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Coupling High Fidelity Computations in Teaching in Aerospace, Mechanical, Biomedical and Electrical Engineering Fields: Case Study using MSC

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SpaceED UCD

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MSC Software

OUTLINE

- Background and Motivation: (High Fidelity Simulations and MSC)
- Approach
- Courses:
- Finite Elements in Structures
- Structural Dynamics and Aeroelasticity
- Computational Methods in Nonlinear Mechanics
- Student Design Projects
- Flight Testing
- CASE STUDY: Fluid Structure Interaction using MSC DYTRAN
- Concluding Remarks
- Acknowledgements : All my students and MSC team

Courses:

Finite Elements in Structures; Structural Dynamics and Aeroelasticity
Computational Methods in Nonlinear Mechanics; Student Design Projects; Flight Testing. Applications to Biomedical, Aerospace, Electrical, Mechanical Engineering

Abstract:

This paper is based on the author's experience over a decade using high fidelity computational tools in teaching undergraduate and graduate level courses. The courses are Computational Methods in Nonlinear Mechanics; Advances in Finite Elements and Optimization; Structural Dynamics and Aeroelasticity; Finite Elements in Structures; and Flight testing of no-human on board vehicles. The approach taken is uniform in that the lectures cover the fundamental concepts relevant to each subject. Students are not allowed to use high fidelity tools for solving regular homework sets in which they acquire the theoretical background. In addition to these regular homework assignments there are computer labs at undergraduate courses in which students use NASTRAN, PATRAN, FLIGHT LOADS, and DYTRAN. In graduate classes there are no formal labs; however students may use these tools to work on their term papers. Student body in the graduate classes come from Mechanical, Aerospace, Biomedical and Electrical Engineering programs in which the author is a faculty member of these graduate groups. Flight test course uses these high fidelity tools in a way that after the design and analysis, manufacture/actual flight tests are conducted at the Scaled Model Aerospace Research and Testing Laboratory (SMARTLAB) facilities. Based on student questionnaire and the letters send by the students from their first jobs following graduation; the approach used in teaching clearly benefits students. This is because their newly acquired knowledge is reinforced by usage of the high fidelity computational tools. Details of laboratory assignments as well as samples from term papers and flight test will be provided. Coupling high fidelity computational tools in teaching made students familiar with the state-of-the art techniques, and increased students' interest in these subjects. Many continued their thesis/dissertation research.

Background and Motivation

Roadmap to Coupling High Fidelity Computations

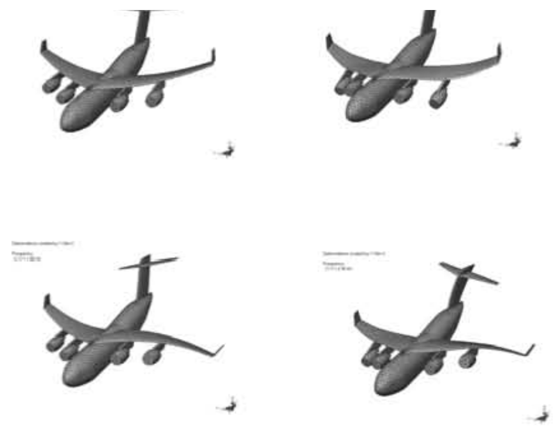
Fundamentals and regular Assignments

followed by high fidelity computational tools:
NASTRAN, PATAN, DYTRAN, FlightLoads

