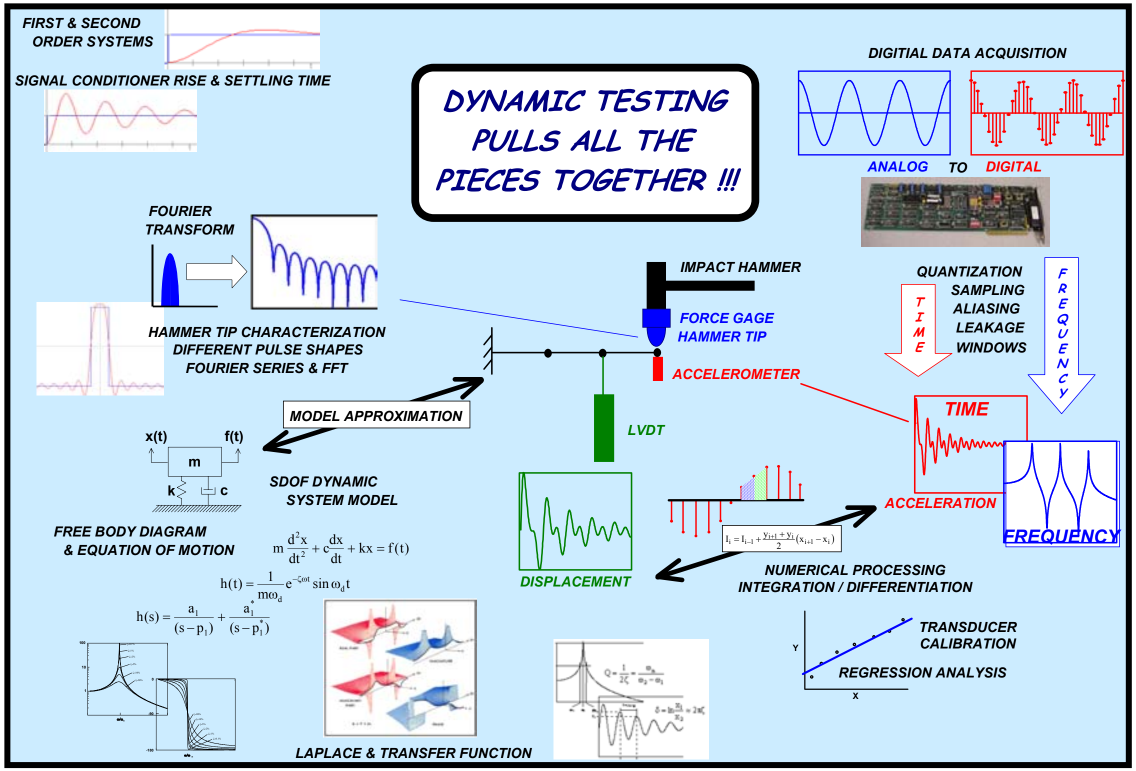
Developing a Multisemester Interwoven Dynamic Systems Project to Foster Learning and Retention of STEM Material



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The Problem

Students generally do not understand how basic STEM (Science, Technology, Engineering and Math) material fits into all of their engineering courses

Relationship of basic material to subsequent courses is unclear to the student.

Practical relevance of the material is not clear.

Students hit the "reset button" after each course not realizing the importance of STEM material

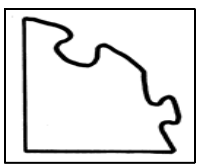
The Problem

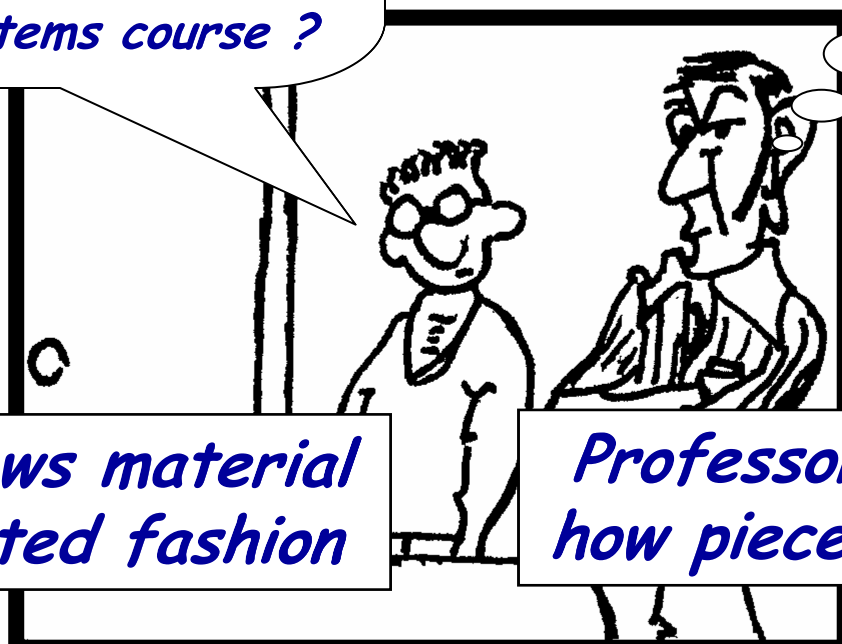
Student Comment:

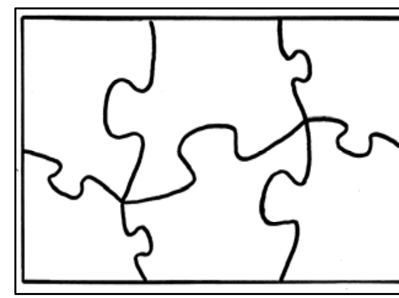
Professor, why didn't you tell us that the material covered in other courses was going to be really important for the work we need to do in this Dynamic Systems course ?

Professor Thoughts:

Hmmmmm...







Student views material in a disjointed fashion

Professor clearly sees how pieces fit together

How to Solve the Problem

A new multisemester interwoven dynamic systems project has been initiated

This is to better integrate the material from differential equations, mathematical methods, laboratory measurements and dynamic systems

This is done across several semesters/courses to help students better understand the relationship of basic STEM material to an ongoing problem

Goals & Objectives

DYNamic SYStems

- *Develop a project which spans across several semesters & courses to interweave related STEM material in a coherent fashion – strongly emphasizing the inter-relationship*

  - *Simple RC Circuit*
  - *Single SDOF System*

Cornerstone of Knowledge

- *Suggested for first evaluations*
- *These are generic to <u>all</u> engineering disciplines in that they exemplify 1st and 2nd order systems*

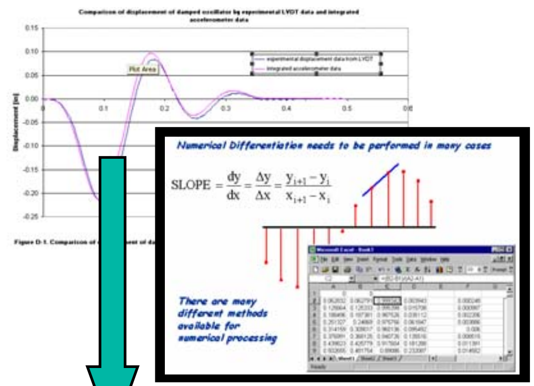
What Needs to be Addressed

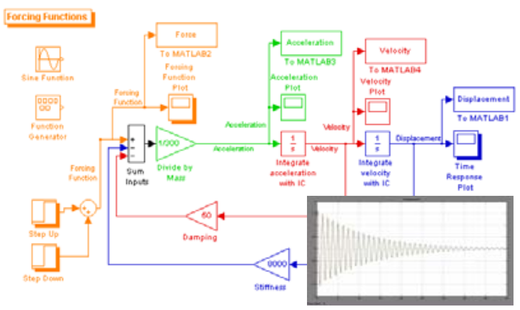
Interwoven, multi-semester problem features:

- Differential equations & numerical processing
- Fourier/Laplace transformations
- Instrumentation/signal processing/calibration
- Analog & digital data acquisition systems
- Time & Frequency data
- Impulse response & frequency response
- Rise time & settling time

