Systems Engineering Practitioner Development via a Multi-semester Design Project

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Outline

- Project Introduction and Scope
- Design Process
- Development Activities
- Current Status and Future Work

Project Initiation and Scope

- Project funded by Assistant Secretary of Defense Research & Engineering ASDR&E through the Systems Engineering Research Center (DoD – UARC).
  - Improve Systems Engineering education through practical application
  - Expand student exposure to SE
- Two-course sequence: concurrent education and application.

Immersive Training

Example: Camp Pendleton Infantry Immersion Trainer (IIT)

- Mixed reality training facility prototype for small unit Infantry located in a 32,000-square-foot (3,000 m^2) former tomato packing plant
- Marine Rifleman and the Small Unit Leader (SUL)
- Focusing on increasing the tempo of the OODA Loop during which an individual Observes a situation, Orients to it and develops courses of action (COA), makes a Decision, and Acts.
- Stress inoculation is conducted at the facility where a rifleman is put into multiple situations that in turn replicate the stressors and physiological responses faced in combat, thus building the individuals stress-immune system.

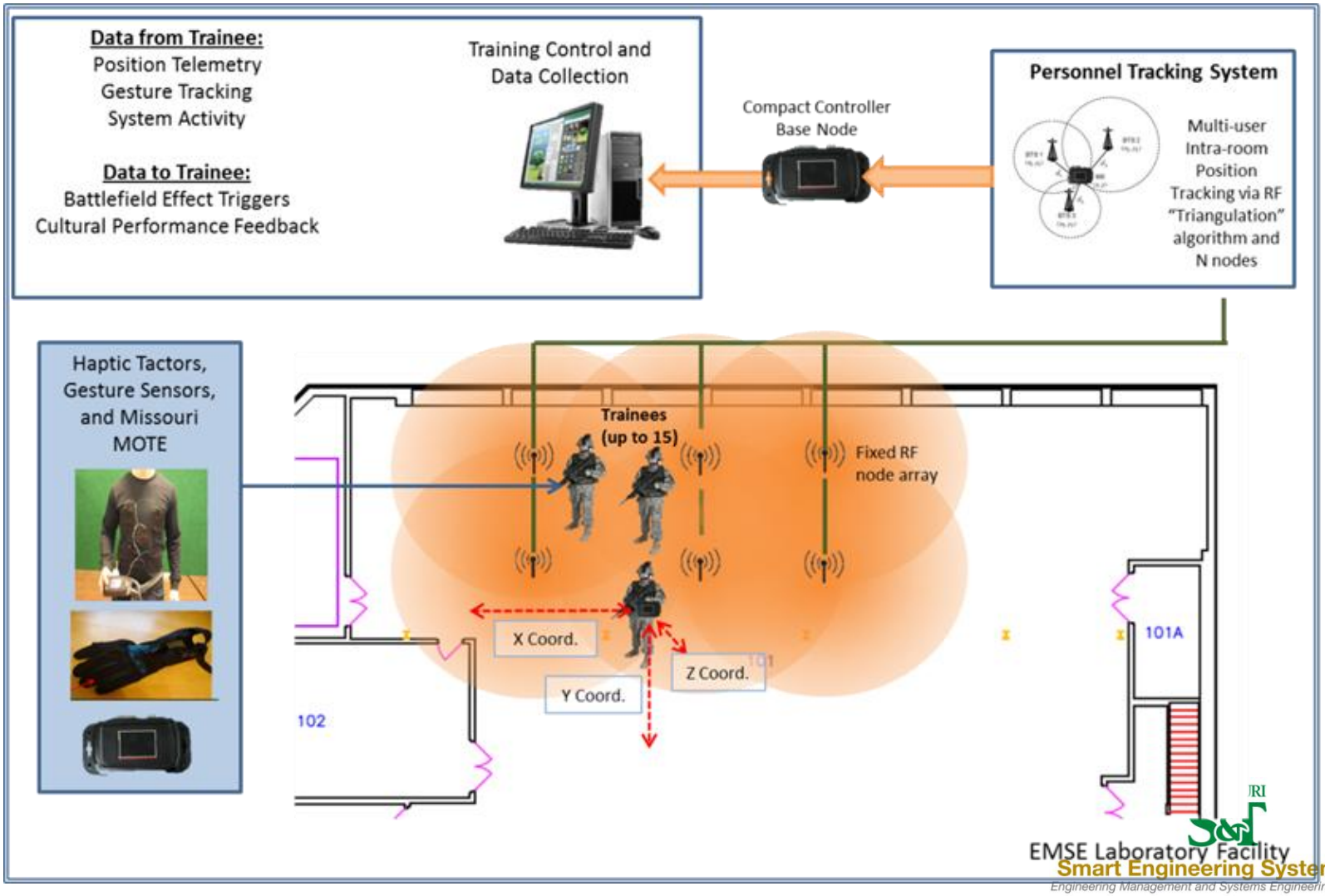
Design Issues

- Open-source
- Adaptable application
- Functional expansion
- Enhanced real-time feedback
- Enhanced after-action review