Computational Laboratory Experience

Term Paper Experience

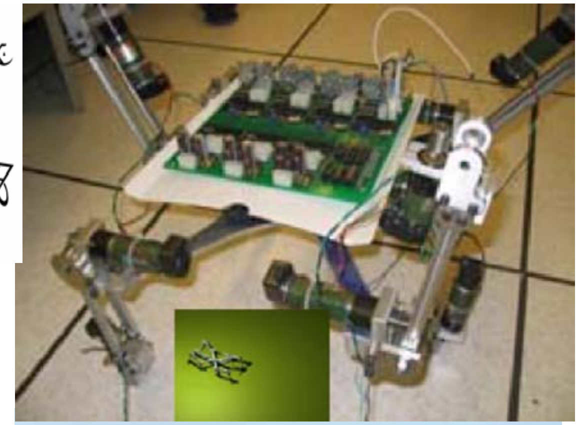
Degree Research Experience



Free Vibration Response

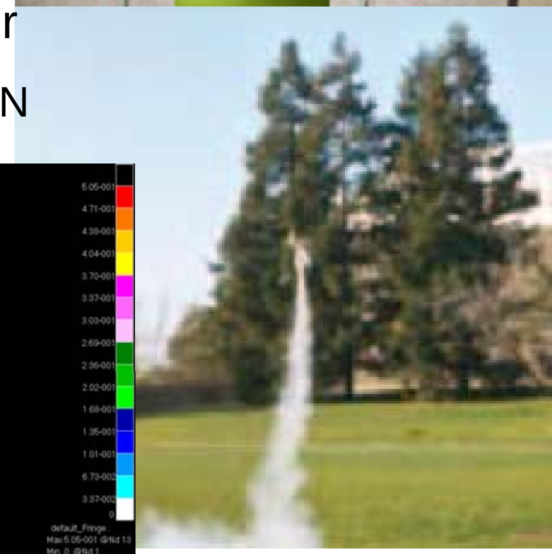
Unmanned Vehicles Design Study :

(Scaled Model Aerospace Research and Testing Laboratory, SMARTLAB))

