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STEVENS
INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

# RT19: Systems Engineering Capstone Experience

**by**
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**Stevens Institute of Technology**

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**Marriott Inn and Convention Center**
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**www.sercuarc.org**

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# Acknowledgments

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- Our sponsors at ASDR&E

- Our colleagues at the participating institutions

# Building Education & Workforce Capacity in Systems Engineering



## Research Question

What methods, approaches, environments, and materials lead to greater SE learning, career interest, and interest in DoD problems?

*Role of mentors*
*Role of student projects*

## Approach

Develop course materials and other value-added SE inputs and conduct pilot courses in 14 diverse institutions; assess impacts on SE learning, career interest and interest in DoD problems among undergraduate and graduate students.

# Partners



| Civilian Universities |
|---|
| 1. Auburn University |
| 2. Missouri University S & T |
| 3. Penn State |
| 4. Southern Methodist University |
| 5. Stevens Institute of Technology |
| 6. University of Maryland |
| 7. University of Virginia |
| 8. Wayne State |

| Service Academies |
|---|
| 1. Air Force Institute of Technology |
| 2. Naval Postgraduate School |
| 3. Air Force Academy |
| 4. Military Academy – West Point |
| 5. Coast Guard Academy |
| 6. Naval Academy |

AFIT
The Air Force Institute of Technology

West Point
The United States Military Academy

UNITED STATES COAST GUARD ACADEMY

UNITED STATES NAVAL ACADEMY
HONOR... COURAGE... COMMITMENT

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# Project Schedule

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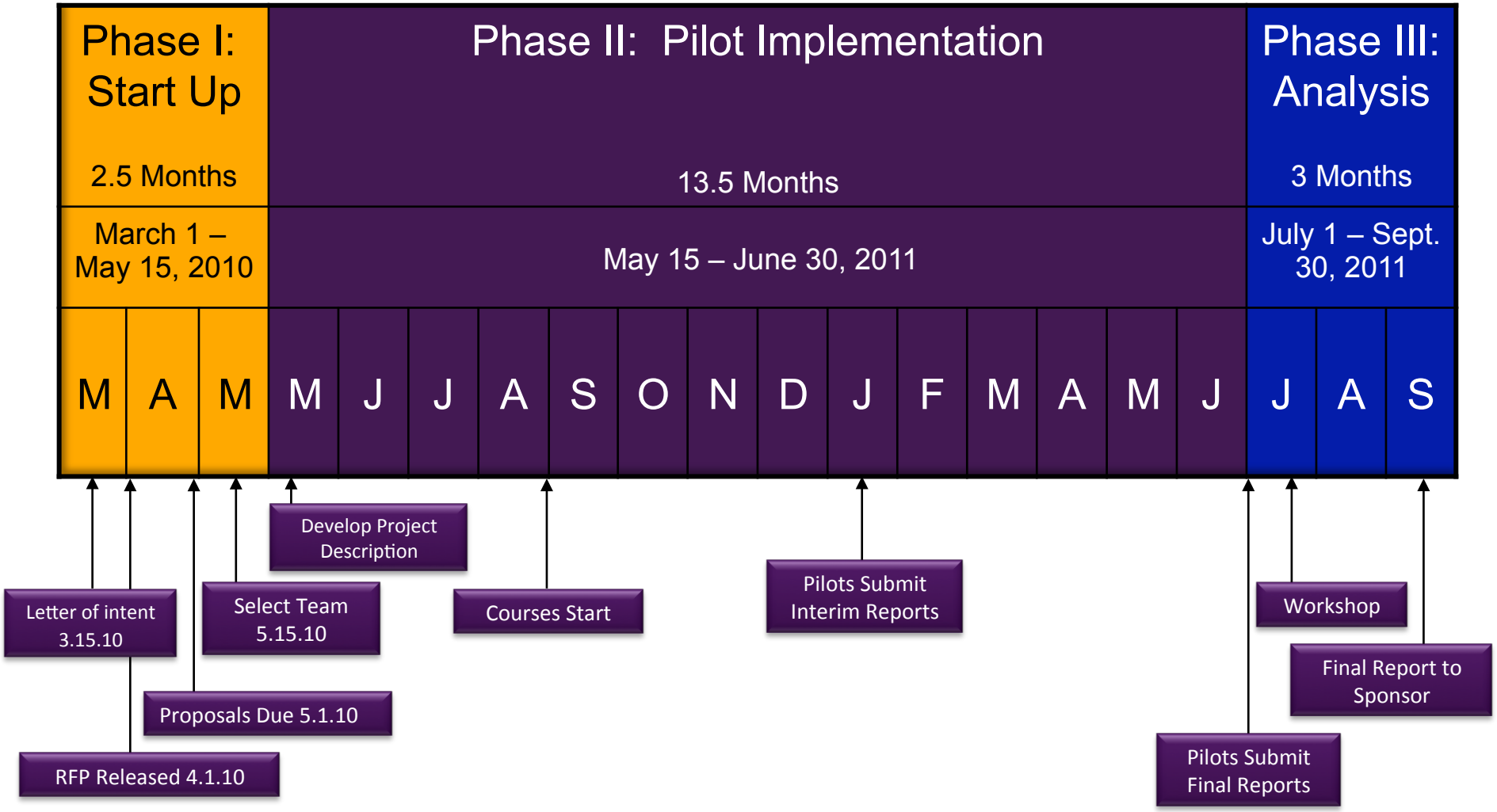


