State of the Center (Winter/Spring 2017 Meeting)

National Science Foundation (NSF)
Industry-University Collaborative Research Center (IUCRC) in
Smart Vehicle Concepts (SVC)
website: svc.engineering.osu.edu

Center Director for Phase I and II: Raj Singh (singh.3@osu.edu)

Department of Mechanical and Aerospace Engineering
The Ohio State University

Outline

- NSF I/UCRC program, SVC mission, membership structure and status
- Role of Industrial Advisory Board, examples of sponsored projects

May 2017
The Industry/University Cooperative Research Centers (I/UCRC) Program

Mission:
- To contribute to the nation’s research infrastructure base by developing long-term partnerships among industry, academe and government
- To leverage NSF funds with industry to support graduate students performing industrially relevant research

Vision:
- To expand the innovation capacity of our nation’s competitive workforce through partnerships between industries and universities

Cooperatively Defined and Shared, Sector Precompetitive Research

1980’s  1990’s  2000’s  2010’s

40 years of fostering and growing long-term partnerships among industry and academe based on shared value
Fast Facts on NSF’s IUCRC Program (from 2014)

Program Funding
• $20.2M in Program Funding (ENG, CISE)
• $137.5M in Total Center Funding,
• 6:1 Leveraging of NSF funds.

Centers Nationally:
• 77 Centers with 216 Sites
• 1150 Memberships held by over ~700 Member organizations

• 60% Large Business, 20% SB, 10% Federal Members

Students
• 2079 students engaged
• 649 graduated in 2014, over 20% hired by members
• 243 PhDs, 251 MS & 155 UGs graduated in 2014, trained in Center research

Sustainability
• About 40 Graduated I/UCRCs remain in operation true to model

National Scope of IUCRCs
ENG – Engineering
<table>
<thead>
<tr>
<th>Period</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct 2005 – July 2007</td>
<td>Planning grant (NSF) awarded to OSU, Planning Conference at OSU, membership sign-ups, etc. (OSU)</td>
</tr>
<tr>
<td>July 2007</td>
<td>Center launched at OSU with funding from the NSF and Industrial Members (Phase I: July 2007 to June 2012)</td>
</tr>
<tr>
<td>Feb 2007 – June 2008</td>
<td>Projects initiated by founding members (OSU)</td>
</tr>
<tr>
<td>July 2008</td>
<td>TAMU joins as an academic partner (July 2008 - June 2013)</td>
</tr>
<tr>
<td>March 2012</td>
<td>Center renewal proposal submitted to the NSF by OSU</td>
</tr>
<tr>
<td>June 2012</td>
<td>Phase II Center renewed by the NSF as a single site center (Phase II: July 2012 – June 2017)</td>
</tr>
</tbody>
</table>
| Feb/March 2017      | Phase III proposal submitted  
No cost extension to Phase II granted until December 2017                                                                                                                                                                                                                                                                         |
| Annual Meetings     | 2 meetings held per year  
(Semi-annual meeting in winter/spring and annual meeting in summer/autumn)                                                                                                                                                                                                                                                                    |
SVC Goals and Research Objectives

- Conduct basic and applied research
- Build an unmatched research, engineering education & technology transfer facility
- Develop well-trained engineers (MS and PhD levels)
Mission of Smart Vehicle Concepts Center

- Pre-competitive technology and research of common interest
- Smart vehicle components and sub-systems (ground, and aerospace vehicles)
- New smart material-based actuators and sensors
- New devices and design tools for vehicle development work
- Superior dynamic response + quiet & smooth operations
- Improved performance and refined diagnostic methods
- Enhanced safety; higher energy efficiency, etc.