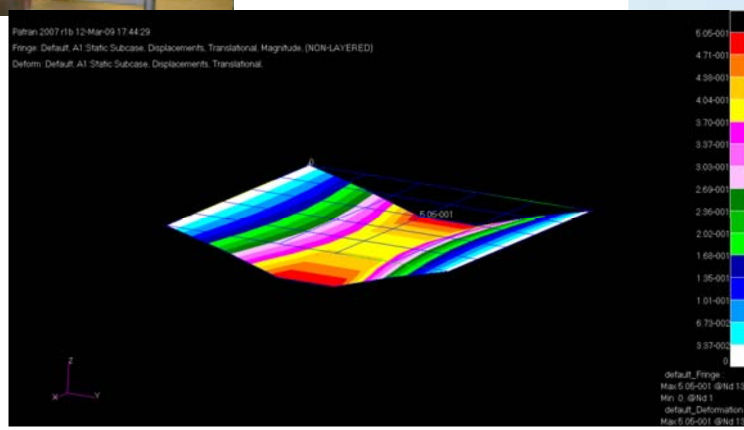


Vibrations; Flutter

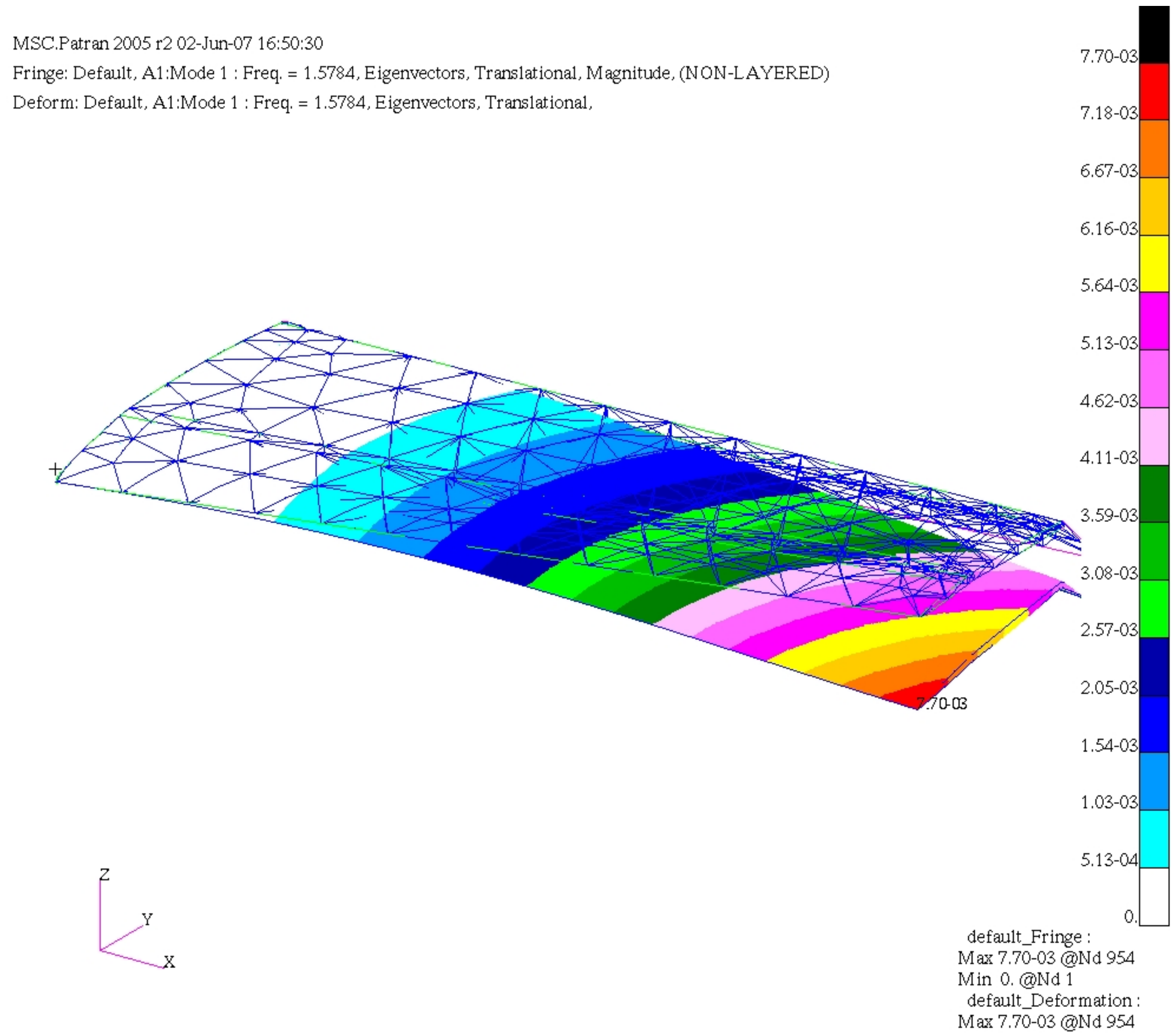
NASTRAN,PATRAN

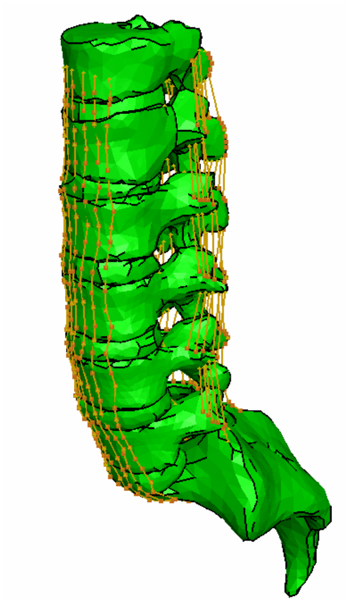


Graduate Students thesis research and Design Competitions/ Research



vibration study: Mechanical and Biomechanics





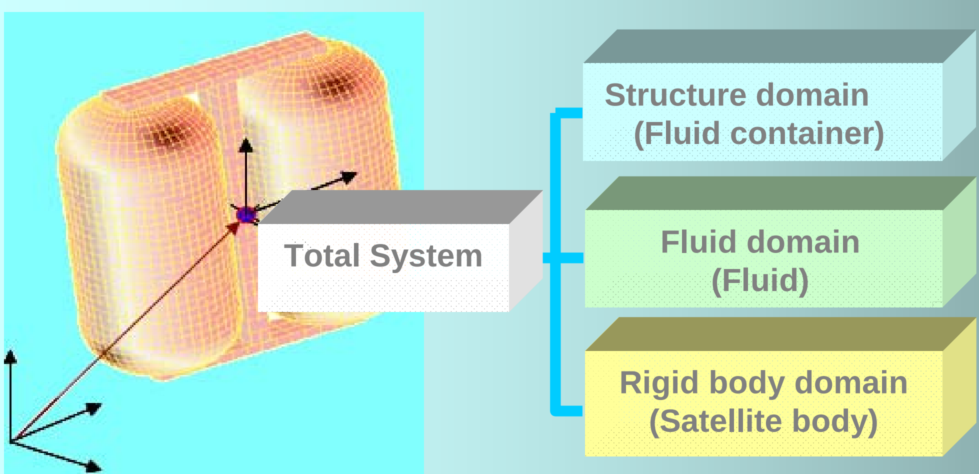
CASE STUDY: Fluid Structure Interaction using MSC DYTRAN, PATRAN, NASTRAN