# Methodology: Measurement of Student Educational Outcomes



## Required Common Assessments

- Pre/Post Survey
  - Knowledge of SE
  - Interest in SE Careers
  - Awareness of DoD problem areas
- Pre/Post Case Student Analysis (Bradley Fighting Vehicle)
  - Growth in SE approach/Analysis (semantic analysis)
- Weekly Blog Posts
  - Qualitative
  - Progress in level of sophistication of student analysis
  - Final blog post-cumulative

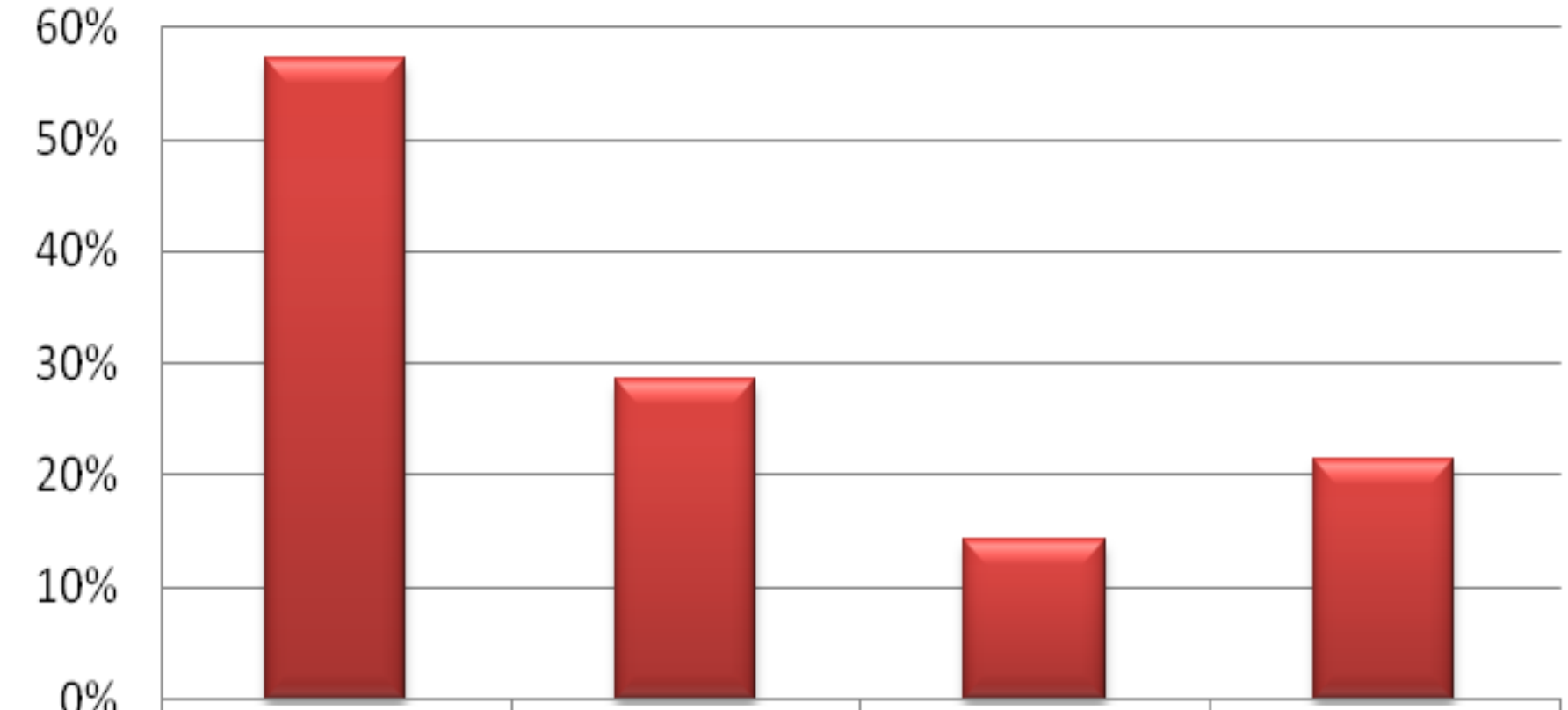
# Measurement of Student Educational Outcomes