Phase I from 2007 – 2012 (OSU-Lead Site, Texas A&M as partner)
Phase II from 2012 – 2017 (OSU - single site)
## SVC Membership Fee Structure (Phase II)

<table>
<thead>
<tr>
<th>Type</th>
<th>Money per Year</th>
<th>Vote</th>
<th>IP Access</th>
<th>Project Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member</td>
<td>$40K*</td>
<td>1</td>
<td>Yes</td>
<td>Made by the IAB (Phase II)</td>
</tr>
<tr>
<td>Affiliate</td>
<td>$10K</td>
<td>0</td>
<td>Limited to one project only</td>
<td>No Say</td>
</tr>
<tr>
<td>Invited Observer</td>
<td>In-kind ($10K +)</td>
<td>0</td>
<td>No</td>
<td>No Say</td>
</tr>
<tr>
<td>Observer</td>
<td>In-kind (&lt; $10K)</td>
<td>0</td>
<td>No</td>
<td>No Say</td>
</tr>
</tbody>
</table>

*New project fee structure implemented by the IAB (from March 1, 2013)*

### Additional Project Fee Schedule to Ensure a Guaranteed (Solo) Project in Phase II

<table>
<thead>
<tr>
<th>Center Year</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional Fee</td>
<td>$4K</td>
<td>$6K</td>
<td>$8K</td>
<td>$10K</td>
<td>$12K</td>
</tr>
<tr>
<td>Membership Fee + Project Fee</td>
<td>$44K</td>
<td>$46K</td>
<td>$48K</td>
<td>$50K</td>
<td>$52K</td>
</tr>
</tbody>
</table>

- **Members or Affiliates:** Companies, Government Agencies, R&D Organizations, and Small Businesses
- More than one membership is allowed
- Industrial Advisory Board (IAB) has established bylaws for the Center
- Invited Observer would attend the closed Center Technical meetings, but not the IAB only meetings.
### 2016-2017 SVC Memberships (Phase II - OSU)

**Members (2016-17)**
- Battelle Memorial Institute
- Bridgestone Americas Tire Operations
- F.tech R&D (2 memberships)
- Ford Motor Company
- Honda R&D Americas (4 memberships)
- Moog
- NASA Glenn
- Owens Corning
- REL
- Tenneco
- Toyota Technical Center
- Transportation Research Center (2 memberships)

*Total = 17 (13 Certified in Feb. 2017)*

**Invited Observers (2016-17)**
- LMS/Siemens PLM Software
- MSC Software
- Romax

*Total = 3*

**Affiliates = None**

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SVC Industrial Advisory Board and Evaluation

Industrial Advisory Board (IAB)

- One representative per full membership (at most 2 IAB representatives for any company)
  - Chair: Tom Greetham, Moog
  - Vice Chair: Duane Detwiler, Honda R&D Americas

- Responsibility:
  - Approve center bylaws and procedures
  - Evaluate current research thrusts and projects
  - Suggest new opportunities
  - Evaluate center operations and suggest new partnerships
  - Match center capabilities with unfilled research needs

NSF Assessment Coordinator (Victoria Hill)

- Assigned by the NSF
- Assessment coordinator’s fees and expenses provided by the NSF

Academic Advisory Committee

- Key SVC project leaders are consulted on important issues
**SVC Funds and Resources in Phase II**

<table>
<thead>
<tr>
<th>Source</th>
<th>Funds for Phase II (2012-17)</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSF</td>
<td>$0.45M</td>
<td>Center administration and evaluator fees</td>
</tr>
<tr>
<td>Industry Membership Fees</td>
<td>≥ $2.4M</td>
<td>Average 14 members/year (at least $40K/year for each membership)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NSF supplements (incl. funds from NASA, Army)</td>
</tr>
<tr>
<td>Indirect Cost Relief</td>
<td>~$1.3M (Rate = 10%)</td>
<td>Overhead reduction from 54.5% (standard rate) for grants</td>
</tr>
<tr>
<td>Graduate Fellowships</td>
<td>4 Fellows Per Year</td>
<td>Fellowships (tuition waiver) from the OSU Graduate School</td>
</tr>
<tr>
<td>OSU Cost Share</td>
<td>~$0.25M</td>
<td>Staff support and misc. services from the College and Department</td>
</tr>
<tr>
<td>Other Funds</td>
<td>Ongoing effort</td>
<td>Related projects; supplements from NSF; etc.</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>≥ $6.1M</td>
<td>$1.6M/year in Phase I; about $1.2M/year in Phase II</td>
</tr>
</tbody>
</table>