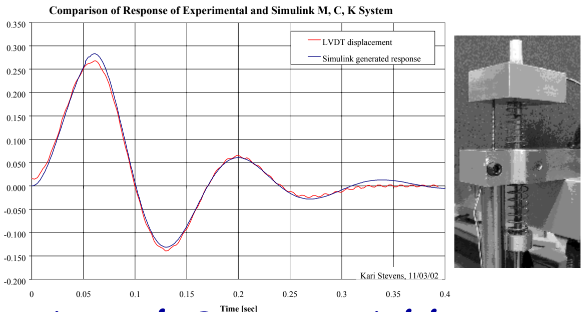
Components of Integrated Project

Numerical Tools with Attention to Real Measurements

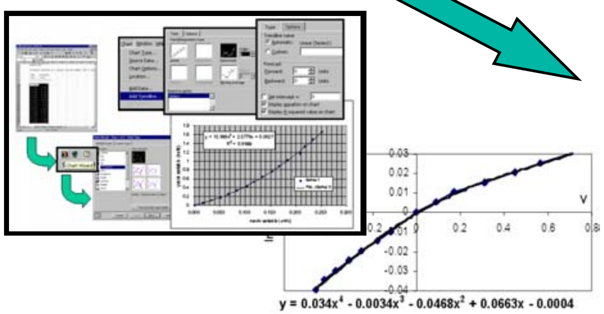




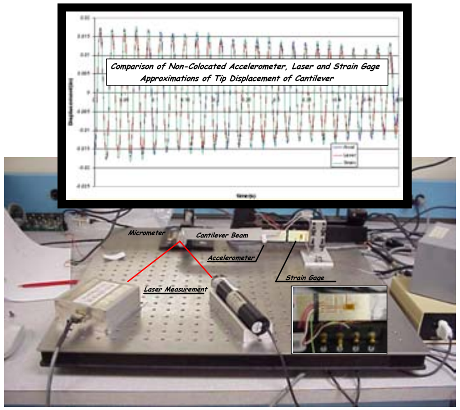
Analytical Tools Required



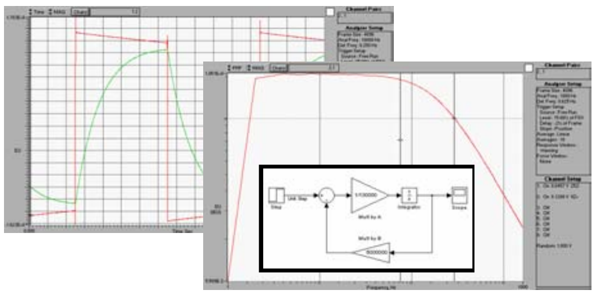
Actual System Addresses Real Measurement Problems



Mathematical Methods



Experimental Problem Integrates STEM Material



Filtering Integrates First Order Systems

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Mechanical Engineering Department

Scope of the Complete Project

Phase 1 — Develop analytically oriented material to address the problems and techniques for solving dynamic system problems. The intent is to provide analytical tools but also address the anticipated problems encountered in a real measurement environment

Phase 2 — Develop experimentally oriented acquired data that extends the application of previously identified analytical techniques and addresses measurement issues associated with collecting real world data

Phase 3 — Implement materials generated in another discipline and another institution. Modify and enhance of all materials based on feedback

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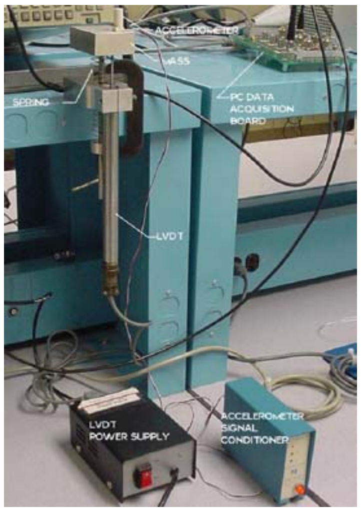
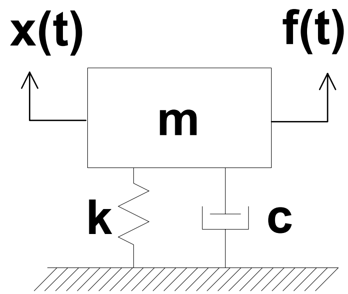
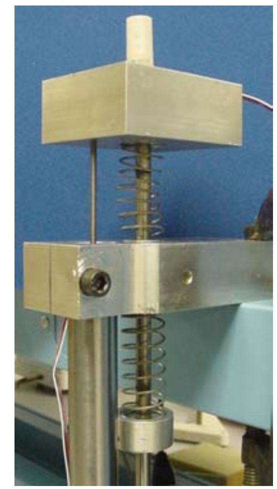
MCK Measurement System

A simple mass, spring, dashpot system is used to measure displacement and acceleration







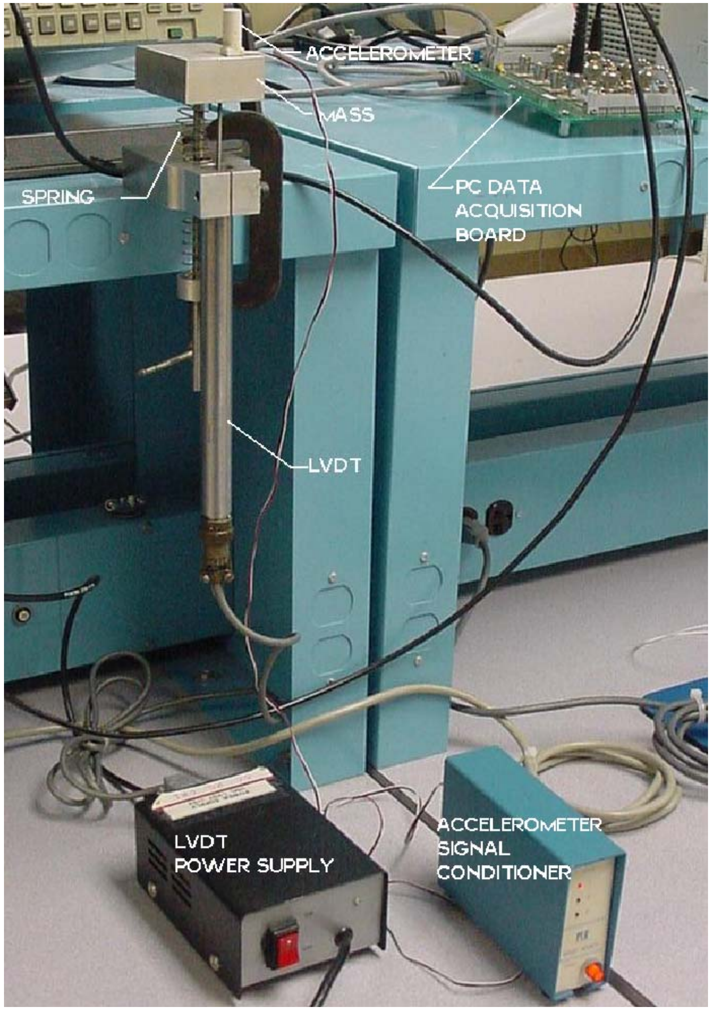
Numerical processing of integration/differential needed to process data

MCK Measurement System

Requires extensive use of a wide variety of different analytical tools.

Significant numerical data manipulation needed.

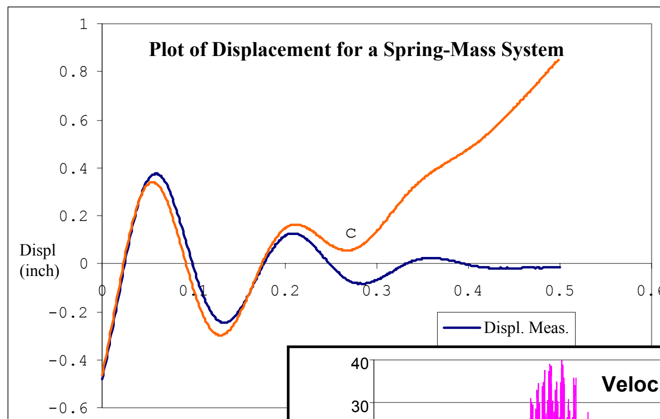
- Regression Analysis
- Data Cleansing
- Integration
- Differentiation

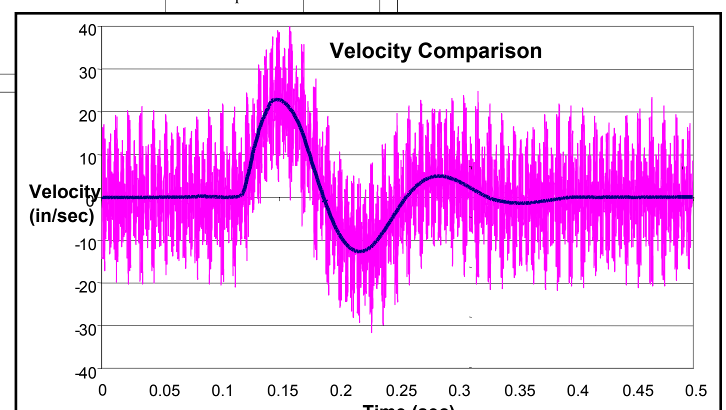


MCK Measurement System

The data acquisition system and transducers are intentionally selected such that the majority of possible errors exist in the data