## Customized Assessments

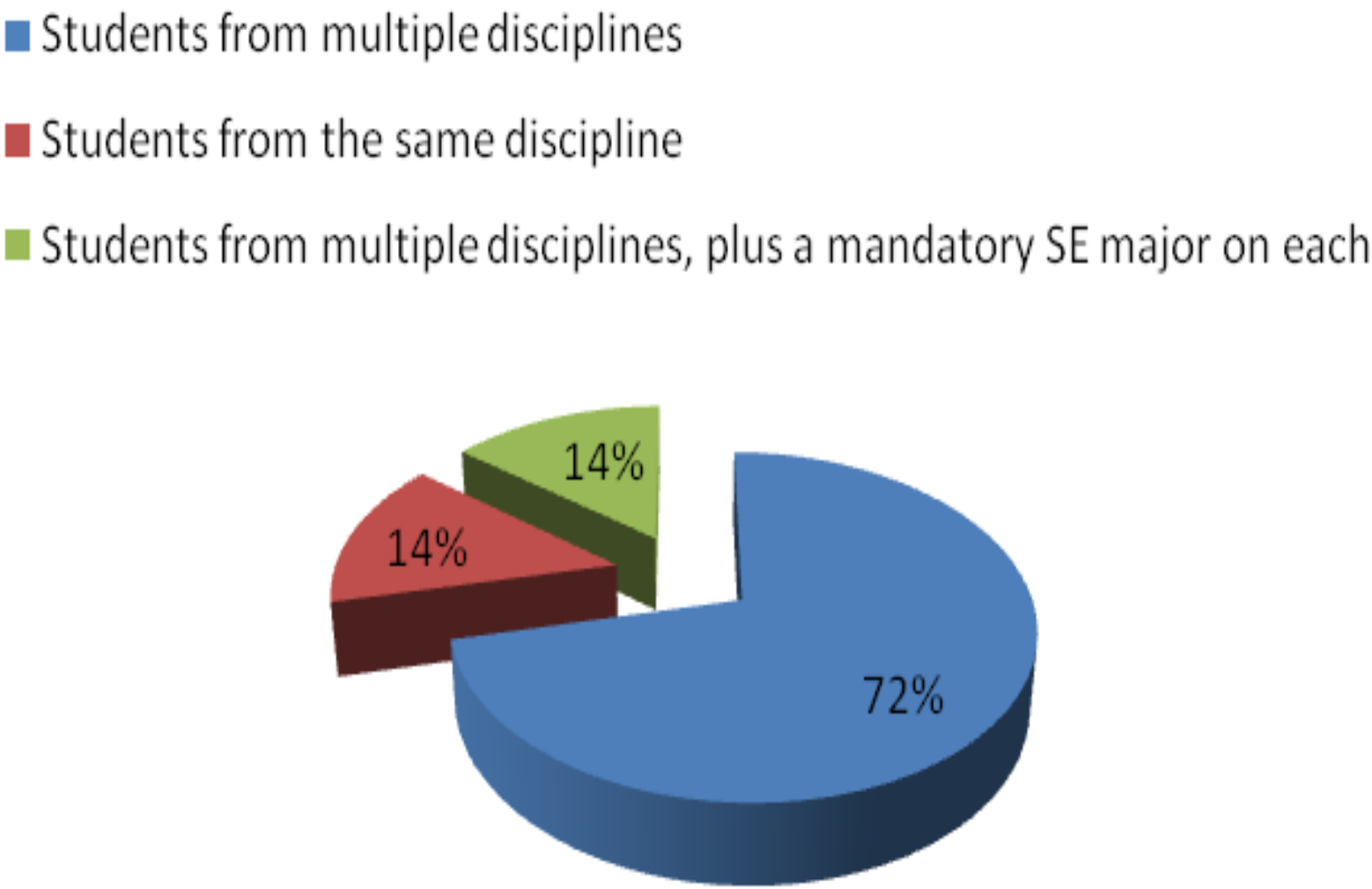
- Faculty-developed assessments unique to their courses
  - Comprehensive Rubrics
  - Student presentations
  - Peer reviews
  - Team reports
- PI Evaluation of course effectiveness
- PI Reports on DoD and Industry Mentors

