The Los Alamos National Laboratory Dynamics Summer School – A Mechanics Motivator

Phillip J. Cornwell, Charles R. Farrar
Rose-Hulman Institute of Technology/Los Alamos National Laboratory

Abstract

A unique summer educational program focusing on engineering dynamics has been developed and implemented at Los Alamos National Laboratory. The purpose of this summer school is to expose a select group of students to the broad field of engineering dynamics with the hopes that they will be motivated to pursue this area of research in their graduate studies. The summer school activities included 1) lectures on various engineering topics such as computational structural dynamics, experimental modal analysis, random vibrations, signal processing, etc., 2) a distinguished lecturer series in which prominent guest lecturers gave talks about cutting edge research in structural dynamics, 3) field trips and 4) an eight week project having both an analytical and an experimental component. In this paper the details of the program and of how it was assessed will be presented.

I. Introduction

Over the last 20 years there has been a 20% decline in the number of engineering degrees granted while university degrees in general have increased approximately 20%[1]. Engineering dynamics, which encompasses areas such as flight dynamics, vibration isolation for precision manufacturing, earthquake engineering, blast loading, signal processing, experimental modal analysis, etc. is naturally affected by this decrease in numbers. The competition for talented individuals with the background necessary to replace those leaving the field of engineering dynamics necessitates a proactive approach of motivating and educating students who are embarking on their graduate school career. The Los Alamos Dynamics Summer School was designed not only to benefit the students through their educational experience, but also to motivate them to attend graduate school and to make the students aware of career possibilities in defense-related industries after they have completed their graduate studies.

The summer school had two focus areas. First, the multi-disciplinary nature of research in engineering dynamics was emphasized throughout the summer school. For example, the students were assigned to multi-disciplinary teams and each team was assigned a project that had both an analytical and an experimental component. Second, the program was designed to develop the students' written and oral communications skills. To develop these skills, the students were required to give numerous informal oral presentations of their work as it progressed throughout the summer, culminating in a formal presentation and a paper written for a technical conference.

The summer school was taught for the first time in the summer of 2000 to thirteen students from nine universities. Four of the students had completed their junior year, seven of the students had completed their senior year and were planning on starting graduate school in the fall, and two of the students had complete their first year of graduate school. The students were mostly mechanical or civil engineering majors, although there was one computer engineering/math major. The average GPA for the students was 3.5 on a scale of 4.0.

II. The Project

The centerpiece of the summer school was an eight-week project having both an analytical and an experimental component. Students were placed in teams and assigned a project. An attempt was made to make the groups as multidisciplinary and diverse as possible. The experimental component was a critical aspect of the program since practical experimental activities in engineering dynamics are almost nonexistent at the undergraduate level. Students were assigned to multidisciplinary teams consisting of three or four students. Each team had a mentor from Los Alamos National Laboratory or Sandia National Laboratory. The mentors worked closely with their groups, providing guidance, encouragement, and technical expertise. All of the projects resulted in papers to be presented at the 2000 International Modal Analysis Conference. The titles of the resulting papers and their abstracts are listed below:

- *Characterization of Damping in Bolted Lap Joints*
  Abstract: The dynamic response of a jointed beam was measured in laboratory experiments. The data were analyzed and the system was mathematically modeled to establish plausible representations of joint damping behavior. Damping was examined in an approximate, local linear framework using log decrement and half power bandwidth approaches. In addition, damping was modeled in a nonlinear framework using a hybrid surface irregularities model that employs a bristles-construct. Experimental and analytical results are presented.

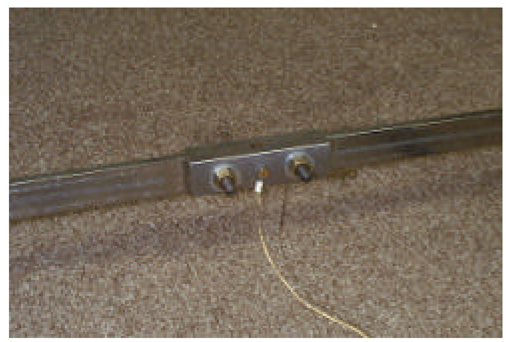

Figure 1 - Instrumented lap joint

A picture of the lap joint studied is shown in Figure 1.