- Drift
- Bias
- Offset
- Quantization
- Noise

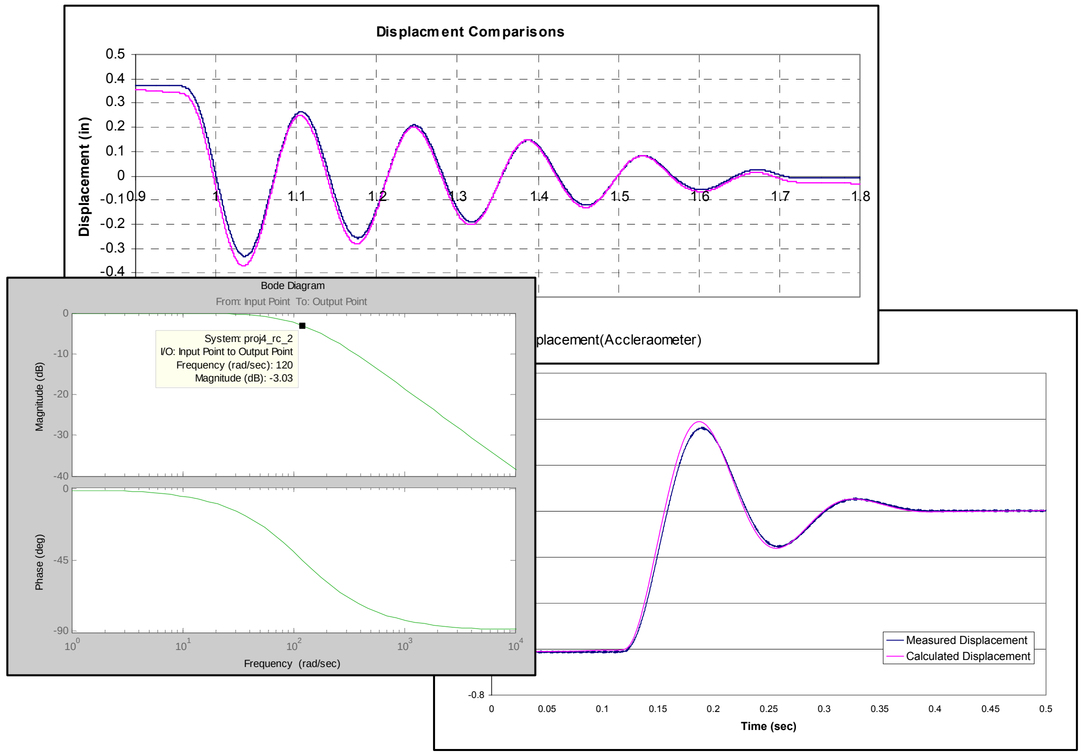




MCK Measurement System

The students are forced to integrate key STEM material and concepts to solve this problem

- Numerical processing
- Filtering
- Thinking is required !!!



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What Has Been Addressed To Date

Several tutorials have been developed related to aspects of dynamic system response evaluation

MATLAB scripts utilizing a simple graphical user interface (GUI) emphasizing the inherent aspects of 1^{st} and 2^{nd} order system response developed

LABVIEW modules were also developed

Voice annotated tutorials being finalized

Dr. Peter Avitabile, Associate Professor
Mechanical Engineering Department

What Has Been Addressed To Date

Theoretical Aspects of First and Second Order Systems

First Order Systems – Modeling Step Response with ODE and Block Diagram

Second Order Systems – Modeling Step, Impulse, and Initial Condition Responses with ODE and Block Diagrams

Mathematical Modeling Considerations

Simulink and MATLAB Primer Materials

Miscellaneous Materials

Some examples are illustrated on the following sheets

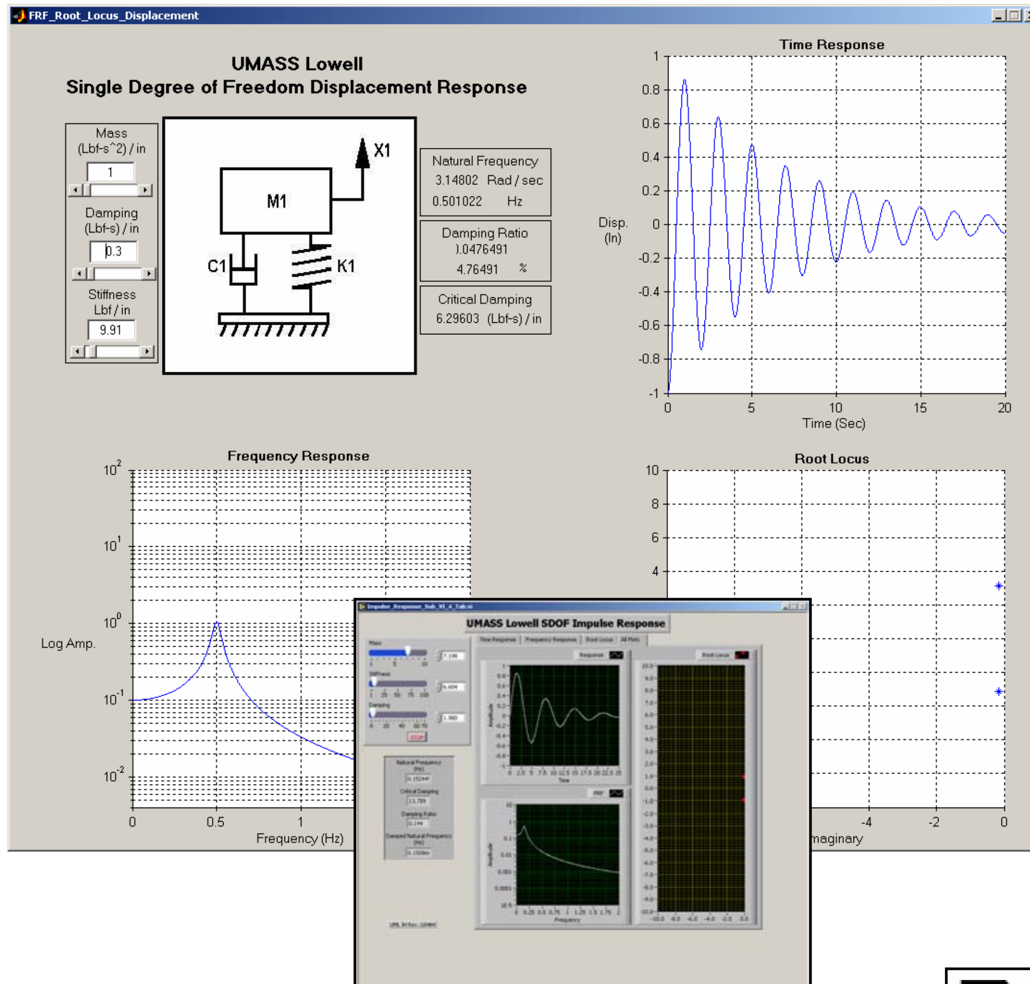
2nd Order System Initial Condition GUI

DYNamic SyStems

User enters M, C, K and natural frequency, critical damping and damping are reported.

User can vary the physical parameters with slide bars.

The frequency response function magnitude is displayed root locus and time response.



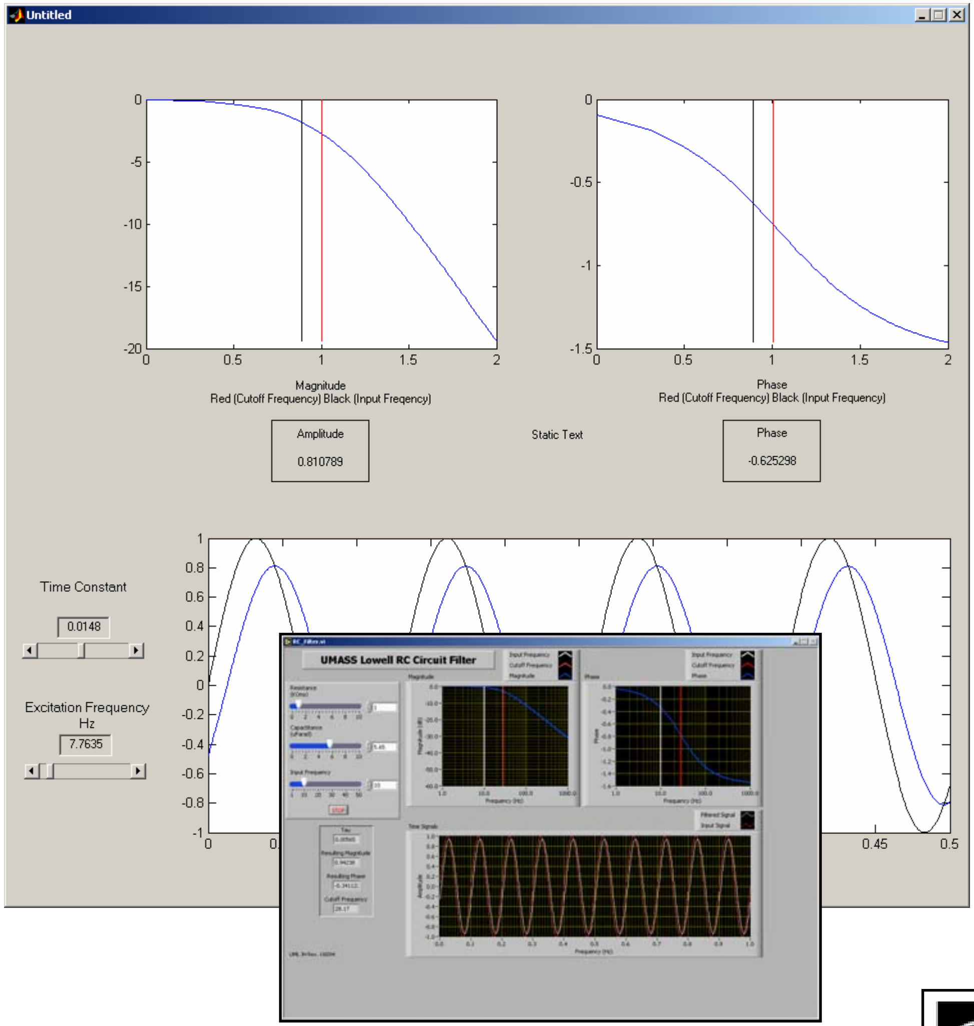
UMASS LOWELL

First Order Low Pass Filter GUI

User enters time constant and sinusoidal frequency.

The Bode plot is displayed with the cutoff frequency and the sinusoidal frequency applied.

The initial sinusoidal signal and "filtered" time signal are also displayed.