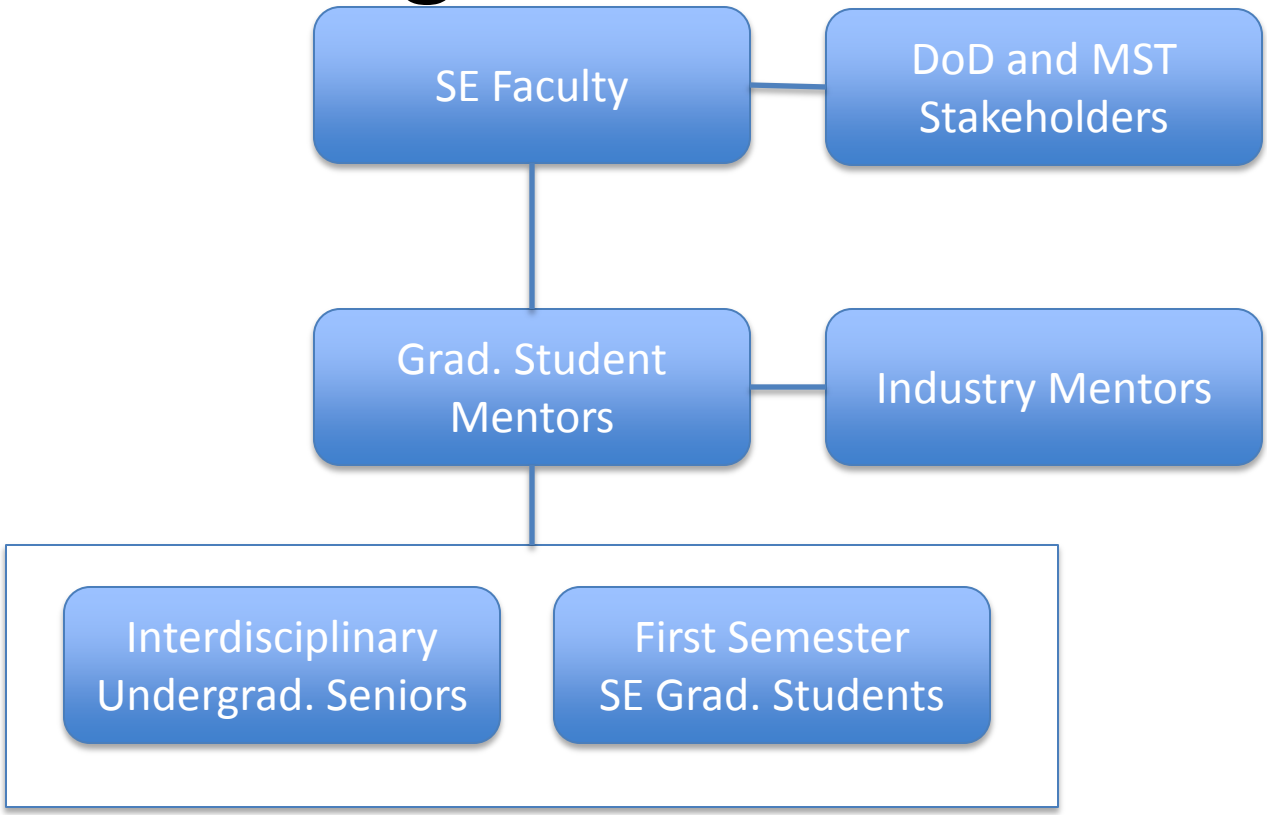
Stakeholder-derived Desired Capabilities

- Multi-functional “vest” platform
  - Processing, Networking and Power
  - Salient and discrete individual performance feedback
    - Battlefield effects
    - Behavior infractions
    - Prompted response
- Track elements of cultural awareness behavior
  - Location
  - Posture/Gesture
- Support advanced training AAR
- Validate trainee immersion
  - Expected cognitive and physiological responses

Operational View



Organization



Project Teams

Program Manager – Systems Engineering PhD Student
Defense Company Mentor – Systems Engineering from various defense company Sites
Faculty Mentor – Missouri S&T Systems Engineering Faculty
Course Project – Four or Five SysEng 368 Students

Integrated Project Status Board

Systems Engineering Program Director
Program Manager for each group
Systems Engineering PhD Student
Defense Company Mentor for each group
Systems Engineers from Various Defense Company Sites
Faculty Mentor for each group
Missouri S&T Systems Engineering Faculty
DoD Mentor
Customer
Owner of the need
Artifact Manufacturing
Department Technician

Two-Course Sequence

- Course 1: Introduction to systems engineering.
  - Primary focus conceptual modeling, requirements, high level trade studies, and architectures
- Course 2: Application of methods of engineering to create better systems through analysis.
  - Goal programming, simulation, time series forecasting, Discriminant Analysis, and others to verify or increase fidelity of design.

Course 2

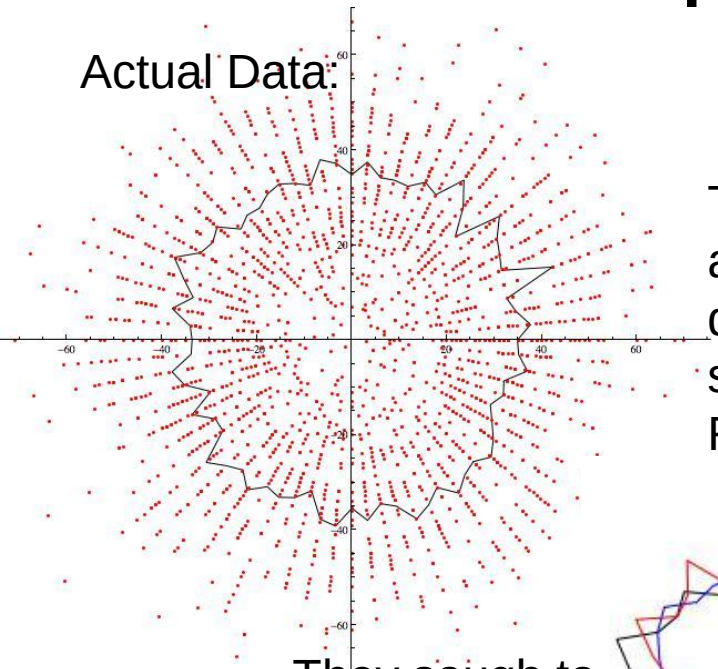
- Was broken into traditional and case-study methods
- Traditional: Student were given individual homework assignments focused on specific methods
  - Goal Programming, Discriminant Analysis, Time Series, and Simulation
  - Regular lectures were given to teach the mechanics of each method.
  - This allowed students to learn and internalized the methods and how to execute them using software packages.

Course 2 (Cont.)

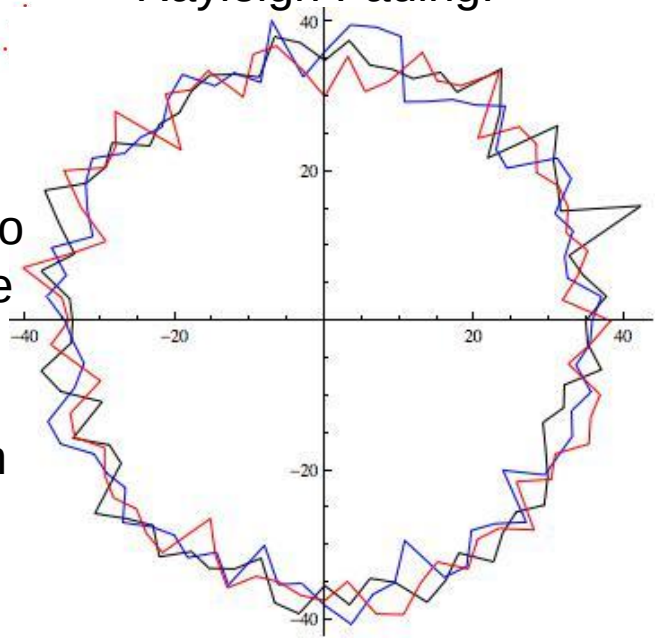
- Case Studies: used to highlight each of the presented analysis techniques in the context of systems engineering.
- Student were given actual experimental data to analyze.
- A technician is assigned to build actual hardware, software, and that met the DoD project's goals.
- The design was based on in the student's work from previous course.