# DoD Problem Areas Addressed

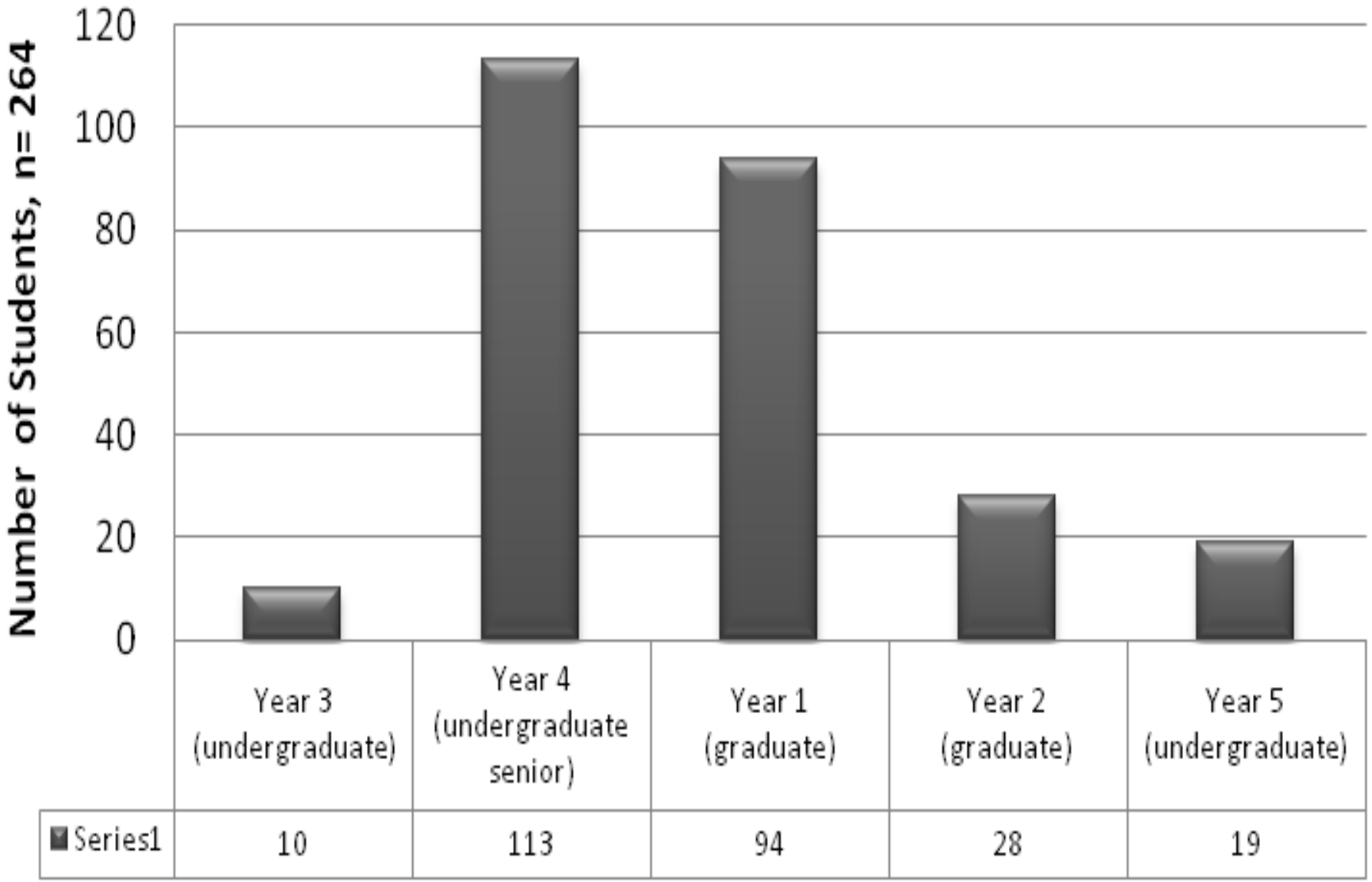



| | Problem Area 1: Low-cost, low-power computers | Problem Area 4: Immersive training technologies | Problem Area 2: Expeditionary assistance kit | Problem Area 3: Expeditionary housing systems |
|---|---|---|---|---|
| Series1 | 57.10% | 28.60% | 14.30% | 21.40% |

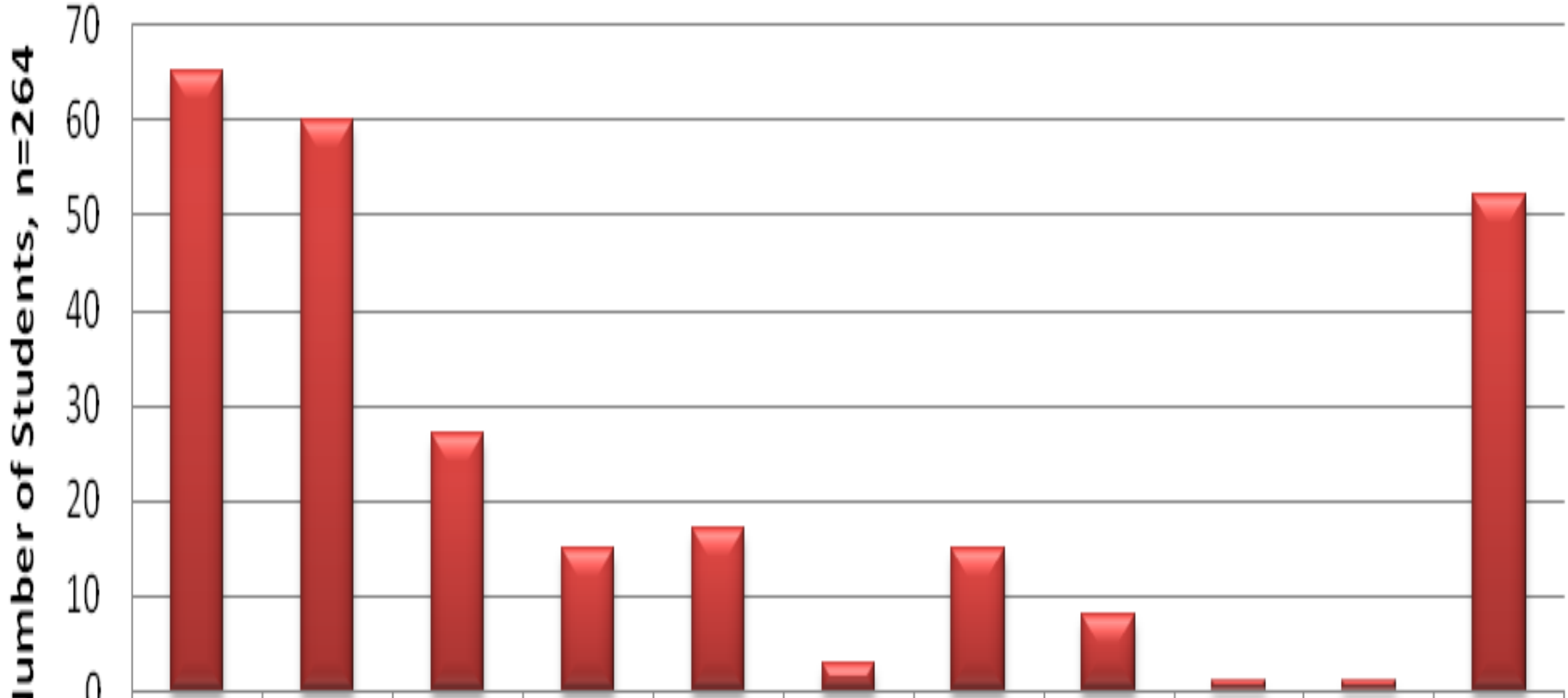
# Disciplinary character of student body