Fourier Series Signal Generation GUI

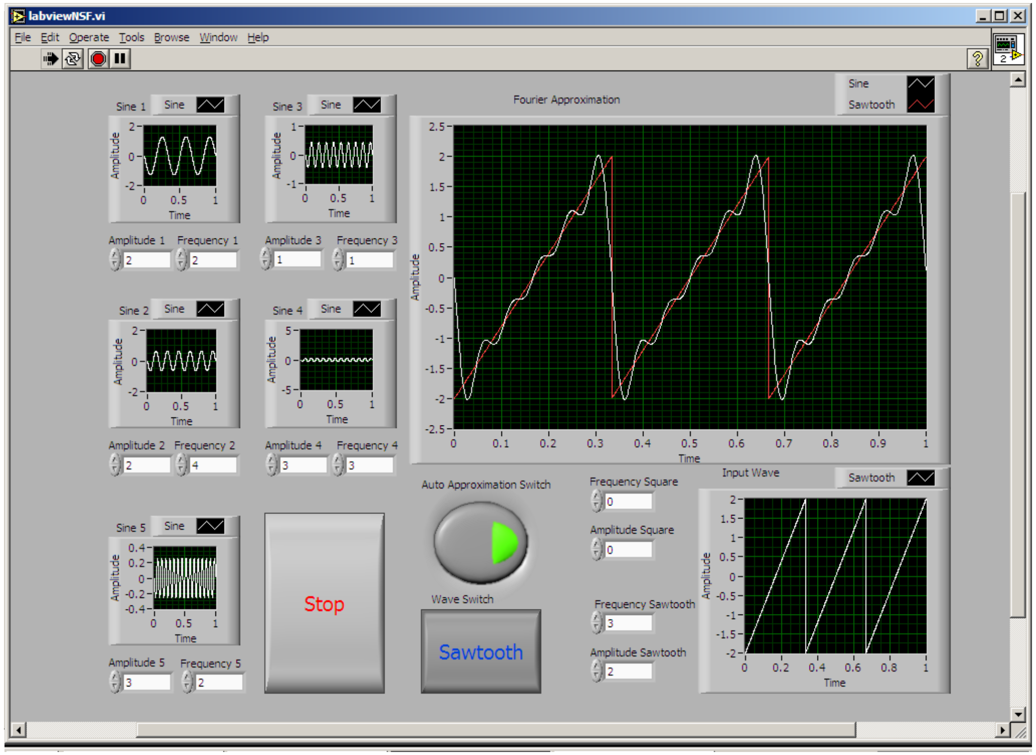
DYNamic SYStems

User enters frequency, amplitude and phase components of a user defined signal to display the resulting signal.

The user can also select sample signals such as square, triangle, etc and the pre-determined fourier coefficients are applied to the user-defined signal.

The time signal as well as the corresponding frequency component is displayed.

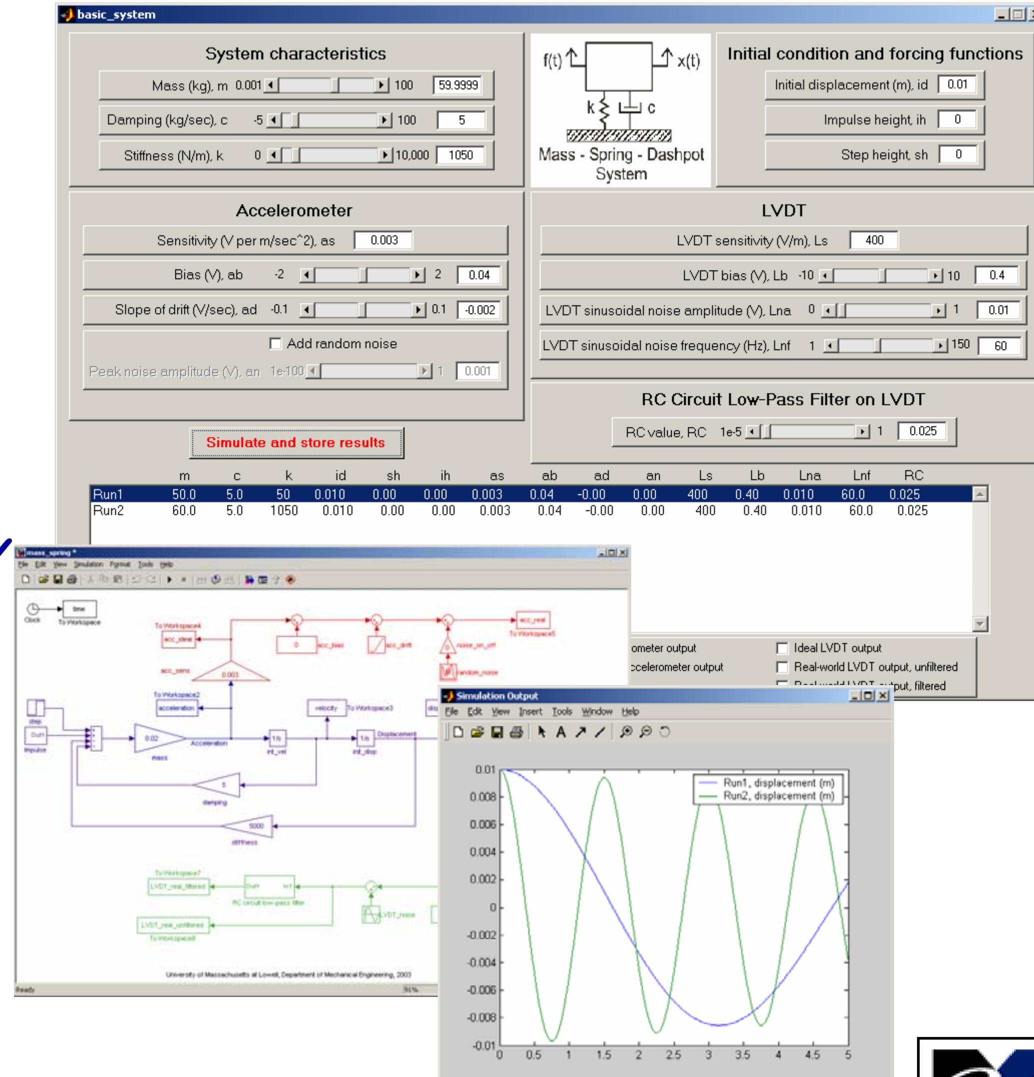
Labview GUI
MATLAB GUI



Virtual Measurement System GUI

User enters M, C, K system. User enters the amount of experimental distortion on the accel. (sensitivity, bias, drift) and displacement LVDT (sensitivity, bias, noise) and the low pass filter characteristics to virtually "simulate" the measurement environment.

Data can be exported with ability to select which outputs and what effects are included on the measurement.



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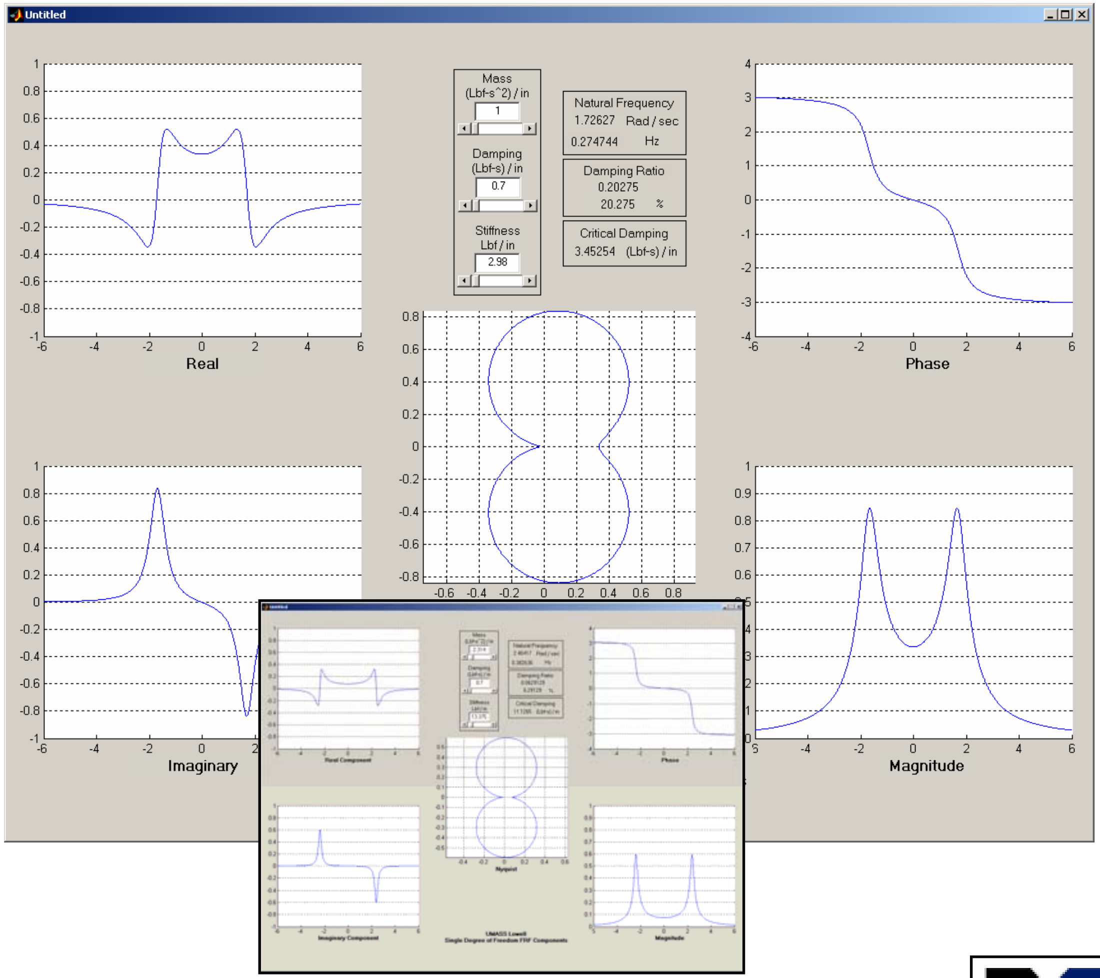
Single DOF Complex FRF Plot GUI

User enters M, C, K and natural frequency, critical damping and damping are reported.