- *Damage Detection in Building Joints through Statistical Analysis of Auto-Regressive Models*
  Abstract: Using a physical model of a three-story building, data was acquired using uniaxial accelerometers to detect vibrations induced by a shaker. Data was collected on a non-damaged model and a damaged model. Determining damage and localization of damage to the model was done using statistical methods.

A picture of the structure instrumented with 24 accelerometers is shown in Figure 2.

Figure 2 – Simple model of a three-story building

- *Identification of Nonlinearities in an 8-DOF System through Spectral Feedback*
  Abstract: The accurate detection and characterization of nonlinearities associated with damage in structural systems is an area of vibration analysis that is being widely researched. In this paper, nonlinear behavior is considered a potential indicator of damage. Most conventional damage detection methods, such as those based on resonant frequencies and mode shapes, do not accurately identify the location and extent of nonlinearities present in a given structural system. As an extension of previous work at LANL, an effort is made to validate a damage detection method proposed by Adams. This method states that the frequency response function (FRF) matrix obtained from a low-level vibration test approximates the underlying linear FRF matrix of the system. The nonlinear system's responses to high level excitation are combined with the linear FRF in a classic feedback loop to obtain the contributions of nonlinear internal forces. The temporal and spatial characteristics of the nonlinearities present in a structural system are identified. An 8-DOF system is used as a test case to validate the aforementioned method. Results of the tests and important issues concerning the method are presented.

Figure 3 - 8-DOF System

A picture of the experimental setup is shown in Figure 3.

- *Design of a Personal Airbag Spinal Protection Device*
  Abstract: Each year there are approximately 11,000 cases of spinal injuries that result in partial or complete paralysis. A significant number of these cases are the result of sports related injuries that possibly could have been prevented with proper protection. The project undertaken was a preliminary investigation of the feasibility of a personal air bag spinal trauma protection device. A mock torso was constructed with wood, instrumented and subjected to a 1-meter drop. The impact accelerations were measured for trials with and without a prototype air bag attached to the mock torso. Using finite element commercial code ABAQUS/Explicit, a model of the mock torso was subjected to a simulated 1-meter drop. The model was refined to match the results from the experimental drops without an air bag. Then the analysis was performed with springs and dampers inserted to simulate the air bag.

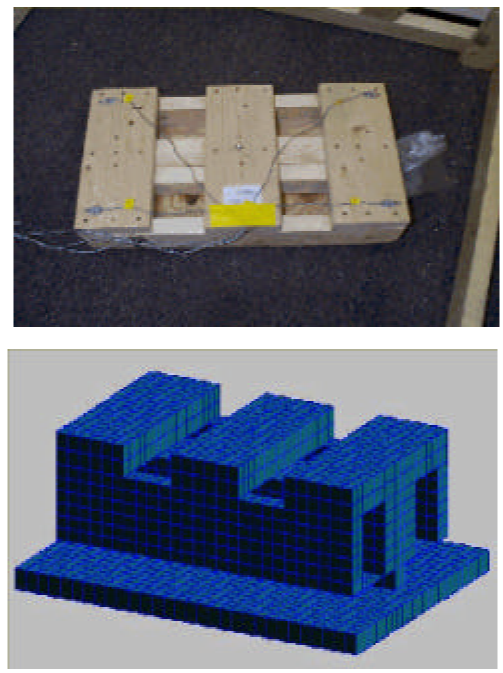

Figure 4 - Mock torso constructed from wood and the finite element model.

Pictures of the mock torso and the finite element model used are shown in Figure 4.

III. Experimental Equipment

Each student had his or her own high-end PC with numerical analysis and signal processing software. Each research group had access to a multi-channel data acquisition system. Finite element analysis software was made available to each research group as necessary. Equipment on hand at the start of the summer school included:

1. 14 PCs with MS office and numerical analysis and signal processing software
2. 40-channel data acquisition system, 2-channel data acquisition system, 4 channel digital oscilloscope
3. Data acquisition/signal processing software
4. Experimental Modal software packages (MEScope)
5. Various sensors, impact hammers, and small shakers
6. Finite element software (implicit and explicit) packages for PCs as needed
7. Rigid-body dynamics software package (ADAMS or Working Model)

A photograph of one of the summer school students and the 40-channel data acquisition system used for two of the projects is shown in Figure 5.