# All Institutions - By Class year



# All Institutions - By Major or Program




| | Systems Engineering | Mechanical Engineering | Electrical Engineering | Computer Sciecne | Industrial Engineering | Civil Engineering | Software Engineering | Engineering Management | Biomedical Engineering | Aeronautical Engineering | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Series1 | 65 | 60 | 27 | 15 | 17 | 3 | 15 | 8 | 1 | 1 | 52 |

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# DoD/Industry Mentors

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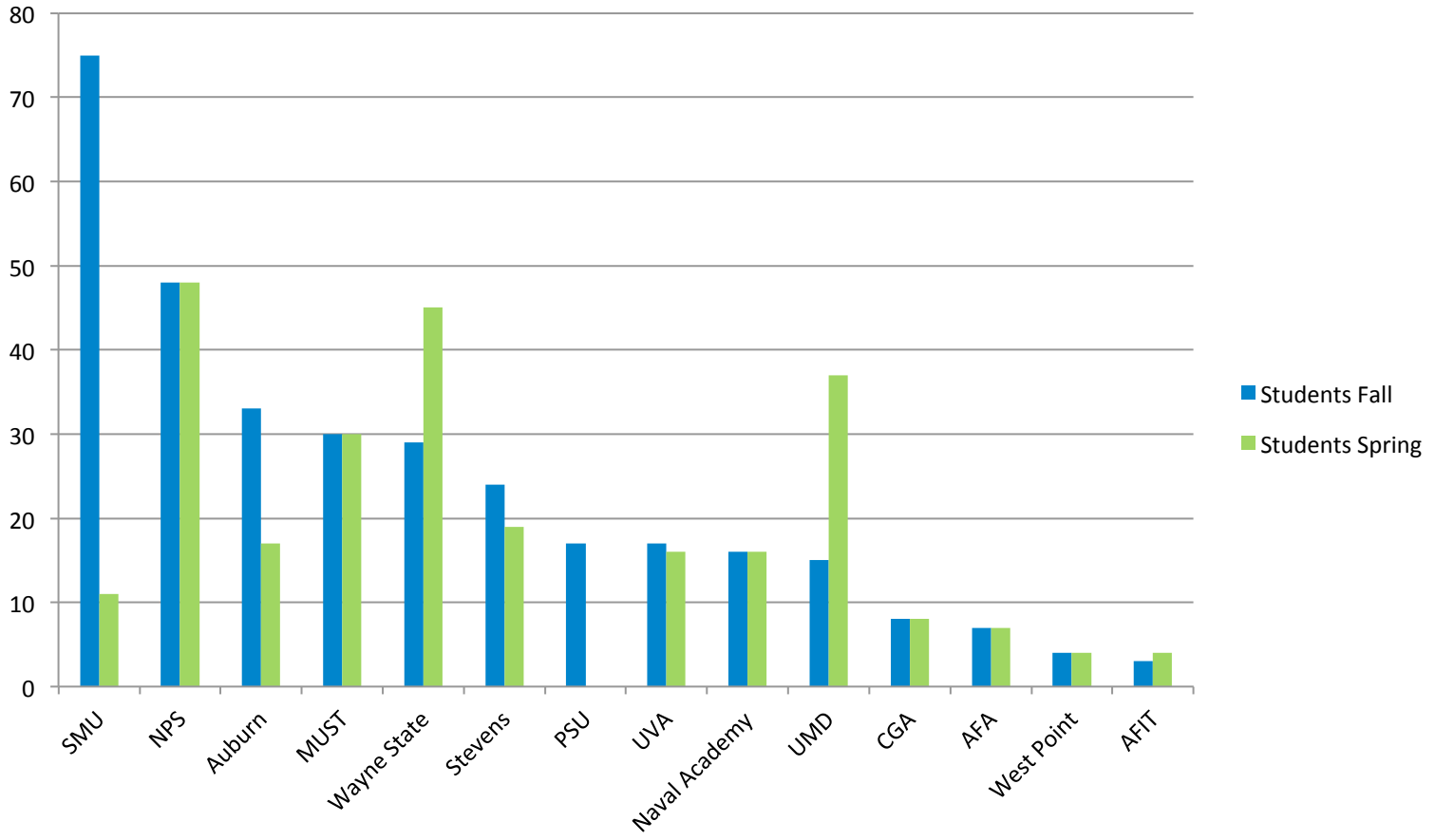
| University/Academy | Mentors |
|---|---|
| Auburn | Advisory board (5 SE professionals from govt. and industry)<br>Industry Mentor (automotive arena)<br>PhD TAs (support team) |
| Missouri S&T | Boeing Company engineers: Dale Waldo, Louis Pape, Nancy Pendleton, Robert Simmons and Robert Scheurer<br>Office of Naval Research: Pete Muller |
| Penn State | DoD Mentors: Col. Nancy Grandy, and Mr. Phil Stockdale |
| Southern Methodist | U.S. Marine Corps<br>Office of Naval Research: Pete Muller |
| Stevens Institute | Naval Surface Warfare Center: Eric Shields<br>Red Gate Group, Ltd: Joseph Barniak |
| U of Maryland | Lockheed Martin: Sandy Friedenthal<br>DoD Mentors: Dr. David Robie, Kim Watkins |
| U of Virginia | DoD Mentor: Bill Campbell<br>Northrop Grumman engineers |
| Wayne State | Army Shelter Expert, Claudia Quigley<br>Army TARDEC: Dr. Pete Schil |
| Military Academy | SRI/Sarnoff: Dr. Rakesh Kumar<br>DoD Mentors: LTC Joe Nolan, LTC Chris Vaughn [Joint Advanced Training Technologies Lab] |
| Air Force Academy | DoD Mentors: a reserve AF Colonel, a retired USMC officer |