An example Sample Case Study

Actual Data:



The students used analysis techniques to determine the statistical performance. Rayleigh Fading.

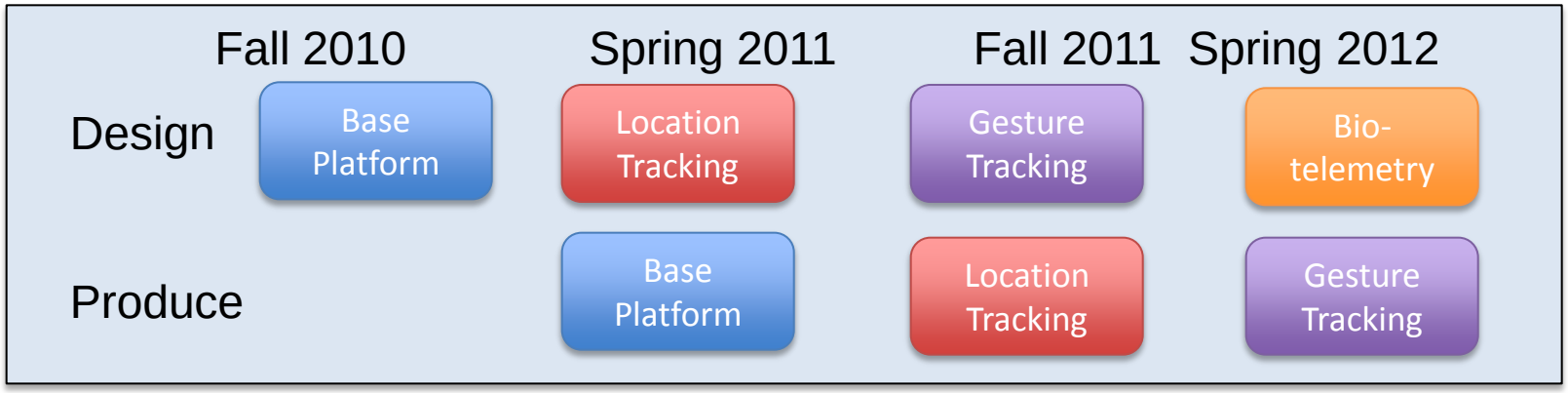


They sough to determine the coverage of the sensor system within the training environment.

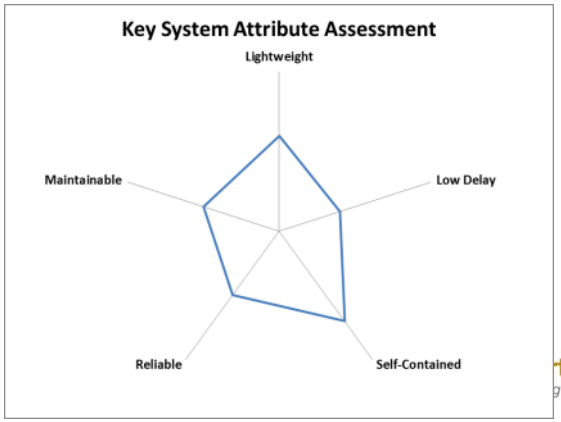
- Collected receiver signal power within the testing environment.
- The student were asked to assess the fading environment.
- The component has sensitivity thresholds and due to stochastic behavior the communication is not as reliable as thought.

Development Process

- Two-course series yields incremental system development over the course of four semesters.



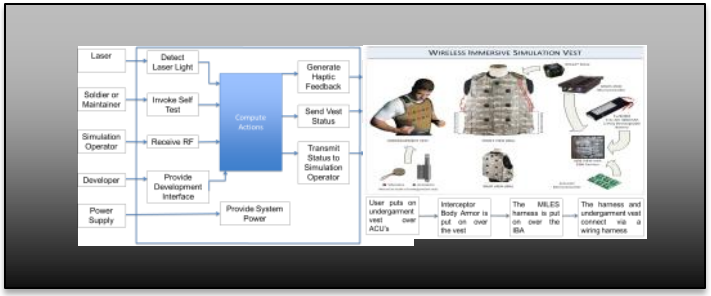
- Competitive Design -> Collaborative Integration/Prototyping/Test
- Assessment Tool and Reviews

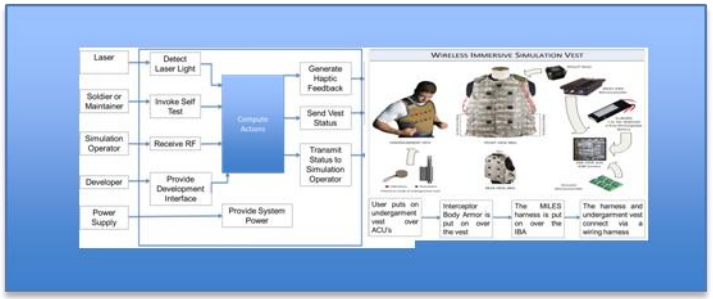


Development Process

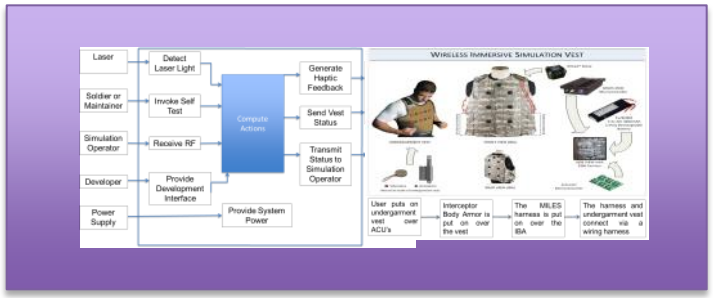
Requirements
Functional Analysis
Trades and AoA
Physical Architecture
Risk Assessment
etc..