High Fidelity Computational Methods in Prediction of Slosh dynamics including tank structure flexibility

Method of solution MSC DYTRAN

• ALE method (model)

- Micro/Small space vehicle with Two identical multiple tanks
- Simplification (Three region) : Flex. Tank, Rigid frame, Fluid
- Flexible Tank & rigid frame : Non-linear FE, Explicit
- Multiple fluids : ALE-FVM

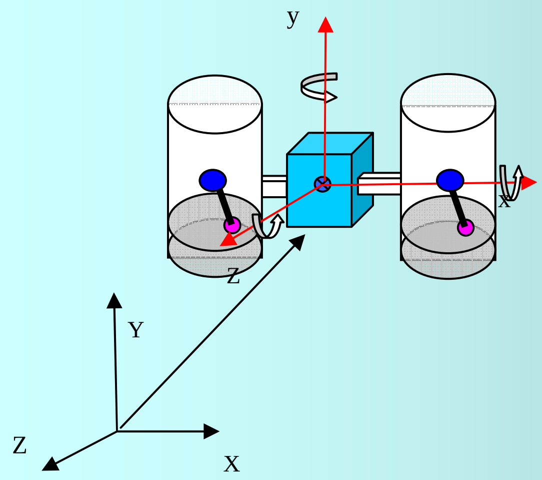


Parts	Method	Computational structure
Fluid container	Lagrangain (Flexible)	Shell structure(QUAD)
Fluid inside (Water / air)	ALE	Eulerian solid(HEXA)
Support Frame	Lagrangian (Rigid)	Lagrangian solid(HEXA)

Method of solution

• Multibody dynamic method (MBM)

- **Multi-connected rigid-body motion (Frame, tank, fluid)**
- **Spherical pendulum : liquid motion**
- **2-liquid pendulum and 3-body inter-connected system**
- **Kane's dynamics for MBM**



$$F_r + F_r^* = 0 \qquad r = 1,\ldots,n$$

$$\mathbf{F}_p^* = \sum_{\mathbf{i}=1}^{\mathbf{v}} \mathbf{v}_p^{Bi} \bullet \mathbf{R}_{Bi}^* + \sum_{\mathbf{i}=1}^{\mathbf{v}} \mathbf{w}_p^{Bj} \bullet \mathbf{T}_{Bi}^*$$

$$\mathbf{T}_{Bi}^* = (\mathbf{I}^{B\,N}\boldsymbol{\alpha}^B + {}^N\mathbf{w}^B \times \mathbf{I}^{B\,N}\mathbf{w}^B)\cdot {}^N\mathbf{w}_p^{Bi}$$

$$F_p = \sum_{i=1}^{\kappa} \mathbf{v}_p^{pi} \bullet \mathbf{R}_{pi} + \sum_{j=1}^{\lambda} \mathbf{w}_p^{Bj} \bullet \mathbf{T}_{Bj}$$

$$\mathbf{R}_{pi}^* = m_{Bi}\,{}^N\mathbf{a}^{Bc}$$

$$\mathbf{R}_{pi} = \sum_{i=1}^{3} f_i^{act}\hat{B}_i - f_x^{ext}\hat{B}_1 + f_y^{ext}\hat{B}_2$$