User can vary the physical parameters with slide bars.

The complex frequency response function is displayed simultaneously as real, imaginary, magnitude, phase and nyquist plots.



Start MATLAB GUI

Webpage --- dynsys.uml.edu

Project Overview

Technical Papers

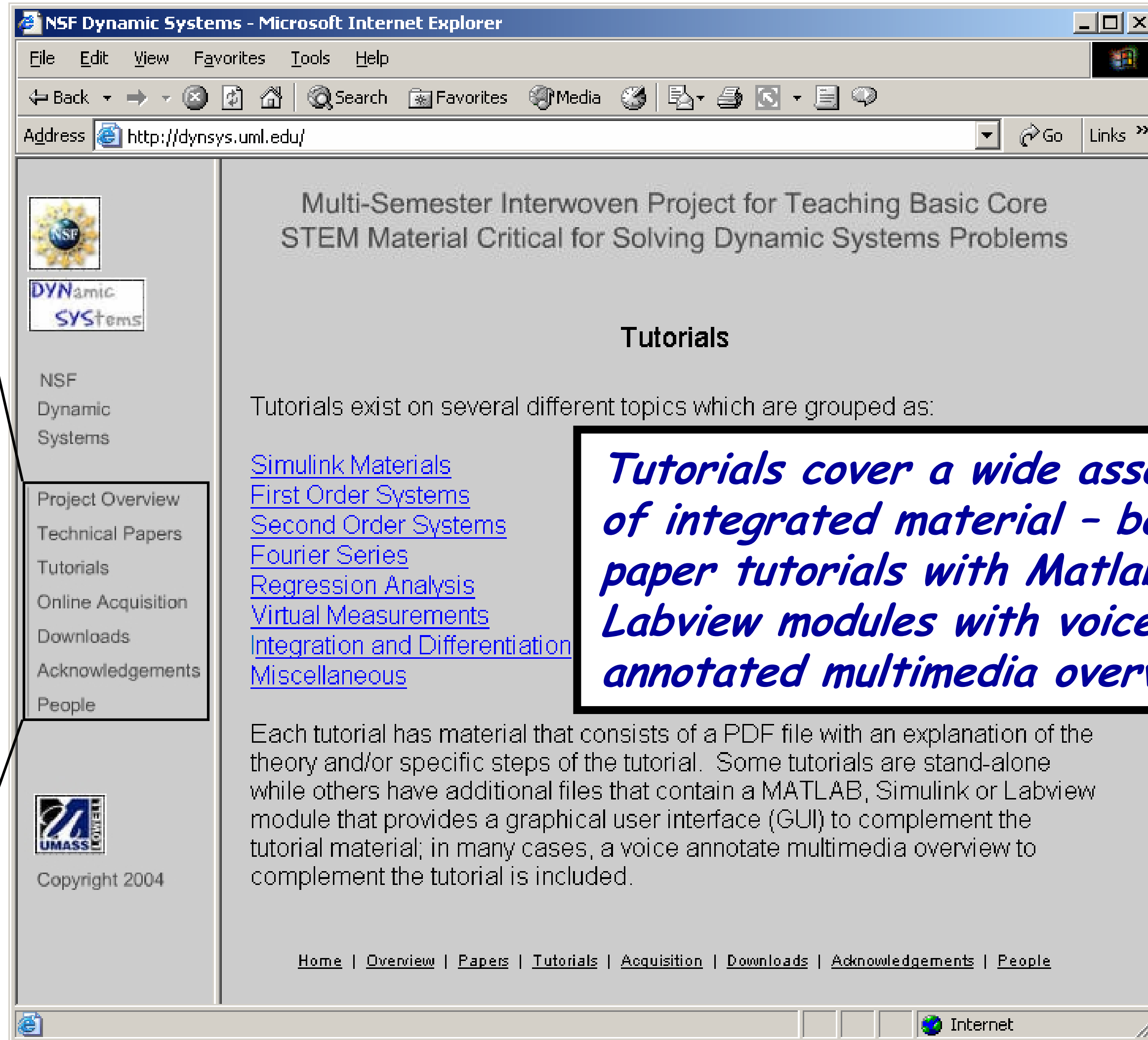
Tutorials

Online Acquisition

Downloads

Acknowledgements

People

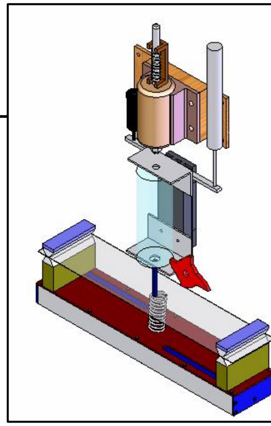


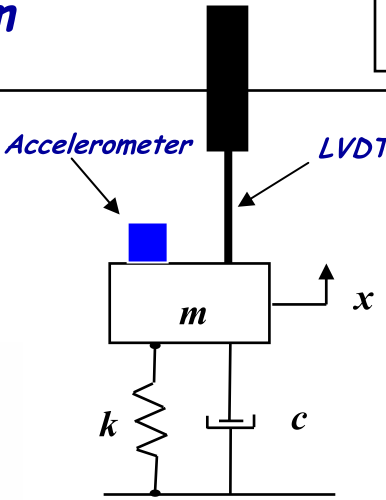
Tutorials cover a wide assortment of integrated material – both paper tutorials with Matlab and Labview modules with voice annotated multimedia overviews