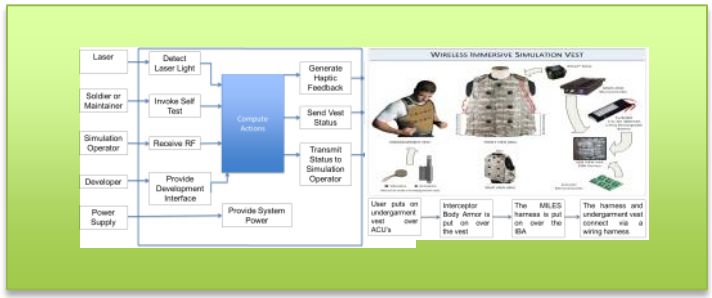
Development Process





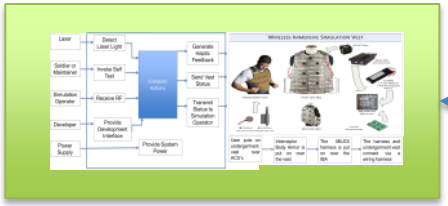
Need Statement
X





Development Process

- Prototype
- Test
- Val/Ver



Need Statement
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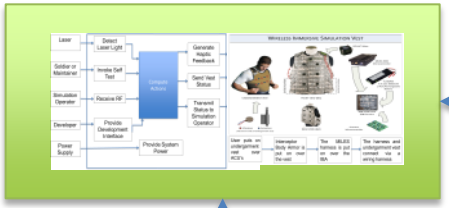
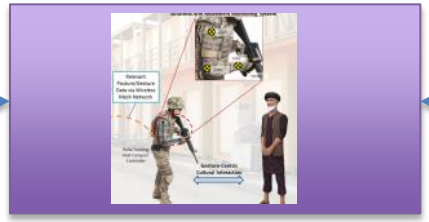
Tech.
Development
Problem(s)

- Applicable Requirements
- Performance measures

Development Process





Need Statement
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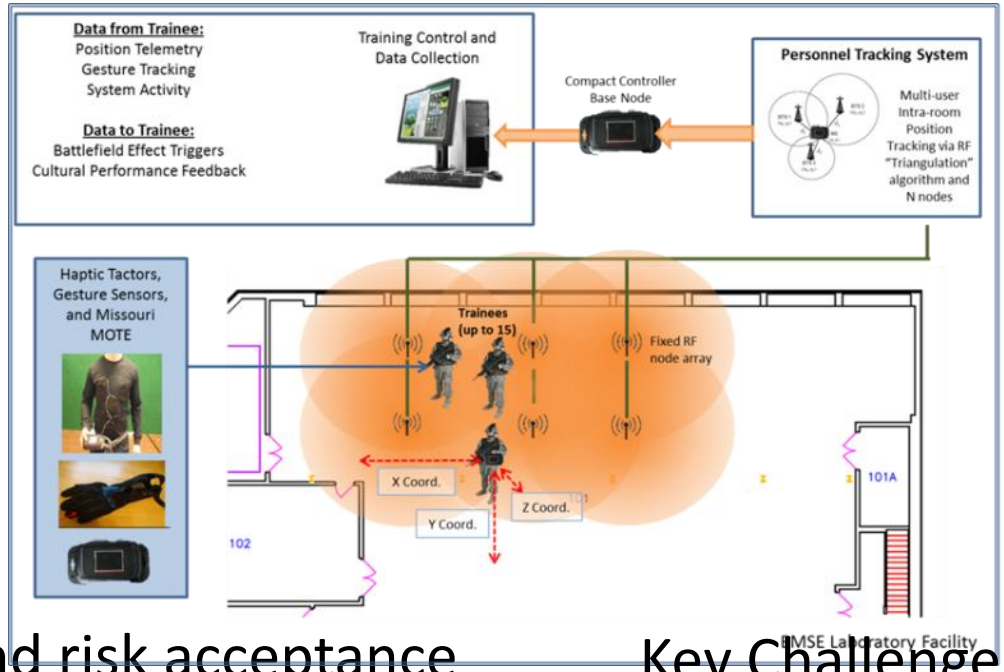
Tech.
Development
Problem(s)

Development Process



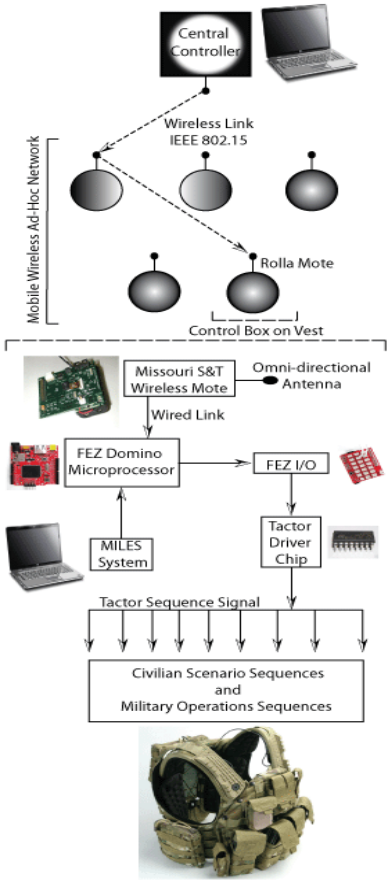
Limitations and risk acceptance

- Selection biases
- Experimentation
- Data fusion and visualization
- Revision of early designs

Key Challenges:

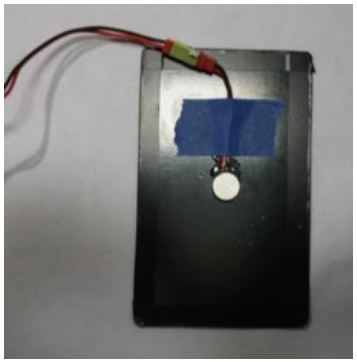
- Interfaces
- Planned expansion vs. traditional design objectives

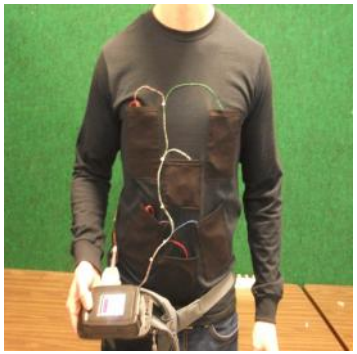
Phase 1: Controller and Wireless Network