$$\mathbf{T}_{Bi} = \sum_{i=1}^{3} M_i^{act}\hat{B}_i = m_y\hat{B}_2$$

Results - Desired

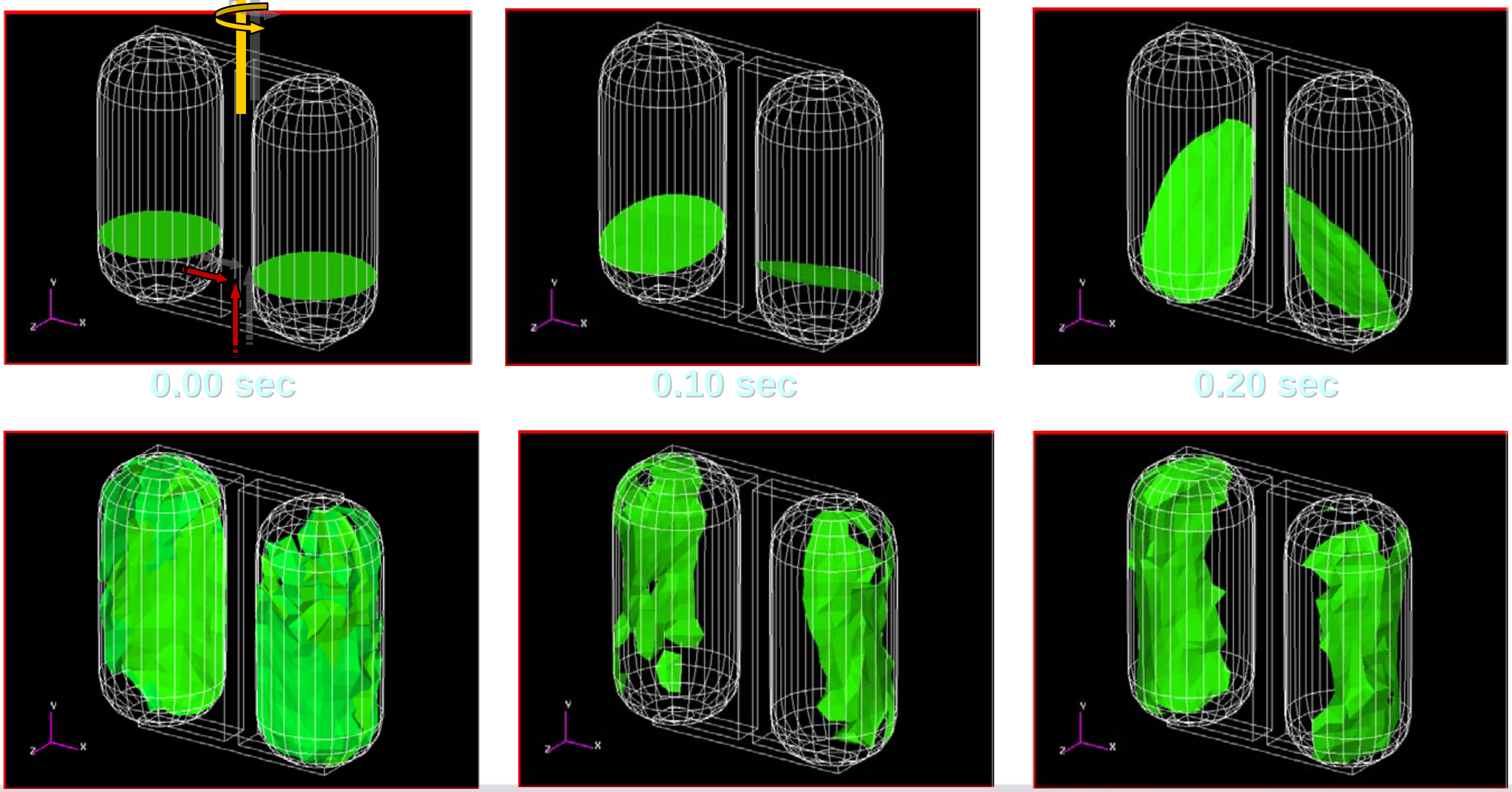
- **Motion of translation & rotation**
  - **Overall CM motion and CM disturbance (ALE/MBM)**
  - **Compare (ALE-Rigid / ALE-Flexible)**
  - **Investigate the flexibility on the slosh dynamics**
  - **Compare (MBM / ALE-Rigid)**
- **Structure deformation**
  - **Strain with time**
  - **K.E & I.E**
- **Sloshing motion**
  - **Pressure variation with ALE**
  - **Liquid motion with time**
  - **Spherical pendulum motion**
  - **Compare (Liquid motion/pendulum motion)**

ALE method

Results

Liquid motion & Sloshing (19.3%)

- **Fluid motion (Free surface motion)**



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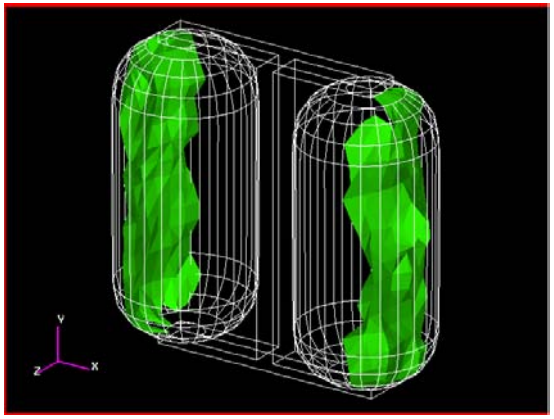
Results