Online Measurement System

RUBE

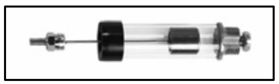
Response Under Basic Excitation





Measurement Devices

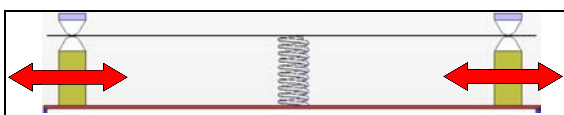
Variable Damping



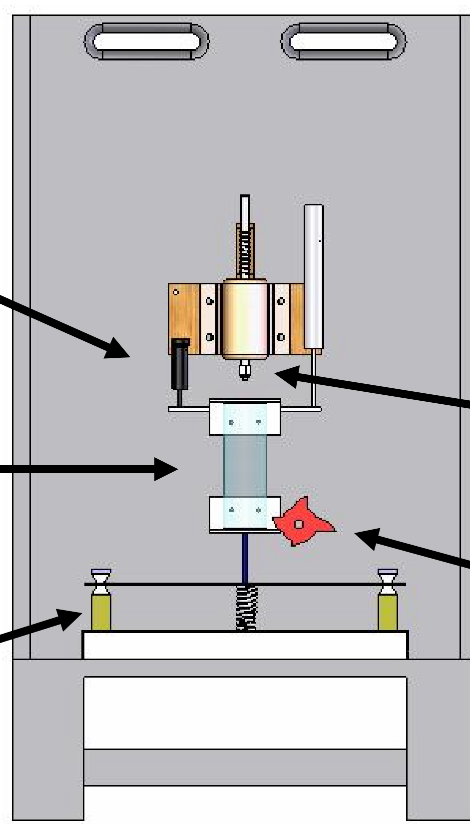
Variable Mass

System Characteristics

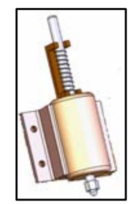
Variable Stiffness



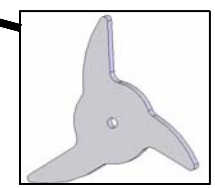
$$k_{EQ} = k_{LEAF} + k_{COIL}$$



Excitation

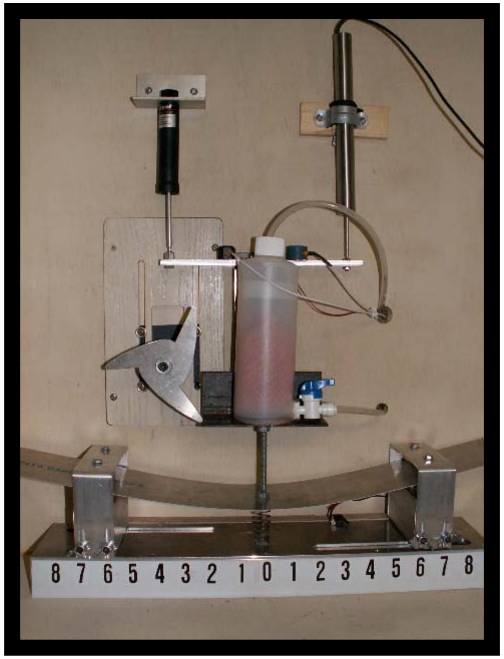


Impact Force

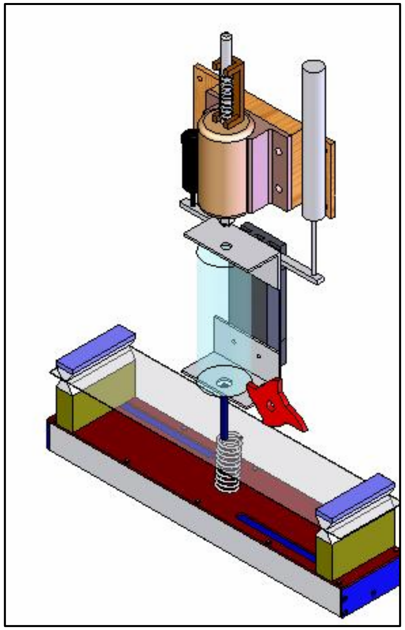


Initial Displacement

Online Measurement System



RUBE I



RUBE

Response Under Basic Excitation

RUBE II

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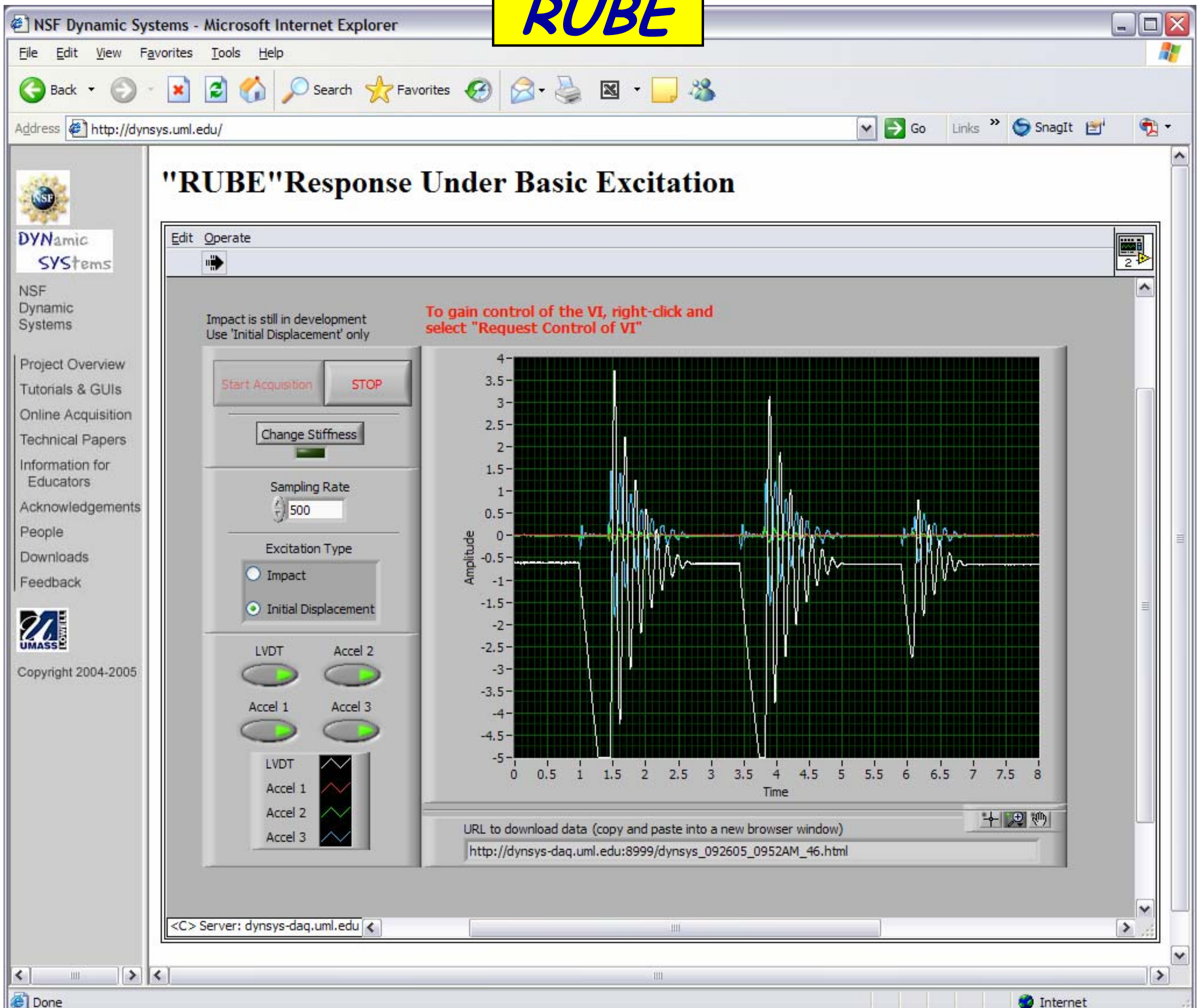
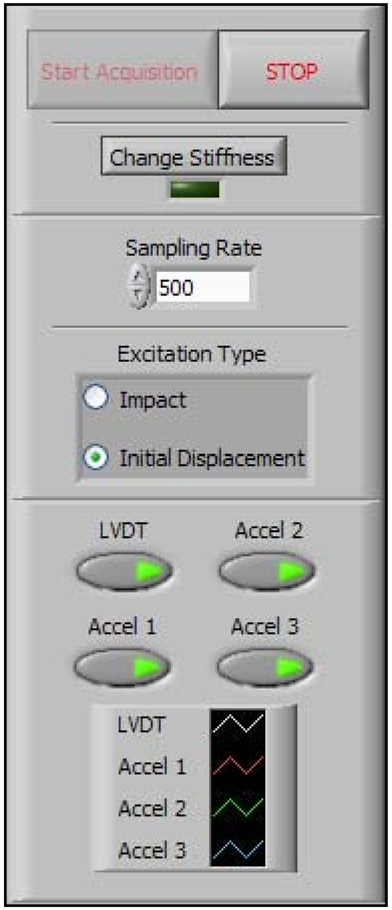
Online Measurement System

RUBE



RUBE



System can be remotely run

Stiffness is changed for each run

Sampling rate can be set

Impact is available
Initial displacements – three inputs

LVDT and accelerometers can be turned on and off as desired

Data saved and captured to browser

URL to download data (copy and paste into a new browser window)
http://dynsys-daq.uml.edu:8999/dynsys_092605_0952AM_46.html