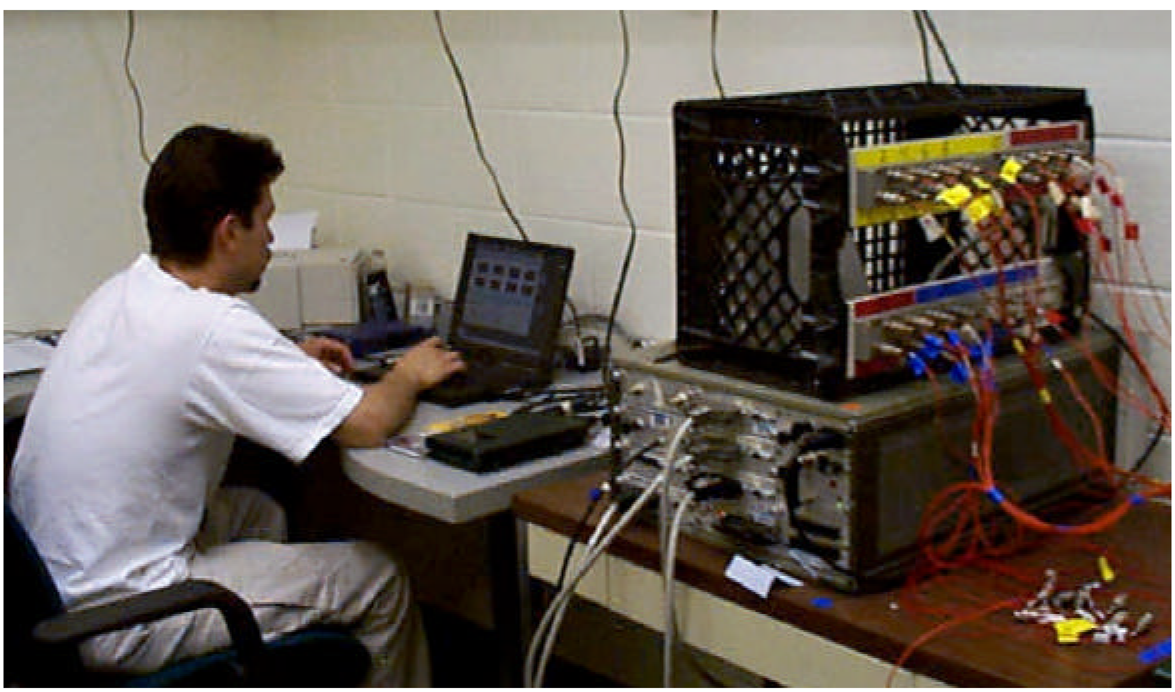

Figure 5 – One of the summer school students and the data acquisition system.

IV. Field Trips

Several field trips were taken during the summer, including tours of the Aging Aircraft Facility, Robotics Facility and Micro-Electromechancial Systems Facility at Sandia National Laboratory.

V. Visiting Distinguished Lecturers

Each week a prominent guest lecturer in the field of engineering dynamics gave a talk to the students about "cutting edge research" in structural dynamics. These lecturers and the titles of their talks are listed in Table 1.

Table 1 – Distinguished Lecturers

Name	**Title, University**	**Title of Talk**
Dan Inman	Director of Center for Intelligent Material Systems and Structures; George R. Goodson Professor of Mechanical Engineering, Virginia Tech	"Smart Structures for Vibration Reduction"
David Zimmerman	Associate Professor of Mechanical Engineering, University of Houston	"Structural Dynamic Model Validation & Verification"
Pete Avitabile	Assistant Professor in Mechanical Engineering; Founder and President of Dynamic Decisions; Developer of the Multimedia Format Modal Handbook, University of Massachusetts Lowell	"Introduction to Experimental Modal Analysis and Design Optimization by Inverting Targets"
Anne Kiremidjian	Professor of Civil Engineering; Director of the John A. Blume Earthquake Engineering Center, Stanford University	"Seismic Probabilistic Risk Assessment"
Dave Brown	Professor of Mechanical Engineering; Director of the Structural Dynamics Research Laboratory, University of Cincinnati	"Experimental Modal Testing Techniques"
Geof Tomlinson	Professor; Director, Division of Aerospace Engineering; Director of Research, Engineering and Physical Science Division, University of Sheffield	"Novel Approaches to Structural Damping"
Robert Nigbor	Associate Research Professor, USC	"Earthquake Simulation Testing", "Civil Structure Monitoring Examples"