# Participants





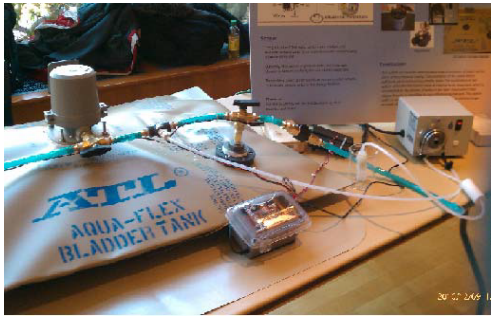
# How DoD problems were addressed

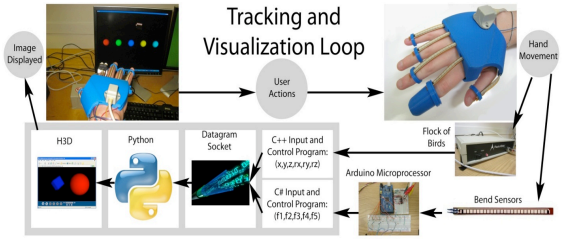


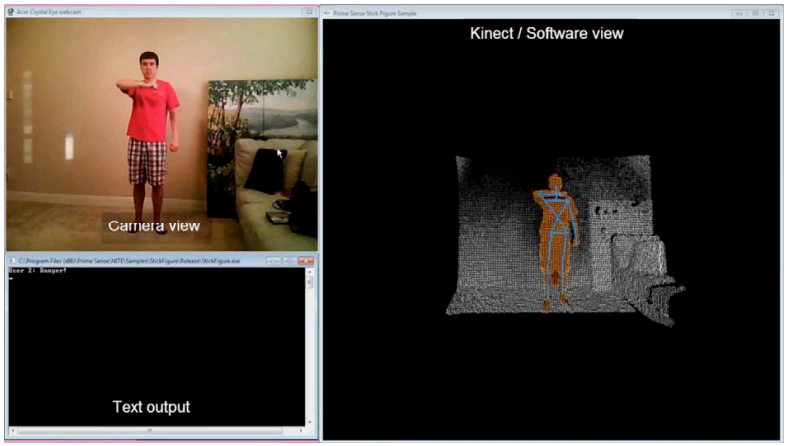
- One design problem broken into subsystems, each addressed by a separate team (one example)
- One design problem, with each team working on the entire problem (several examples)
- Several design problems, with each team working on a different problem (most common)