Liquid motion & Sloshing (19.3%)

- **Fluid motion (Free surface motion)**



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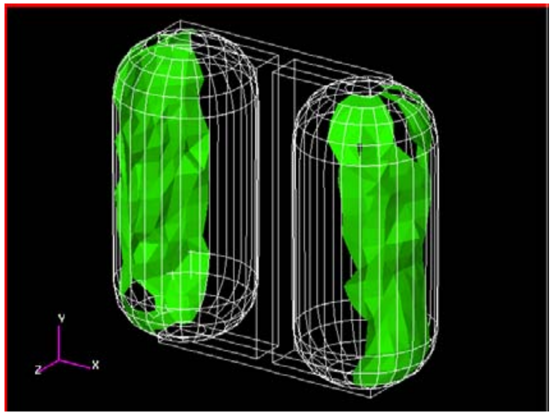

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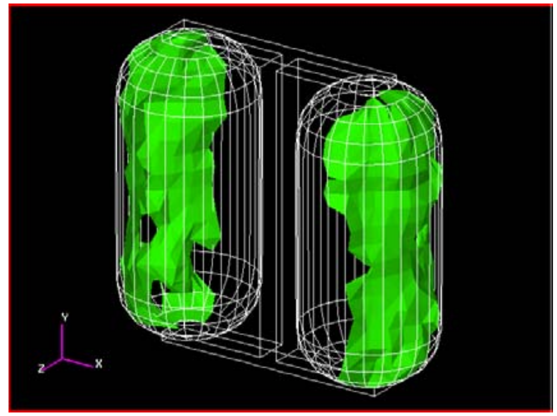

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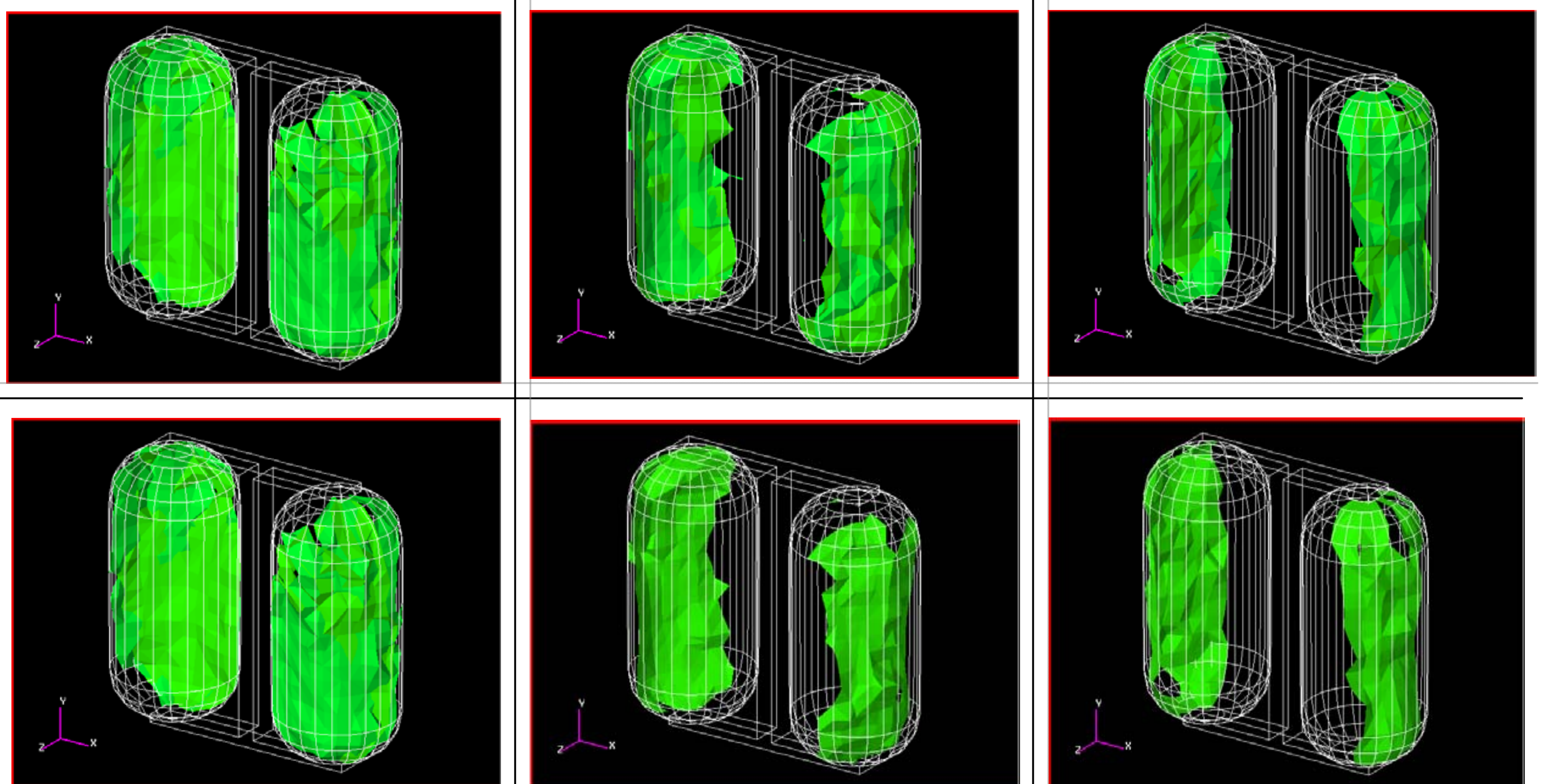
Results