Most of the lecturers spent two or three days in Los Alamos. In addition to one formal presentation to the students, visiting lecturers were asked to spend time with the students to discuss their projects, provide suggestions and provide additional motivation.

VI. Additional Lectures

In addition to the project and the lectures by and interaction with the visiting distinguished scholars, the students received instruction on a variety of topics in engineering dynamics. This instruction took the form of lecture series on fairly general topics such as random vibrations or computational structural dynamics and single lectures on more specific topics such as bridge aerodynamics. The titles of these talks are listed in Table 2.

Table 2 – Additional instruction received by the students

Title	Presenter	Title, Organization	Number of Lectures
"Rigid Body Dynamics"	Phillip Cornwell	Associate Professor, Rose-Hulman Institute of Technology	4
"A Rigid Body Dynamics Code – ADAMS"	Scott Doebling	Staff member, Los Alamos National Laboratory	1
"Signal Processing"	Norm Hunter	Staff Member, Los Alamos National Laboratory	3
"Wavelets"	Amy Robertson	Staff Member, Los Alamos National Laboratory	2
"Applications of Wavelets"	Chris Brislawn	Staff Member, Los Alamos National Laboratory	1
"Random Vibrations"	Tom Paez	Staff Member, Sandia National Laboratory	5
"Improving Your Chances of Getting Valid Data"	Bill Baker	Professor, University of New Mexico (retired)	3
"Computational Structural Dynamics"	Joel Bennett	Staff Member, Los Alamos National Laboratory	5
"Practical Application of Vibration Analysis and Testing"	Chuck Farrar	Staff Member, Los Alamos National Laboratory	3
"Confinement Vessel Blast Analysis"	Bob Stephens	Staff Member, Los Alamos National Laboratory	1
"Bridge Aerodynamics"	James Brownjohn	Associate Professor, Technological University, Singapore	1
"Satellite Testing and Analysis"	Tom Butler	Staff Member, Los Alamos National Laboratory	2
"Environmental Testing"	Norm Hunter	Staff Member, Los Alamos National Laboratory	1

VII. Assessment

Students were required to provide written feedback regarding their experiences in the summer school program. This written feedback included evaluations of each speaker, field trip, guest lecturer and a final overall evaluation of the summer school. The assessment of each speaker and guest lecturer will be used to decide which speakers to invite back next year as well as to give the individual speakers suggestions on how they can improve their contribution to the summer school. The distinguished lecturers were rated very highly with an average score of 4.51 and a median score of 4.46 on a scale from one to five where a one is “poor” and a five is “excellent.” The average rating of the speakers giving the additional lectures was a 4.13 and the median score was 4.5 using the same scale. The average score for the additional lectures was pulled down significantly by one particularly bad speaker (who will not be invited back next year). The field trips to the Aging Aircraft Facility, the MEMs Facility and the Robotics Facility at Sandia National Laboratory received ratings of 4.35, 4.70 and 4.40 respectively using the same scale discussed earlier. The average rating of the mentors was a 4.8. Based on the written comments, one of the strongest aspects of the program was the project mentors.

The last day of the summer school the students were given a final overall survey. A summary of the results from this survey is shown in Table 3. Clearly, the program benefited students educationally as well as motivating students that had not already decided on attending graduate school to do so. The fact that all 13 students would encourage someone they know to apply to the program next year is a clear testimony as to how positively the students viewed the program. As can be seen from Table 3 the average overall rating of the summer school was a 4.92, since 12 of the students gave the school a 5 (excellent) and one student rated it as a 4 (very good).