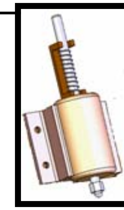
Online Measurement System - Sequence

DYNamic SyStems

Initialize Virtual Interface

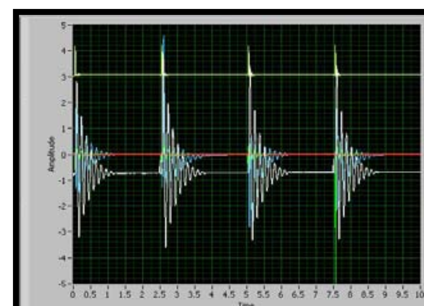
Change Stiffness

Impact or Initial Displacement

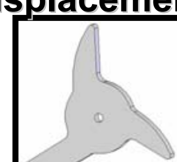


Start Acquisition

Acquire Data



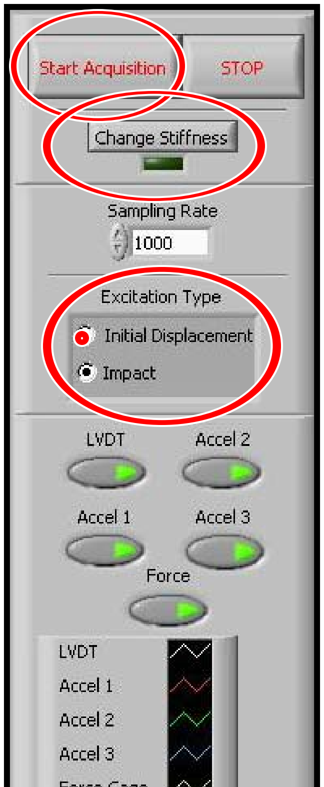
Initial Displacement



Start Acquisition

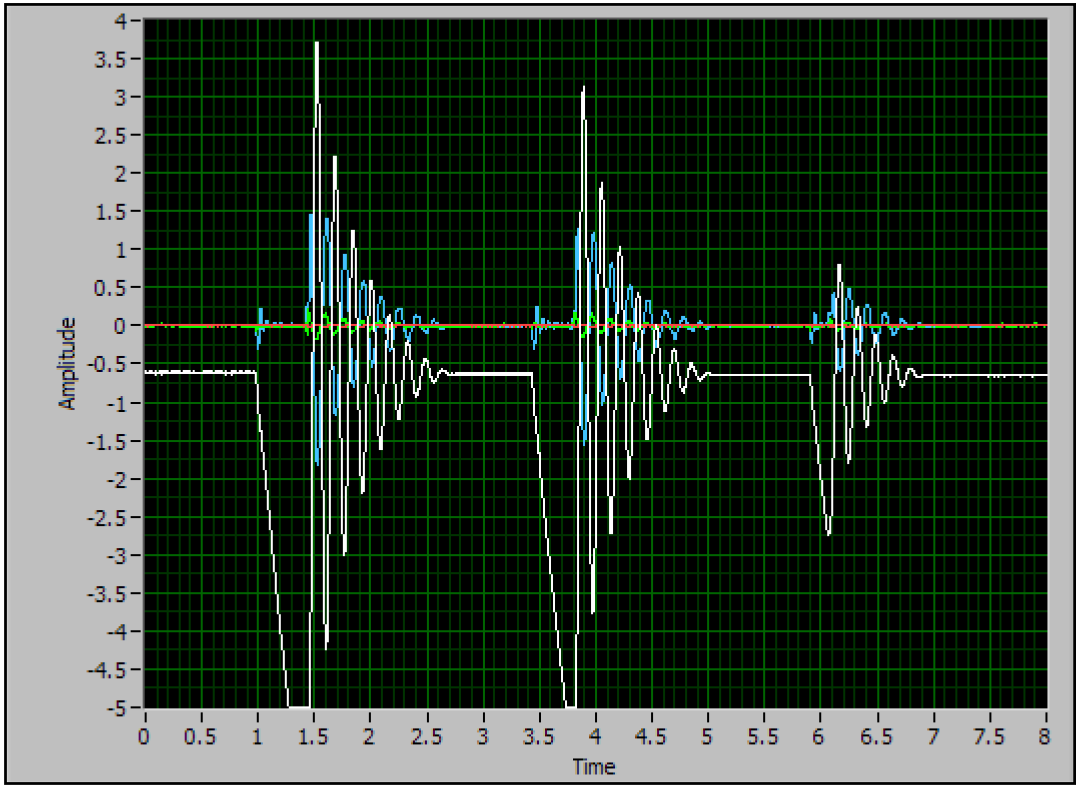
Acquire Data

Cam Switch Depressed Shutting off Motor



RUBE

Data has different contaminants that distort data



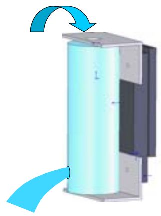
Online Measurement System Variation

	Highest	Lowest	Percent Change	Percent change of Damped Natural Frequency
Damping Ratio	0.06	0.03	50%	2.30%
Mass	.134 slug	.115 slug	14%	6.70%
Stiffness	11.5 lbf/in	9.68 lbf/in	16%	8.00%
Damped Nat. Freq.	4.5 Hz	5.6 Hz	20%	N/A

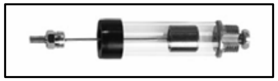
Online Measurement System Variation

System Characteristics

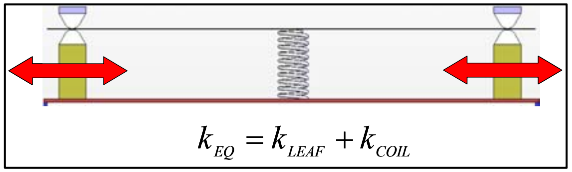
Variable Mass



Variable Damping



Variable Stiffness



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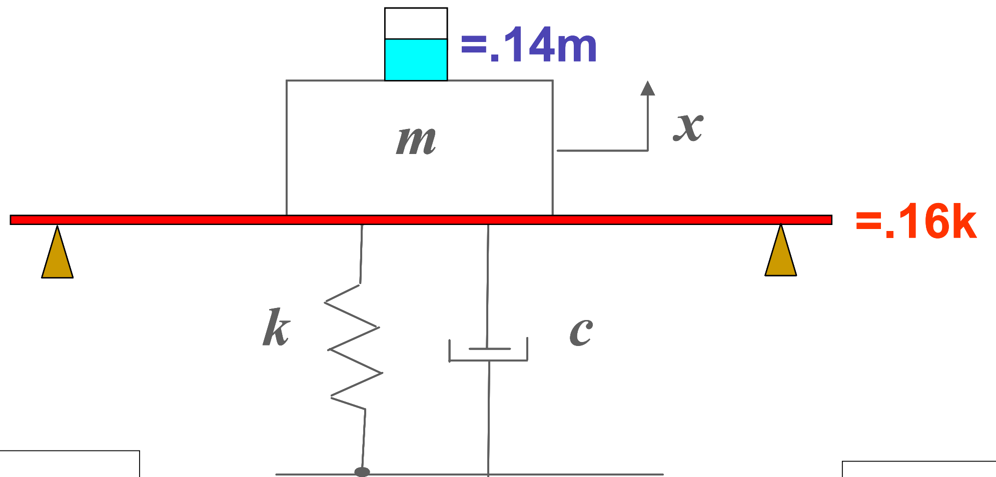
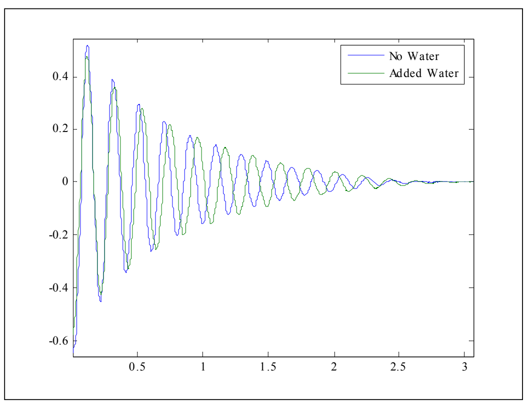
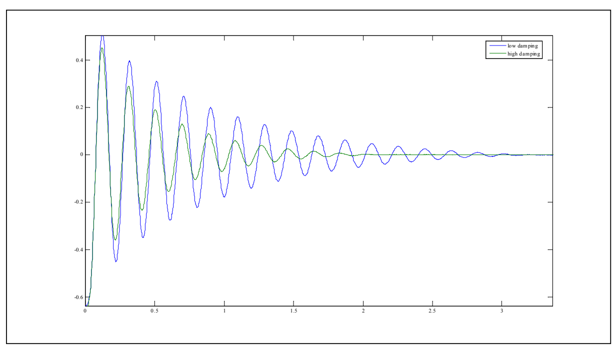
Stiffness	11.5 lbf/in	9.68 lbf/in	16%	8.00%
Damped Nat. Freq.	4.5 Hz	5.6 Hz	20%	N/A

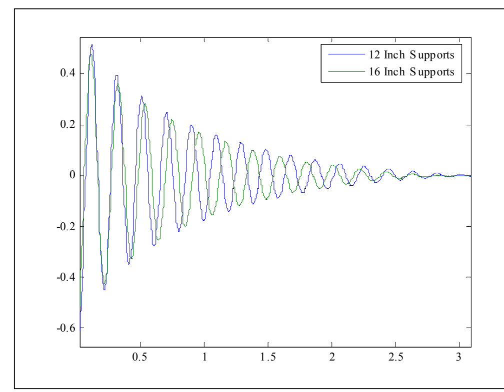
Online Measurement System Variation

$$4.5\,Hz < f_n < 5.7\,Hz$$









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Implementation of Materials Generated

Materials implemented at UMASS Lowell in the Mechanical Engineering Department

- 22.361 Numerical Methods for ME
- 22.302 Mechanical Engineering Lab I
- 22.403 Mechanical Engineering Lab II
- 22.451 Dynamic Systems
- 22.457 Vibrations

as well as in the Mathematics Department

- 92.236 Differential Equations

Implementation of Materials Generated

Materials implemented at UMASS Lowell in the Chemical Engineering Department

10.303 Fluid Mechanics

10.315 Unit Operations Lab

10.317 Applied Problem Solving Course (MATLAB)

10.415 Process and Controls Lab

as well as in the Mathematics Department

92.236 Differential Equations

Implementation of Materials Generated

Materials implemented at Michigan Tech in the Mechanical Engineering Department

- ***MEEM3000 Mechanical Laboratory Sequence***
- ***MEEM3700 Vibrations***
- ***MEEM4700 Controls***
- ***MEEM4701 Experimental Structural Dynamics***

Some General Observations

Specific evaluations for all the implemented materials for all the courses were not available at the time of the paper submission.

These will be published in a future ASEE paper.

Some general student's statements are useful for overall comments that thread a theme through the implementation of this material.