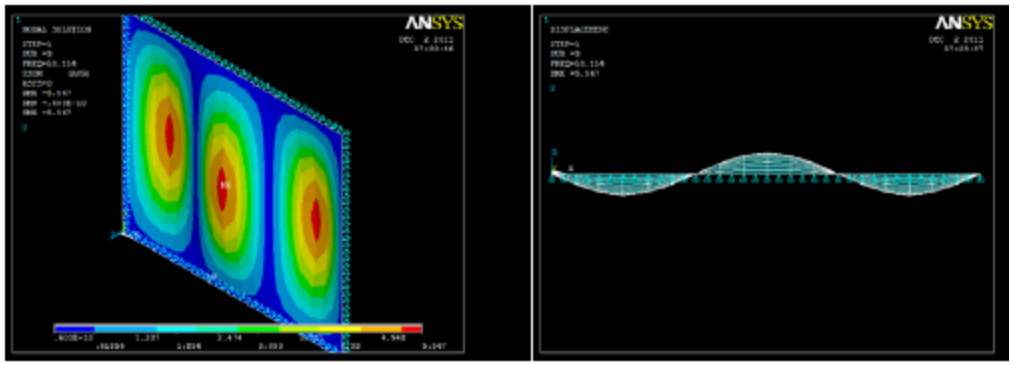
- Small wearable control unit (Mote)
  - color touch screen
  - RF radio
  - Microcontroller
  - Rechargeable battery
- Mobile ad-hoc network architecture
- “text message” data transfer
- Requirements and process for modification

Tech Problem 1: Enhanced Haptic Array

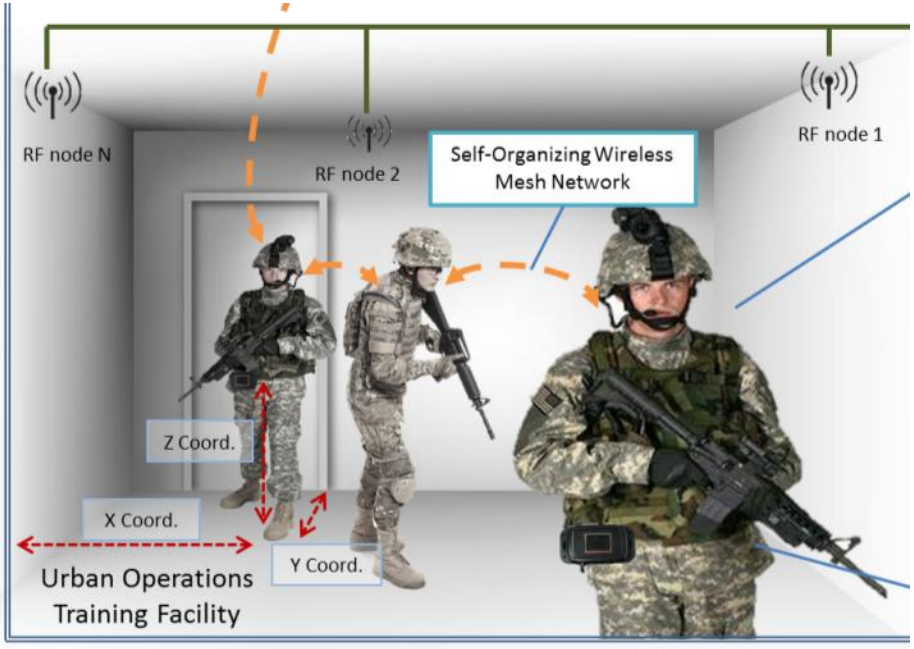




- Layered carbon-fiber composite plates (~ 10 cm x 10cm x 0.5 mm) tuned to amplify 1.7g vibrating tactor motor (12 mm x 3.4 mm)
- Bilaterally symmetrical arrangement (6 front, 6 back) on torso. Placement at highly sensitive zones.
- Anecdotal improvement in vibration perception, objective perceptibility test TBD.
- Notional information transmission patterns prototyped; optimization to be studied.



Phase 2: Position Tracking



- Alternatives
  - RF Tagging
  - RF Localization
  - Optical (individual or environment centric)

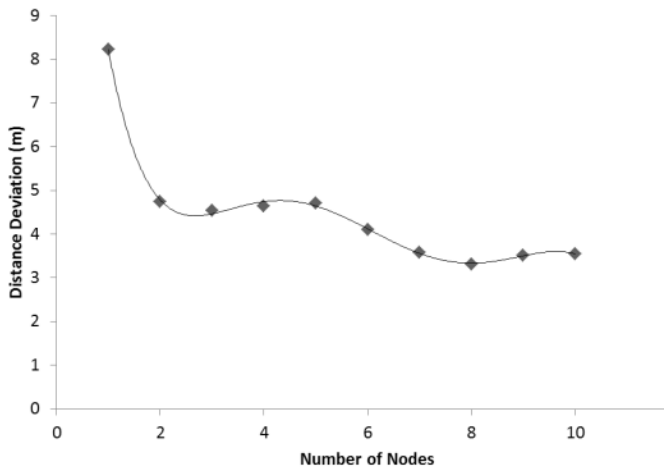
- Radio Frequency Location
- Network infrastructure design and data schema optimized via emperical regression analysis and stochastic simulation.

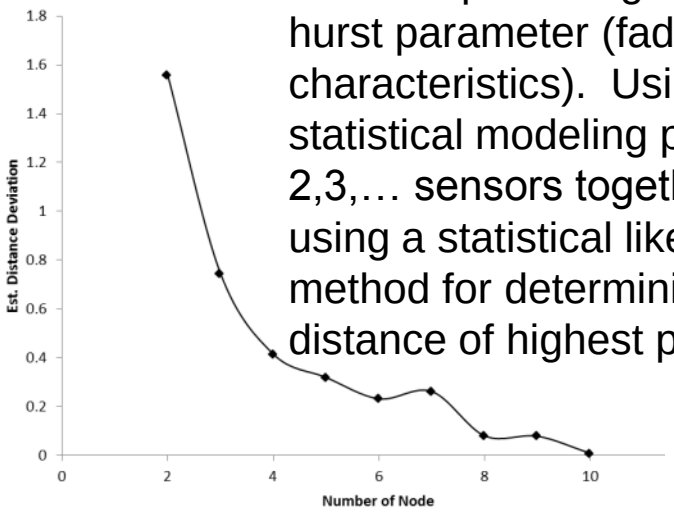
Tech Problem 2: Position Tracking Accuracy

Experimental Data: 175 measurements (1-20 m) from 10 independent nodes.

