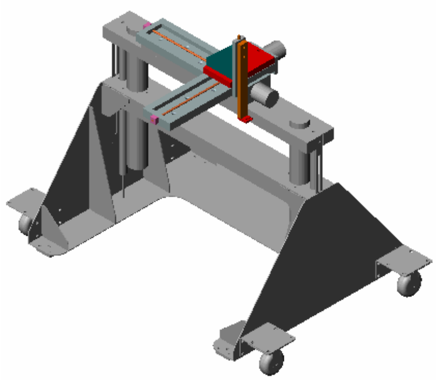

Fig. 19 CAD assembly drawing

Fig. 20 Scan-O-Matic final design build.