During Phase I, institutional resources (such as the indirect cost relief, graduate fellowships, staff support, and other funds) provided an extra $5.4M in research funding.
## Phase II Project Groups and Typical Sponsors

<table>
<thead>
<tr>
<th>Project Groups (PG)</th>
<th>Typical SVC Project #</th>
<th>Strategic Thrusts</th>
<th>Typical Sponsors in Phase II</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG-1 Interfacial Forces and Stiffness</td>
<td>20C, 40B, 40C, 40E, 40F, 55, 56</td>
<td>Interfacial Mechanisms, Safety</td>
<td>Eaton, Honda R&amp;D, F.tech R&amp;D, Tenneco, Ford, Owens Corning, TRC</td>
</tr>
<tr>
<td>PG-2 Vibration, Noise, and Motion Control</td>
<td>31ABC, 40D, 42A, 42B, 45, 47ABC, 50, 52</td>
<td>Adaptive NVH</td>
<td>Moog, Honda R&amp;D, TRC, F.tech R&amp;D, Tenneco, Ford, Hyundai-Kia, Toyota, NASA Glenn, Eaton, Parker Hannifin</td>
</tr>
</tbody>
</table>

See Day 2 Agenda for a listing of currently sponsored projects.
3D Printing of Smart Structures with Embedded Optical Fiber Sensors
– Prof. Marcelo Dapino

Aircraft actuation systems require embedded condition monitoring and load sensing devices.
**Project Example I: Smart Condition Detection and Monitoring for Tires**

**Objective:** Develop autonomous, self-powered, wireless smart tire sensors that log tire history and generate real time information on tire condition and tire-road interactions.

**Benefits:** Improved passenger safety, higher vehicle performance, and expanded design space for tire manufacturers.

**Research focus:** Analytical and computational investigation of smart polymer sensors; experimental testing (in collaboration with industry partner).

**Research team:** Prof. Marcelo Dapino and team.

Smart PVDF sensor utilized to measure tire parameters in real time and harvest electrical energy.

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Slide provided to NSF for Center Showcase at I/UCRC Annual Meeting (January 2015).
Project Example II: Characterization & Modeling of Passive & Adaptive Bushings & Mounts

- Study of conventional elastomeric and hydraulic mounts or bushings
- Examine the role of body frame structures on NVH performance

Powertrain subframe

\[ p_a = \text{Acoustic pressure} \]
\[ \ddot{x} = \text{Acceleration} \]
\[ F = \text{Force input} \]

- Fueled by demand for light weight and cost-effective components without compromising vehicle performance
- Research team: Prof. Raj Singh and team.

Published in the MAE Research Booklet in Fall 2013.
**Center Publicity**

**Center Newsletters**
- Annual newsletters (online as of 2014), December annually
- Latest Newsletter published December 2016

**Web Sites (regularly updated)**
- SVC Main Website: [http://SmartVehicleCenter.org](http://SmartVehicleCenter.org), (also under [https://svc.engineering.osu.edu/](https://svc.engineering.osu.edu/))

**Main Mechanisms**
- Open Sessions in SVC meetings
- Meetings with Potential Sponsors
- Personal Interactions
- Papers at Technical Conferences
- Student Paper Contests
- Faculty Seminars & Invited Talks
- Brochures and Quad Charts
- NSF Meetings
- Web Sites and Newsletters

**Magazine Articles**
- *Smart Vehicle Concept Center – Research for Industry,* OSU Mechanical Engineering Newsletter, October 2008
- *Building smarter materials,* Automotive Engineering International (SAE), 2009

**Institutional Publications**
- Article in Industry-Nominated Technology Breakthroughs of NSF Industry/University Cooperative Research Centers
  - *Design Concept for Smart, Adaptive Seatbelts* in 2014
- Article in Ohio State University’s MAE Department Research News
  - *A Noise, Vibration, & Harshness Technology Success Story,* in 2013
- Article in Ohio State University’s MAE Undergraduate News
  - *An Innovative Capstone Design Experience Based on Simulation Pilot Program Made Possible by GM Foundation,* in 2014

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**Motivation:**
Smart Materials and Elastomers have significantly variable properties and are highly non-linear.