Estimate Distance with *Friis Path Loss Model:*

$$\frac{Pr}{Pt} = Gt * Gr \left(\frac{\lambda}{4\pi R}\right)^2$$

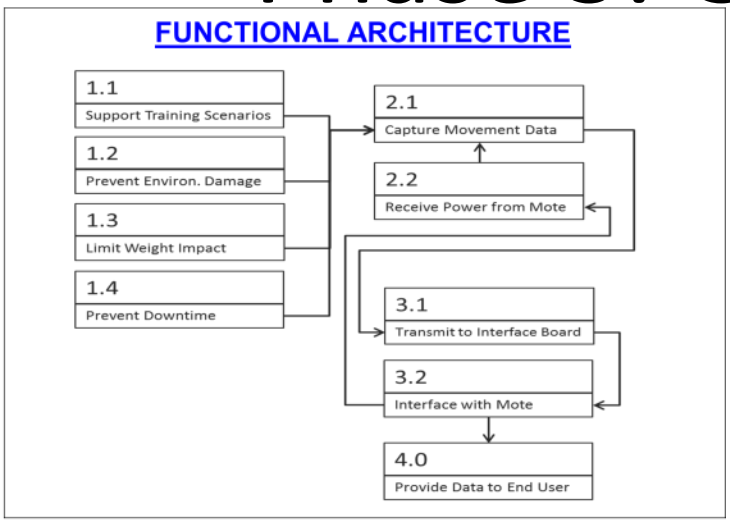


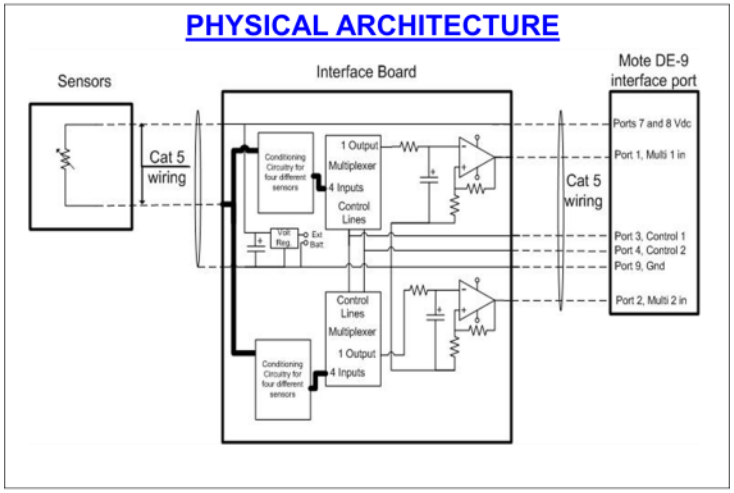


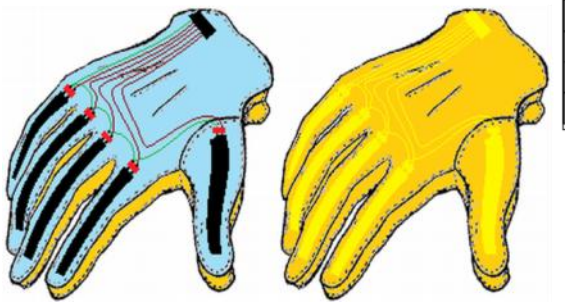
Time series collection of received power signals and hurst parameter (fading characteristics). Using statistical modeling pairing 2,3,… sensors together and using a statistical likelihood method for determining the distance of highest probability.