Liquid motion & Sloshing (19.3%)

- **Fluid motion (Rigid / Flexible)**

Rigid

Flex



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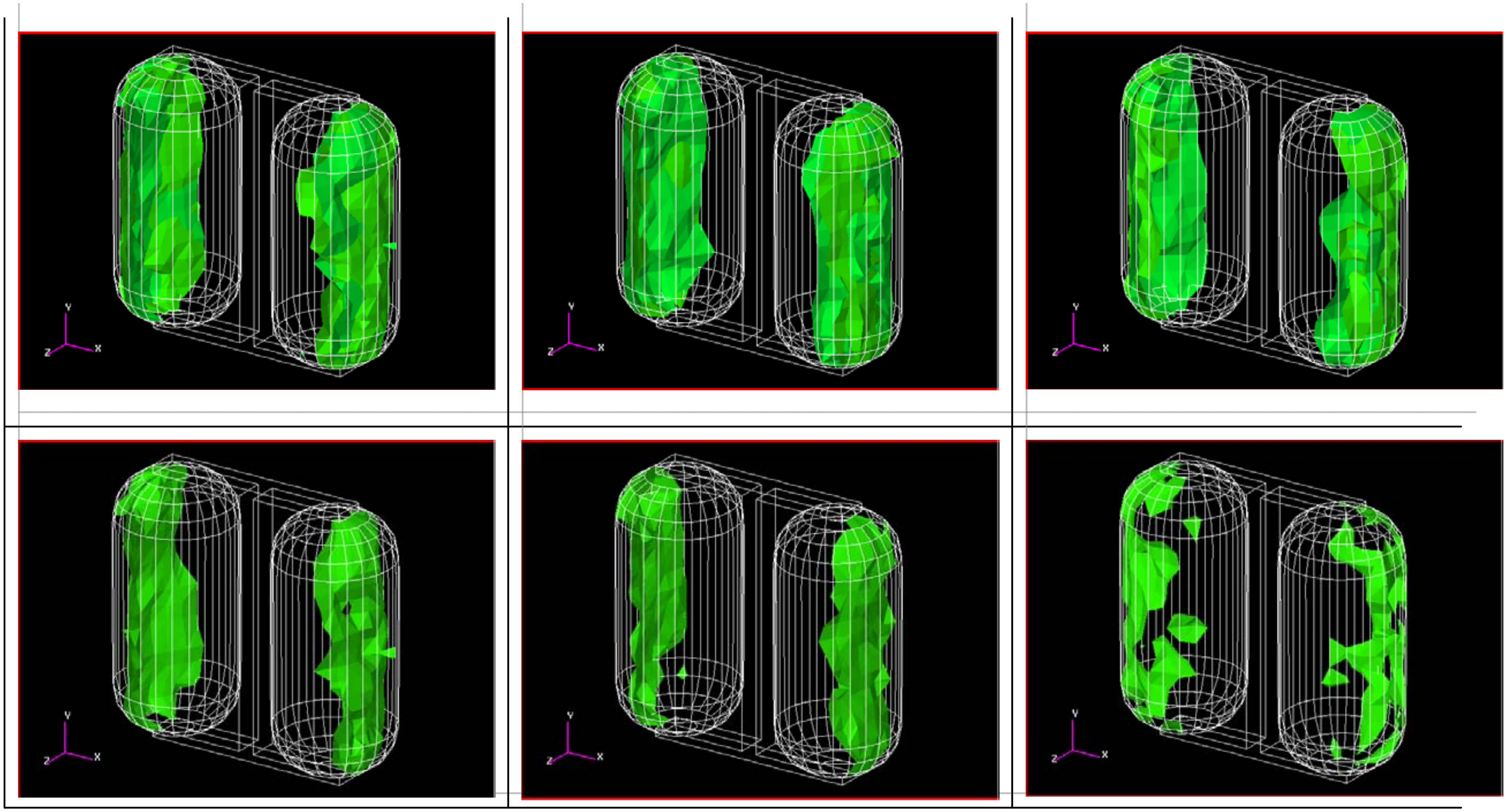
Results