In order to determine the best material for the application, key properties must be highlighted in the same context and tools must be developed to determine the best material for a given performance envelope.

**Project Goals:**
- Extensive literature survey
- Compilation of the data into an easy to use format
- Development of a GUI based tool to utilize the data
- Development of design tools based on the GUI format
- Materials Testing and verification

**Example for SMA Application:**

“Metal straps are made of a shape-memory material which can be a metal alloy such as NiTi, NiTiX (where X is Fe, Cu, or Nb)....” [US patent No.: US 6,401,779 B1]

- Temperature value $A_s$: about 40 °C ~ 90 °C
- Temperature value $A_f$: about 60 °C ~ 120 °C
- Value of maximum stress at temperature $A_f$: 400 ~ 600 MPa

**Design Considerations:**
- Materials have a number of applications that range the space of
  - Force
  - Stroke
  - Bandwidth
  - Size
  - Weight
- Must consider
  - Hysteresis
  - Creep
  - Non linear stress-strain phenomena
  - The “illities”

**Metal reinforcing strap**

<table>
<thead>
<tr>
<th>Metal</th>
<th>$\sigma_{max}$</th>
<th>$A_s$</th>
<th>$A_f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti50Ni50</td>
<td>400 ~ 600 MPa</td>
<td>40 °C</td>
<td>90 °C</td>
</tr>
<tr>
<td>Ti50Ni40Cu10</td>
<td>400 ~ 600 MPa</td>
<td>60 °C</td>
<td>120 °C</td>
</tr>
<tr>
<td>Ti48.5Pd30Ni21.5</td>
<td>400 ~ 600 MPa</td>
<td>40 °C</td>
<td>90 °C</td>
</tr>
</tbody>
</table>

Find largest strain for same application

**Project Initiated by:** Goodyear

Tenth Semi-Annual Meeting, Ohio State, 2-3 May 2017
Summary

- Emphasis is on *pre-competitive research* – exploratory and high-risk research
- The SVC creates research at the intersection of smart material technologies and mobility applications (automotive, aircraft, rotorcraft, etc.)
- The Center is in Year 5 of Phase II (2012-17) with OSU as the single site.
- Significant OSU cost share (reduction in indirect cost rate, fellowships and staff support, etc.) is used to leverage resources
- Opportunity for education of students in critical areas
  - 53 students graduated with PhD/MS/BS degrees in the last 5 years
  - Many of our graduates have joined sponsors
  - Few former students have served on the IAB
  - Top undergraduate students from India invited to work on SVC projects
IAB Meetings and Autumn Meeting

IAB Meetings (May 2-3)
• May 2 - Updates and Action Items
• May 3 - Project Reviews, etc.

Autumn (Tenth Annual) Meeting

Dates:
October 2017
(To be confirmed by the IAB)
Location: Ohio State, Columbus, OH

• Open session (for guests & sponsors) on Day 1
• Project reviews (sponsors only) on Day 2
• IAB meeting(s)
• Student poster display on Day 1
Appendix

- Ohio State Researchers
- Phase II Projects by Project Groups
Ohio State Researchers
(from Mechanical & Aerospace Engineering)

PROF. MARCELO DAPINO
Expertise: Smart materials, nonlinear coupled systems, design, control

PROF. RAJENDRA SINGH
Expertise: Noise & vibration control, geared systems, nonlinear dynamics, DSP

PROF. VISHNU SUNDARESAN
Expertise: Piezoelectric materials, active polymers, bio-derived materials

PROF. SOHEIL SOGHRATI
Expertise: Advanced FEM; modeling multiscale response of advanced/bio-materials and structures

PROF. RYAN HARNE
Expertise: Structural acoustics, vibration energy harvesting, nonlinear dynamics

PROF. JASON DREYER
Expertise: Experimental methods, dynamics, noise & vibration control

DR. LEON HEADINGS
Expertise: Energy systems, mechatronic systems, intelligent control, smart materials