Simple Data Fusion

Phase 3: Gesture Tracking



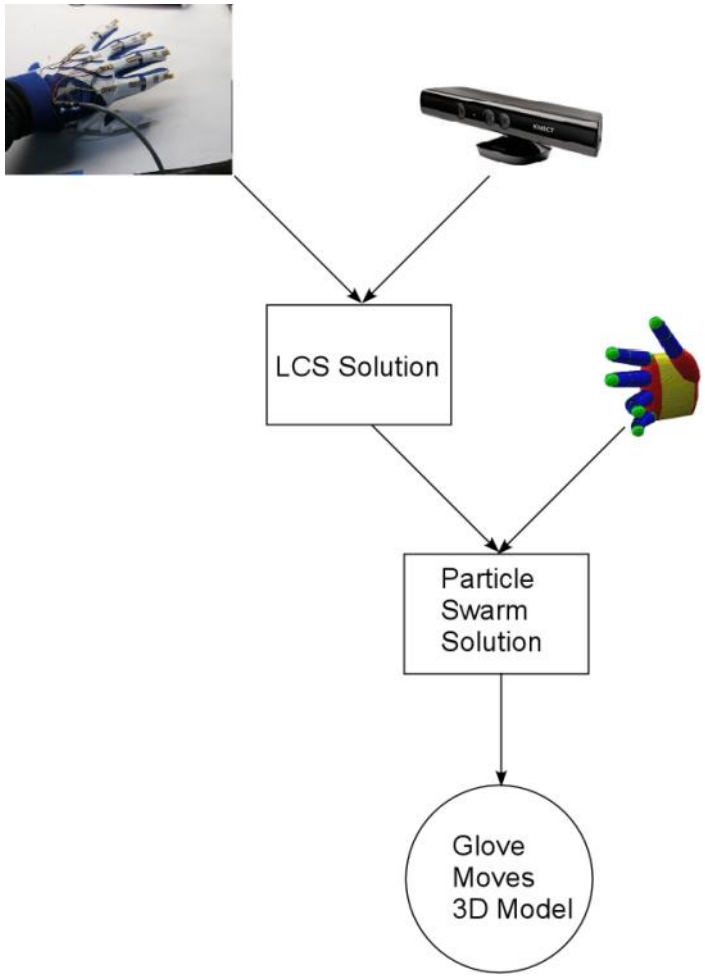




Gesture Sensors

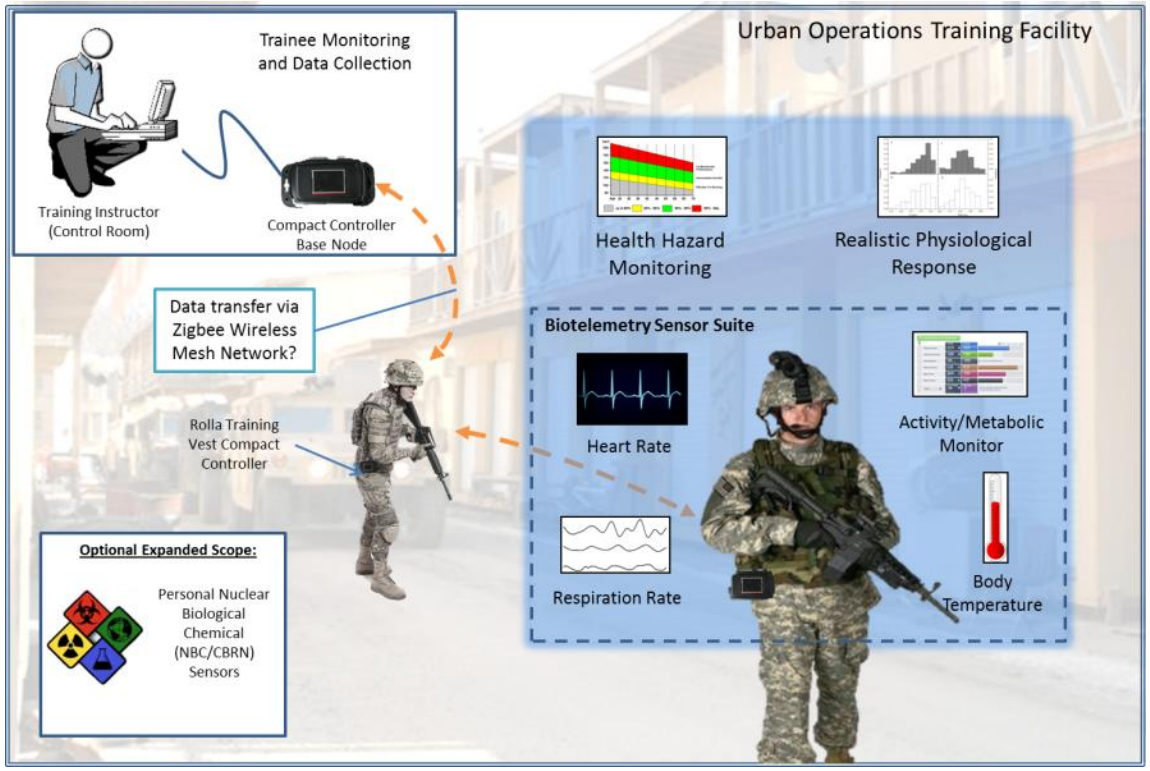
Low profile inertial and stretch sensors measuring hand/arm posture with up to 20 degrees of freedom.

Tech Problem 3: Gesture Calibration



- Computational intelligence (learning classifier system) to map electromechanical sensor input to “ground truth” via visual sensor input (Kinect).

Phase 4: Biotelemetry Monitoring (Spring 2012 project)



- Sensor Suite for health hazard monitoring and assessing physiological response to immersive training.
- Heart rate, respiration rate, temperatures, activity levels, etc.
- Designs are delivered May 2012.

Fall 2012 Need Statement

Immersive Training System

Customer

Col Lou Pape
lep7df@mst.edu 636 734-6789
DaD Training Coordinator
MST SE 368 Fall 2012

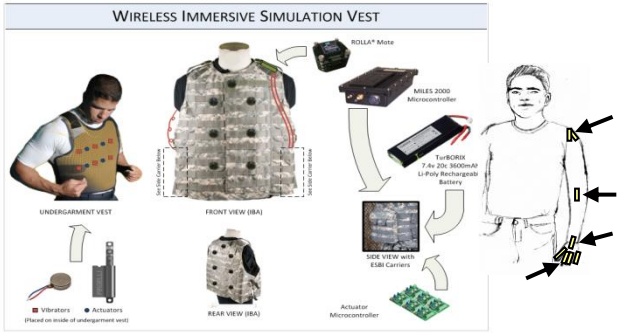
SE368 Need Statement (FS2012)

This project is to design a means to record/relay to a trainer the movements and reactions of soldiers in a given training environment, allowing for the evaluation or their ability to interact culturally with non-combatant foreign nationals. The scenario this will be used in will be an Afghanistan village, although the system must be flexible enough to be applied to other training scenarios. The information provided to the system will be through a set of legacy equipment as specified by the Integrated Training Vest (ITV) system. This information is relayed to a trainer in a control room monitoring a group of up to eight soldiers using the ITV system so that the trainer can evaluate whether a social faux pas has been committed. The system must be capable of monitoring, recording, and conveying sufficient information to evaluate the soldiers' performance within the simulation as well as the health of the soldiers during training. The overall budget for the development of the system is not to exceed $5000. The system design must be available by December 11 of 2012, and a prototype must be available for integration into the Missouri Mote system by May 5 of 2013.

Problem: New Troops make errors in-country that cost lives and Intel opportunities
Mission: Conduct realistic Squad Training in Near Real Combat and Cultural conditions; Efficiently train & test – physically & mentally – to eliminate "rookie" errors; Reduce trainer personnel workload; Increase trainee pressure; Improve trainee safety; Improve cultural understanding; Document trainee performance

What Activities can be "trained?"
How are the activities scored?
What feedback should be real time,
vs. after action?

What data can be collected?
What feedback can be delivered?



Debrief; Records update
Prep for next session
Batteries…storage dump

What does the Missouri Mote do?
What data gets sent?
How fast? Priorities?
Protocols? Error Handling

How is data processed?
What data is displayed?
Stored? Retrieved?
How do the Trainers use it?
How is training with the
System improved?