Fluid sloshing motion inside tank (Flex/Rigid)

- **Fluid motion (Rigid / flexible)**

Rigid

Flex



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Concluding Remarks

- High Fidelity Computational tools are coupled in both graduate and undergraduate level courses. MSC NASTRAN, PATRAN, Flight Loads made available during computational labs at undergraduate levels classes after lectures that covers fundamentals.
- It has been observed that the students develop a better feel for the subject covered during the lectures.
- In graduate classes high fidelity software made available only to be used in the term papers.
- Increases students interest in the subject. Some continue the topic as the graduate degree research such as the case study presented here. High fidelity simulation tool was DYTRAN and NASTRAN.
- Based on our experience, coupling of high fidelity simulations in teaching work well if these tools are incorporated after they learn fundamentals.

Contact Details :

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For further information please contact

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ABOUT THE SPEAKER

Professor Nesrin Sarigul-Klijn has 22 years of experience in theoretical, computational, and experimental research in Aerospace Vehicle Structures and Control including Dynamics, Acoustics and Aeroelasticity effects, Space Transportation Vehicle Trajectory Optimizations/Air Launching Methods, Finite Element Methods, and Flight Testing of Aerospace Vehicles at sub and full scales. At present she is a Professor of Mechanical and Aeronautical Engineering at UCD. She received her Ph.D. degree from the University of Arizona in 1984. From 1984 until 1989 she was an Assistant Professor of Aeronautical and Astronautical Engineering at The Ohio State University. She also worked at NASA Glenn Research Center in Advanced composites and Propulsion Structures research as a faculty fellow. From July 1989 to July 1996, she was a tenured Associate Professor in the MAE Department at UCD Campus. She was promoted to Full Professor rank in 1996. In 1994, she founded the Scaled Model Aerospace Research and Testing Laboratory and has been serving as its Director. In 1996 she co-founded the Transportation Noise Control Center and has been serving as its Co-Director. In 2001 she established the Space Engineering Research and Graduate Program and has been serving as its Leader. She holds zero percent appointments as a Professor in two departments' graduate groups: the Biomedical Engineering Graduate Group, and the Electrical and Computer Engineering at UCD. In addition to her Engineering academic degrees, she is an instrument rated commercial pilot with flight experience in 34 different types of aircraft and has completed the FAA Wings level IV proficiency award program. She has over 100 technical publications. Professor Sarigul-Klijn has been the director of thesis and dissertation research of 26 MS and 15 PhD (1 MD/PhD) degree students under research funding from NASA, NSF, DARPA(AirLaunch LLC), NASS, Steller Solutions, AFRL(SpaceDev), and California Space Flight. Professor Sarigul-Klijn is an Associate Fellow of the AIAA. She was the technical co-chair of the AIAA Joint Propulsion Conference 2006. She delivered two invited keynote technical lectures in 2008. She is a member of ASME, SAE and IEEE.