Table 3 – Summary of assessment results of the overall program

Question	Average rating
As a result of the program your knowledge and experience in experimental vibrations: (5 –Increased a great deal, 3 – Increased slightly, 1 – Stayed the same)	4.62
As a result of the program your knowledge and experience in analytical methods in vibrations: (5 –Increased a great deal, 3 – Increased slightly, 1 – Stayed the same)	4.46
If you had not already decided to go to graduate school prior to the program, did this program influence you to do so? (If you are already in graduate school or are attending one in the fall please leave blank)	5 yes, 0 no, 8 blank
Would you encourage someone you know to apply to the program next year?	13 yes, 0 no
Overall rating of the summer school? (5 – Excellent, 4 – Very good, 3 – Good, 2 – Fair, 1 – Poor)	**4.92**

When the students were asked to rate the quality of the teamwork in their groups, two of the groups averaged a score of 5, one had an average of 4.66 and the final group had an average of 2.33. It was later discovered after reviewing these numbers that the group that rated the teamwork very low had one group member that did not fully participate in the project. Unfortunately the program coordinator and mentor did not diagnose this problem earlier in the summer. A greater effort will be made in future years to diagnose the health of the groups early in the summer. It is interesting to note that even though two of the students were extremely frustrated with their remaining team member, they still rated the summer school as excellent.

VIII. Selected Quotes

The following quotes were obtained from the final survey of the students.

- "Overall the LADSS was the best engineering experience I have had. It definitely reaffirmed my desire to pursue advanced degrees in engineering."
- "As a graduate student, the concepts/background in structural dynamics that I learned during the summer school were of great importance and provided me with great motivation to continue graduate work in the field of NDT."
- "Thanks for a great summer."
- "Thanks guys! Awesome summer. Really opened my eyes to graduate school and all the things I can look forward to learning."
- "What a great opportunity! This was the best summer I've spent at LANL. I learned a ton."
- "I enjoyed the camaraderie of the students."
- "It's the closest thing I've done to real engineering problem solving."
- "Great project. I learned a lot."
- "Overall best experience I've had here (at LANL) yet."

Even though the overall assessment of the program was overwhelmingly positive, there were a number of suggested improvements. These primarily had to do with the ordering of the lectures, the lecture times, the limited or mildly inadequate experimental or computer equipment, and the relatively rare poor lecturer.

It is the authors' opinion that the success of the program was due to a number of factors including:

1. The quality of the students
2. The projects being relatively well defined at the beginning of the summer
3. The team nature of the projects
4. The already existing infrastructure at the lab for dealing with student programs
5. The overall quality of the mentors, distinguished lecturers and the other speakers.

IX. Conclusions

An eight-week dynamics summer school was developed and implemented at Los Alamos National Laboratory. The program appears to have achieved its primary goals of motivating undecided students to go to graduate school, of introducing a talented group of engineering students to both analytical and experimental engineering structural dynamics and of making them aware of career opportunities at national laboratories such as Los Alamos, Sandia and Livermore National Laboratory. The students rated the summer school as excellent and every student indicated they would encourage someone they knew to apply to the summer school.

Bibliography

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PHILLIP J. CORNWELL

Phillip Cornwell is an Associate Professor of Mechanical Engineering at Rose-Hulman Institute of Technology. He received his B.S. from Texas Tech University in 1985 and his M.A. and Ph.D. from Princeton University in 1987 and 1989 respectively. His present interests include structural dynamics, structural health monitoring, and undergraduate engineering education. Dr. Cornwell has received several awards including the 1990 ASME Aerospace Division Award, an SAE Ralph R. Teetor Educational Award in 1992, Teacher of the Year from a Rose-Hulman student group in 1994 and the Dean's Outstanding Teacher award in 2000.

CHARLES R. FARRAR

Chuck Farrar has 18 years experience as a technical staff member, project leader, and engineering mechanics team leader at Los Alamos National Laboratory. While at Los Alamos, he earned a Ph. D. in civil engineering from the University of New Mexico. His current research interests focus on the application of statistical pattern recognition algorithms to structural health monitoring. Dr. Farrar has been the project leader for a number of large-scale structural dynamics test programs and has been actively involved in field investigations of damage sustained by lifeline systems after earthquakes. He also teaches mechanical vibrations and dynamics at the University of New Mexico's Los Alamos Branch and has developed a short course on structural health monitoring.