ITS Key Performance Parameters

- Number of simultaneous Trainees
- Number of cultural and combat Faux Pas detected
- Time to alert of a Faux Pas (Training Error) or Medical Emergency (related to System Latency)
- Size of operational area of the system
- Reliability of System equipment suite over a 4 or 8 hour training mission
- ITS Trainee Equipment Weight
- System acquisition cost
- Annual operations cost of System (5 days, 45 weeks)

Patrol tactics for a combat zone

- Use & Follow Team Leader signals
- Don't bunch up too close – you'll invite a group attack
- Don't get too far apart or get out of sight of the rest of your squad
- Don't all look the same direction at the same time
- Don't point a weapon at non-combatants or squad members
- Know where the closest cover is at all times, from all directions
- Stay hydrated
- Know your Rules of Engagement (ROE) at all times
- Don't fire your weapon at a target you're not sure of
  - It violates the ROE
  - Wastes ammunition
  - Endangers non-combatants
  - It informs the enemy that you don't know where he is

Cultural behaviors to be learned

- Don't use the *left* hand for physical contact with others, to eat, or to make gestures; it is considered unclean
- Do shake hands firmly but gently in greeting and departure. Always shake with the *right* hand
- Do try all food offered. This acknowledges the hospitality of the host. Often, items offered may have been difficult to acquire
- Don't show a woman attention by addressing, touching, or staring at her. Don't ask men direct questions about their female relatives
- Don't walk away from someone who is speaking to you
- Don't beckon or point with a finger. It is considered rude and may be mistaken for a challenge
- Do beckon others by extending your hand, palm downward, and curling fingers inward
- Don't wear sunglasses indoors. It is considered disrespectful of the building's status and its host

The survey

- Students were surveyed to assure that this pedagogy was working and that students valued the education.
- More importantly, we wanted to gage the student perception regarding learning, critical thinking, and engagement.
- A sample of 32 students responded out of 52 to a survey

CONCLUDING REMARKS

- The approach is well received by faculty, students and industry.
- It became a part of systems engineering graduate education on campus.
- It is also enhancing the research activities in this area.

Questions?

SURVEY RESULTS

LEARNING	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I felt the use of RT-19 Research Project was relevant in about the systems engineering concepts.	32.4%	**48.6%**	5.4%	10.8%	2.7%
The Integration of RT-19 Research Project helped me analyze the basic elements of systems engineering concepts.	27.0%	**54.1%**	2.7%	13.5%	2.7%
I felt that what we were learning in using the RT-19 Research Project was applicable to the field of systems engineering	29.7%	**48.6%**	8.1%	8.1%	5.4%
The RT-19 Research Case was helpful in helping me synthesize ideas and information presented in the course.	18.9%	**56.8%**	8.1%	5.4%	10.8%
The RT-19 Research Project allowed me to retain more from the class.	18.9%	**40.5%**	21.6%	13.5%	5.4%
I felt that we covered more content by using the RT-19 Research Project in the class.	13.5%	29.7%	**32.4%**	18.9%	5.4%
I felt that having a "customer" within the RT-19 Research Project helped me in understanding system scoping skills and methods.	16.2%	**35.1%**	18.9%	16.2%	13.5%
I felt having an industry "mentor" within the RT-19 Research Project helped me in understanding real-world systems engineering processes.	13.5%	**27.0%**	24.3%	**27.0%**	8.1%
The availability of a "Program Manager" allowed me to understand system engineering fundamentals.	18.9%	**27.0%**	16.2%	13.5%	24.3%

CRITICAL THINKING	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I thought the use of the RT-19 Research Project in the class was thought provoking.	24.3%	48.6%	13.5%	10.8%	2.7%
The use of RT-19 Research Project allowed for more discussion of course ideas in the class.	18.9%	48.6%	18.9%	10.8%	2.7%
The RT-19 Research Project allowed me to view an issue from multiple perspectives.	16.2%	54.1%	18.9%	10.8%	0.0%
The RT-19 Research Project allowed for deeper understanding of systems engineering concepts.	13.5%	48.6%	24.3%	8.1%	5.4%
The RT-19 Research Project brought together material I had learned in other engineering courses.	18.9%	43.2%	18.9%	10.8%	8.1%
I was able to apply the systems engineering concepts and theories to new situations as a result of using the RT-19 Research Project information.	18.9%	35.1%	32.4%	8.1%	5.4%
The "customer" within the RT-19 Research Project helped me perceiving system engineering methods from multiple perspectives.	10.8%	24.3%	35.1%	18.9%	10.8%
The industry "mentor" within the RT-19 Research Project helped me perceive systems engineering as a useful tool in real-world engineering.	5.4%	32.4%	29.7%	21.6%	10.8%
The availability of a "Program Manager" allowed me to think about project organizational methods.	10.8%	24.3%	27.0%	24.3%	13.5%

ENGAGEMENT	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The RT-19 Research Project added a lot of realism to the class.	27.0%	54.1%	5.4%	5.4%	8.1%
I was more engaged in class when discussing the RT-19 Research Project.	21.6%	40.5%	27.0%	8.1%	2.7%
The RT-19 Research Project was more entertaining than it was educational.	5.4%	16.2%	27.0%	37.8%	13.5%
I felt immersed in the activity that involved the use of the RT-19 Research Project	13.5%	45.9%	29.7%	8.1%	2.7%
I took a more active part in the learning process when we discussed / used the RT-19 Research Project in the class.	16.2%	48.6%	18.9%	10.8%	5.4%
I was frustrated by ambiguity that followed when using RT-19 Research Project as a reference.	18.9%	27.0%	21.6%	29.7%	2.7%
I felt that the use of the RT-19 Research Project was inefficient.	13.9%	13.9%	19.4%	44.4%	8.3%

I felt that the use of the RT-19 Research Project was inefficient.	13.9%	13.9%	19.4%	44.4%	8.3%
I found the use of the RT-19 Research Project format challenging in the class.	10.8%	48.6%	29.7%	8.1%	2.7%
Most of the students I know liked the use of the RT-19 Research Project in the class.	8.1%	27.0%	51.4%	8.1%	5.4%
I needed more guidance from the instructor about the use of the RT-19 Research Project in the class.	16.7%	30.6%	25.0%	22.2%	5.6%
The RT-19 Research Project took more time than it was worth.	10.8%	16.2%	27.0%	40.5%	5.4%
I felt that the guidance of the "customer" was critical to make the RT-19 project interesting.	16.7%	30.6%	25.0%	22.2%	5.6%
The real-world RT-19 Research Project " industry mentor" made the class more enjoyable.	5.4%	29.7%	32.4%	24.3%	8.1%
The "project manager" made the project more challenging and interesting.	10.8%	24.3%	24.3%	21.6%	18.9%
I felt that the RT-19 Research Project's "mentors", "project managers," and "customers" were more time consuming than it was worth.	18.9%	21.6%	35.1%	21.6%	2.7%