Some General Observations

The integration of the material (threaded as a theme) through the courses helped the student to understand the inter-relationship of material

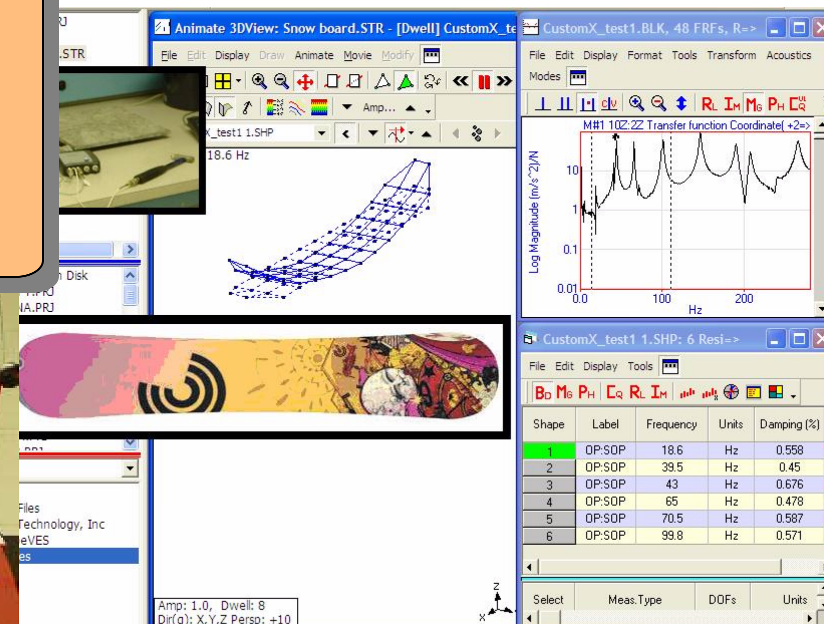
The MATLAB and LabVIEW GUIs helped to solidify general concepts taught in the prerequisite courses

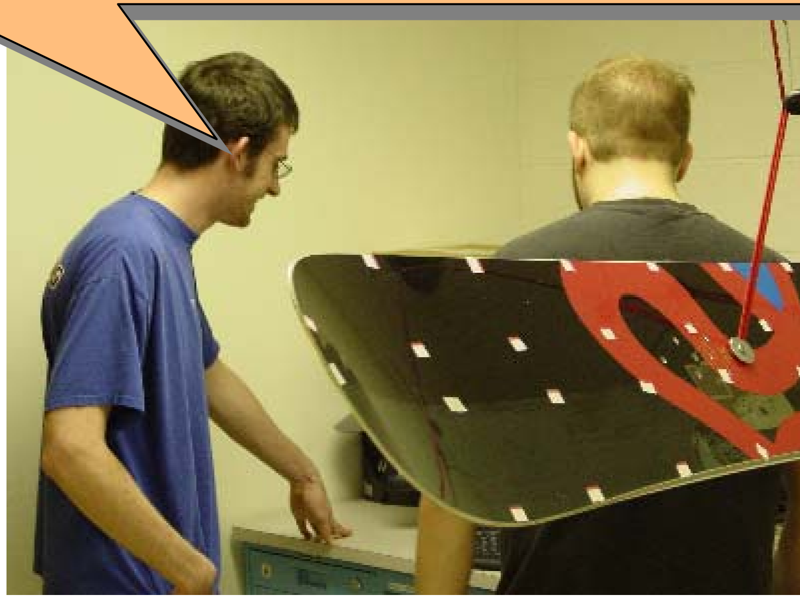
The hands-on application provides reality

The open-ended project with messy data forced students to take ownership of the problem, sort through the problem and think!

Pay attention now – this snowboard is nothing more than a BIG differential equation – you need to know these ODEs to solve these types of problems

important to future
urses





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Summary

A new multisemester interwoven dynamic systems project was described.

Several tutorials and modules developed were presented.

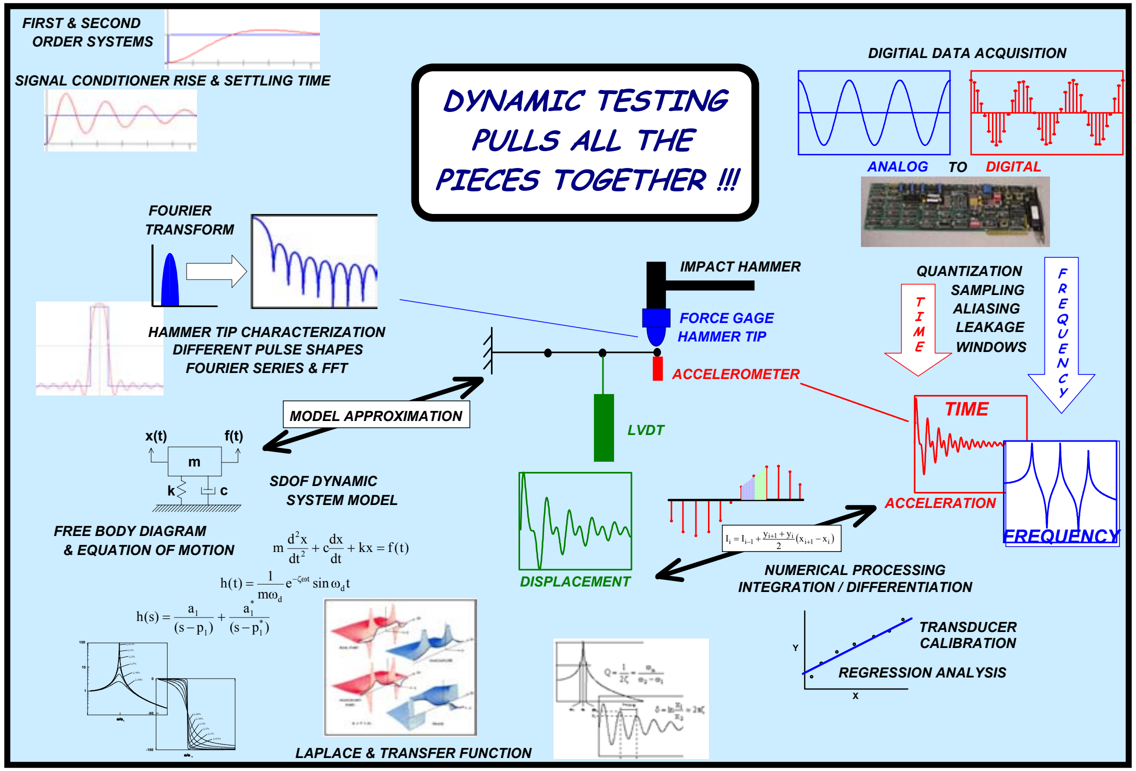
Summary

The salient feature of the project is that material from various courses such as differential equations, mathematical methods, laboratory measurements and dynamic systems is integrated in a fashion that helps the students understand the need for basic STEM (Science, Technology, Engineering and Mathematics) material.

Acknowledgements

This project is partially supported by
NSF Engineering Education Division Grant EEC-0314875

Multi-Semester Interwoven Project for Teaching Basic Core STEM Material Critical for Solving Dynamic Systems Problems



Peter Avitabile, John White, Stephen Pennell

Acknowledgements

A special thanks to the students who have really been the driving force in making all this happen

Tracy Van Zandt, Nels Wirkkala,
Wes Goodman and Jeffrey Hodgkins
Mechanical Engineering Department
University of Massachusetts Lowell

I could not have done any of this without their dedication and devotion to making this all happen

I have the pleasure of working with them and having them contribute to this effort

Acknowledgements

And to the undergraduate students
who have also participated

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Aaron Williams, Chris Chipman
Mechanical Engineering Department
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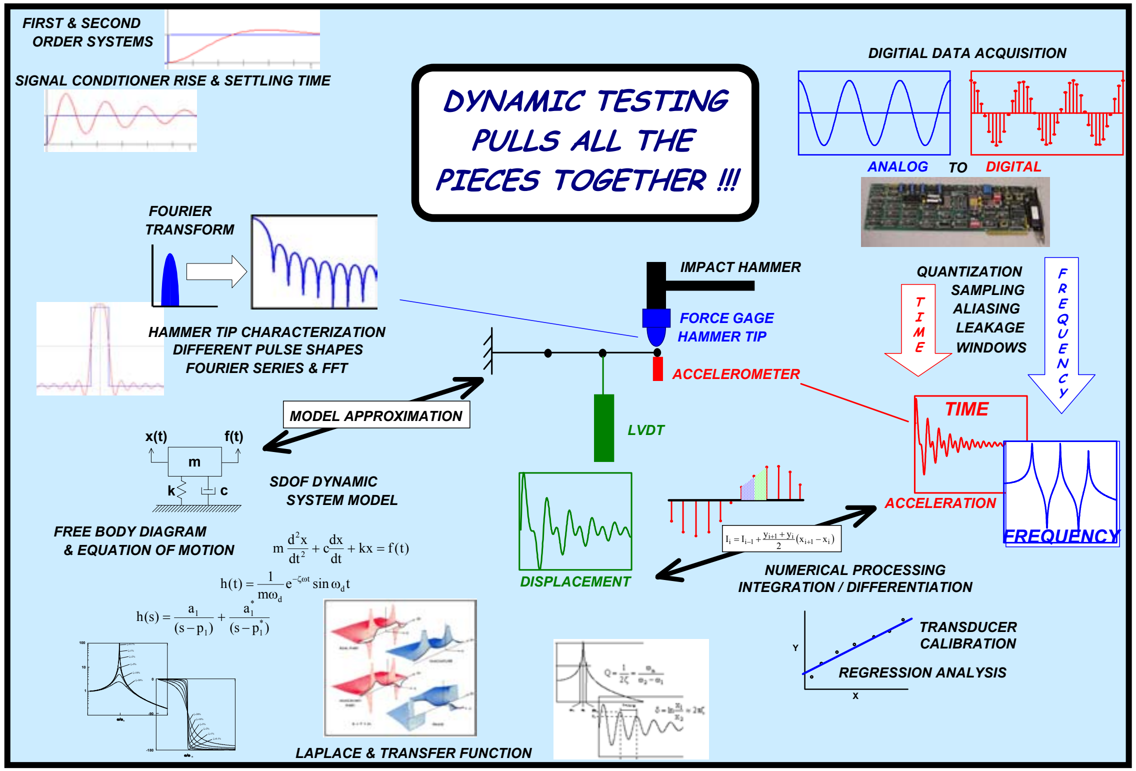
This past year have also
made significant contributions
to the overall project

I am very happy for their
continued support and dedication

Developing a Multisemester Interwoven Dynamic Systems Project to Foster Learning and Retention of STEM Material



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