# Student Prototypes



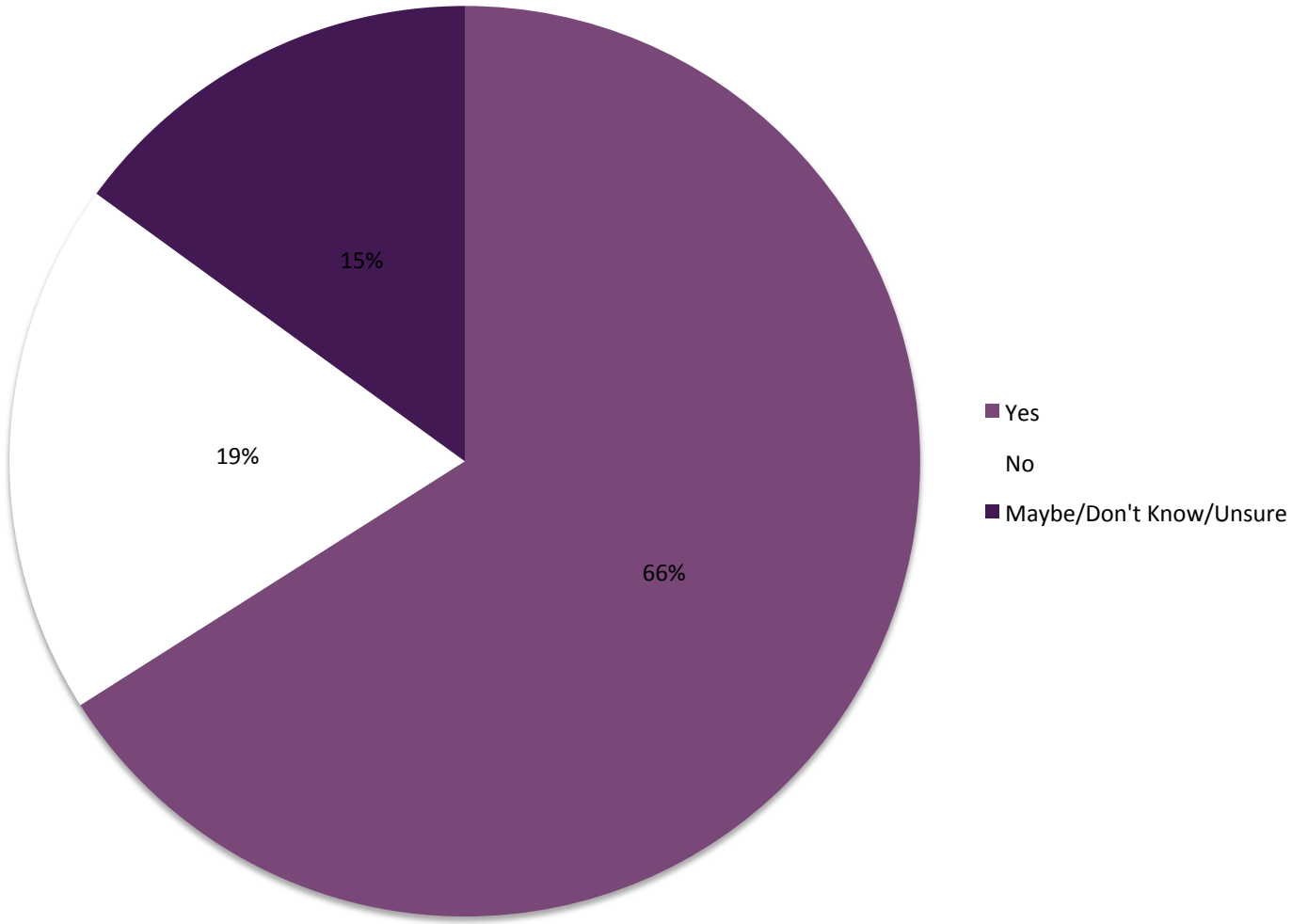


# Would you choose a career in SE?





# Why Choose a Career in SE?



## Problem-solving and intellectual challenge

"It seems like something that would interest me because it is not the same thing day after day and it allows me to be creative with my job. In addition, it's very rewarding producing something that solves people's problems."

"I find thinking about complex systems of systems and their interactions both with the outside world and internally very interesting, and I am excited to work to help organizations improve efficiency."

## Interdisciplinary and project diversity

"... you're exposed to a wide variety of areas, not just one specific area. The projects in systems engineering vary much more than in individual engineering fields."

## Leadership opportunities

"I love working on huge projects and managing a whole lot of people. It's a pain sometimes, but it's so rewarding in the end to see the final huge project."