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<table>
<thead>
<tr>
<th>Project #</th>
<th>Title</th>
</tr>
</thead>
</table>
| #20C     | Development of Interfacial Force Sensing Systems using Experimental and Computational Methods:  
#20C: Characterization of Pump Bearing Surfaces  
(now inactive) |
| #40B     | Characterization and Modeling of Passive and Adaptive Bushings and Mounts  
#40B: Hydraulic Bushings |
| #40C     | Characterization and Modeling of Passive and Adaptive Bushings and Mounts  
#40C: Joint Characterization  
(pending support) |
| #40D     | Characterization and Modeling of Passive and Adaptive Bushings and Mounts  
#40D: Hybrid Modeling Methods  
(pending support) |
| #40E     | Characterization and Modeling of Passive and Adaptive Bushings and Mounts  
#40E: Automotive System Isolation |
| #40F     | Characterization and Modeling of Passive and Adaptive Bushings and Mounts  
#40F: Inverse Identification Method for Radiator Mounts |
| #41      | Force Sensing with Galfenol Alloys  
(now inactive) |
| #55      | Multiscale Finite Element Simulation of the Mechanical Behavior of Fiberglass Insulation Packs |
| #56      | Dynamic Friction Characterization of Icy Road Surfaces |
### Current Project Group 2 - Vibration, Noise, and Motion Control

<table>
<thead>
<tr>
<th>Project #</th>
<th>Title</th>
</tr>
</thead>
</table>
| #31A | Ultrasonic Friction Control  
(now inactive) |
| #31B | Non-contact Measurement, Visualization, and Analysis of Smart Dynamic Systems  
(now inactive) |
| #31C | Ultrasonic Friction Control  
Part C: *Ultrasonically-Assisted Metal Forming*  
(now inactive) |
| #42 | Enhanced Methods for Reducing Powertrain Vibration and Noise  
#42A: Powertrain Vibration Transmitted through Mounts  
#42B: Reduction of Powertrain Surface Radiated Noise  
(now inactive) |
| #45 | Morphing Panels for Aerodynamic Performance |
| #47 | Multifunctional Magnetostrictive Systems: Experiments and Computer Simulation  
#47A: Variable Stiffness Components  
#47B: Vibration Damping and Energy Harvesting  
#47C: GUI-Based Magnetostrictive System Modeling |
| #50 | Active Noise Control of Pulsation Noise from Supercharger in Inlet/Outlet Ducts  
(now inactive) |
| #52 | Design of Matrix and Particulates for Simulcure 3D Printing Technique  
(committed) |
### Current Project Group 3 – Machine and Material Diagnostics

<table>
<thead>
<tr>
<th>Project #</th>
<th>Title</th>
</tr>
</thead>
</table>
| #20B      | Development of Interfacial Force Sensing Systems using Experimental and Computational Methods:  
#20B: Bearing Preload and Stiffness Estimation *(now inactive)* |
| #40A      | Characterization and Modeling of Passive and Adaptive Bushings and Mounts  
#40A: Rubber Bushings |
<p>| #44       | Smart Condition Detection and Monitoring <em>(now inactive)</em> |
| #48       | Stress Field Development During Load Transfer in Functionally Graded Metal Matrix Composite Macro Interfaces <em>(now inactive)</em> |
| #49       | Embedded Fiber Optic Sensors for Structural Health Monitoring |</p>
<table>
<thead>
<tr>
<th>Project #</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>Electro-Hydrostatic Actuation and Sensing (E-HAS) <em>(now inactive)</em></td>
</tr>
<tr>
<td>#43</td>
<td>Thermally invariant smart composites <em>(now inactive)</em></td>
</tr>
<tr>
<td>#46</td>
<td>Mechanoluminescent Paintable Light Sources in Automotive Lighting Systems</td>
</tr>
<tr>
<td>#51</td>
<td>Ultrasonic Additive Manufacturing for Automotive Structures: #51A: UAM for Automotive Structures #51B: Process Modeling</td>
</tr>
<tr>
<td>#54</td>
<td>Magnetic Additively-Manufactured Structural Hybrid (MASH) <em>(committed)</em></td>
</tr>
</tbody>
</table>