# Industry and DoD Mentors were Critical



"These individuals were vital to the success of the systems engineering capstone because they brought a level of legitimacy, relevancy, and real-world context to the problem that was a catalyst for student learning and mastery of course outcomes." [Faculty]

"[Our mentor's] industry experience allowed him to foresee debilitating problems; his managerial skills enabled him criticize in a gentle, useful manner; and his credentials as former vice president of manufacturing for a large motor company lent credence to his comments." [Faculty]

# SE Approach was Eye-Opening



"This is a different approach [compared] to engineering design approaches I was familiar with, where the focus was more on developing the best product with the most features. I believe that the systems engineering approach is a better one because the perfect useless gadget is still useless." [Student]

"I was not aware of the amount of types of documentation that a systems engineering project required. The different competencies like requirements management and verification and validation showed how important organizational aspects are to a successful project." [Student]

# Multi-Disciplinary Teams



"Without a doubt, the greatest accomplishment of RT 19 is the demonstration that truly cross-disciplinary capstone design projects can be developed by groups of seniors at the undergraduate level." [Faculty]

"[Our project] shows very well how teams of people from different backgrounds should communicate and work together. In the real job world almost all teams consist of people from different academic backgrounds so it is very useful." [Student]

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# 2011 ASEE Conference Papers

STEVENS INSTITUTE of TECHNOLOGY THE INNOVATION UNIVERSITY

1. Fostering Systems Engineering Education through Interdisciplinary Programs and Graduate Capstone Projects. Jacques, David (Air Force Institute of Technology)

2. Integration of Systems Engineering Training Modules into Capstone Courses across College of Engineering Departments. Ellis, Darin (Wayne State)

3. SE Capstone: Experimental Learning in Distributed Classroom Environment for Systems Engineering Capstone Projects. Corns, Steve(Missouri University)

4. SE Capstone: Introducing Multidisciplinary Capstone Design to the United States Coast Guard Academy. Adrezin, Ronald (US Coast Guard Academy)

5. SE Capstone: Implementing a Systems Engineering Framework for Multidisciplinary Capstone Design. Sheppard, Keith (Stevens Institute)

6. SE Capstone: Introduction of Systems Engineering into an Undergraduate Multidisciplinary Capstone Course. Nemes, James (Penn State)

7. SE Capstone: A Pilot Study of 14 Universities to Explore SE Learning and Career Interest through DoD Problems. McGrath, B., Lowes, S., Squires, A., Jurado, C.

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# 2011 SIEDS Symposium Papers

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1. A Systems Engineering Approach to Micro Expression Facial Motion Capture with Structured Light. Bruner W., Chakravarthy, T., Jones, K., Kendrick, R., LaManna D. (Southern Methodist University)
2. Multiple User Motion Capture and Systems Engineering. Colvin, C., Babcock, J., Forrest, J., Stuart, C., Tonnemacher, M., Wang, W. (Southern Methodist University)
3. The Design of a Portable and Deployable Solar Energy System for Deployed Military Applications. Tyner, J., Coates, M., Holloway, D., Goldsmith, Daniels, C., Vranicar, T., Roling, J., Jensen, D., Mundy, A., Peterson, B. (US Air Force Academy)
4. Rapid Adaptive Needs Assessment (RANA) Water Quality Kit. Barham, S., Kazlauskas, S., Reynolds, R., Tabacca, J., Verrilli, E., Zhang, K., Harrison, P., Mathew, M., Louis, G. (U of Virginia)
5. Hand Tracking and Visualization in a Virtual Reality Simulation. Cameron, C., DiValentin, L., Manaktala, R., McElhaney, A., Nostrand, C., Quinlan, O., Sharpe, L., Slagle, A., Wood, C., Zheng, Y., and Gerling, G. (U of Virginia)
6. Using Electroactive Polymers to Simulate the Sense of Light Touch and Vibration in a Virtual Reality Environment. Cameron, C., DiValentin, L., Manaktala, R., McElhaney, A., Nostrand, C., Quinlan, O., Sharpe, L., Slagle, A., Wood, C., Zheng, Y., and Gerling, G (U of Virginia)

# Next Steps



- "Promising practices" by DoD site visitors informs selection criteria for second cohort of SE Capstone partners
- Final report/recommendations October 31, 2011
- RT-19A will study contexts for promising practices, deployable student products; sustainability and scale up models

# Problem Area 5



- Assistive technologies for wounded warriors to facilitate rehabilitation and contribute positively to wounded warrior quality of life, including but not limited to:
  - application of haptic research
  - augmented reality
  - research from traumatic brain injury
  - bio-medical advances
  - hybrid assistive approaches (e.g., human- machine interfaces) and other leading-edge technologies

# Promising Practices (1/2)



1. Fall semester tools/techniques/approaches SE theory course, followed by spring semester design project course
2. Cross-disciplinary student teams
3. Regular, direct involvement of mentors with student project teams
4. Established relationships with nearby DoD commands and facilities
5. Creative use of mentors from defense prime contractors

# Promising Practices (2/2)



6. Structured design reviews with DoD and industry mentors serving as reviewers
7. Use of SE Ph.D. candidates as project advisors
8. Creative imposition of technical, budget, and schedule constraints by faculty to model "real world"
9. For civilian institutions that have on-campus ROTC units, established relationships with ROTC units for requirements analysis, use case testing, and solution viability

# Questions?

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# Contact for more information

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