HOME BODY – HOW TO DETECT AND PREVENT FALLS IN THE HOME.

HOME BODY – HOW TO DETECT AND PREVENT FALLS IN THE HOME.

Falls are the leading cause of fatal injuries in older Americans. Sixty percent (60%) of falls happen inside the home. Twenty-nine thousand (29,000) adults die each year from falls; 850,000 who fall will be hospitalized. This project can help reduce those numbers.

OBJECTIVES.

This senior design is two projects in one.

The first project is to develop a sensor system that detects and reports a fallen human body in the home.

The second project is to integrate the sensor system into a residential structure while developing novel and innovative methods of preventing falls and improving access and usability in homes. Both are equally important; teams must work together to arrive at optimal solutions to their issues.

The first objective is to research, design and test a low-cost, portable, ambient environment device that detects the presence of a fallen stationary human body using InfraRed (IR) technology and/or sound at floor level and transmits an email message or some other alert to a designated email address. Although slips, trips, and falls occur in commercial and industrial environments, this senior design is limited to the home environment. When this device detects the presence of a near motionless human body within the constraints of a TBD timeline, it will generate and transmit an email message or activate an auditory alert. The intended audience are residential caregivers and adults who desire an extra layer of safety should they fall without someone else nearby to rescue them.

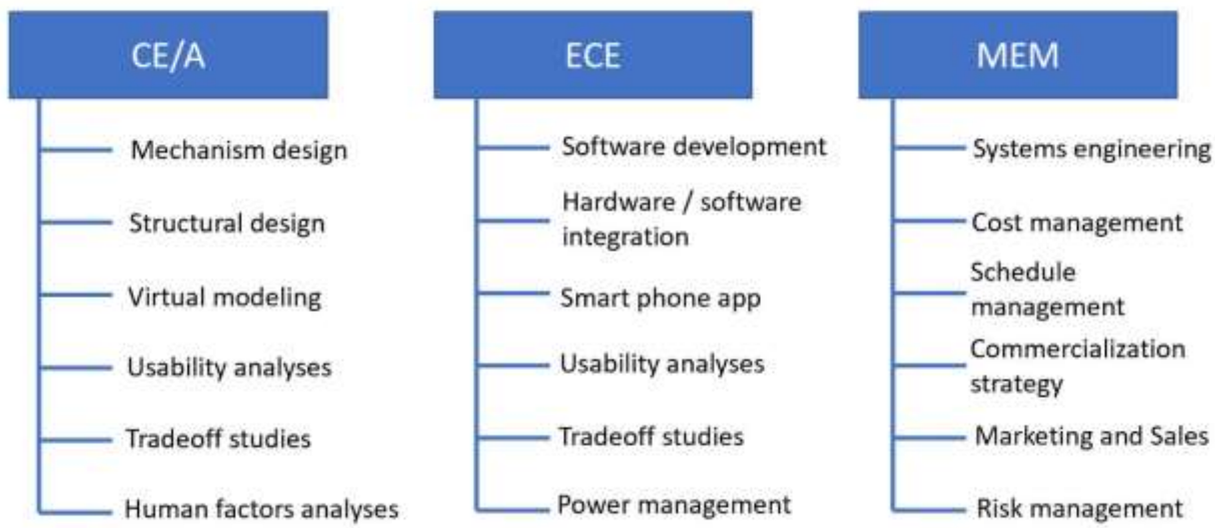
The second objective is to integrate this device into a typical house (3 bedrooms / 2 baths) and identify characteristics of residential structure, furniture, and floor design that contribute to falling. Teams must identify techniques, designs, or visual displays that might prevent falling accidents. For instance, there may be new ways of constructing kitchen cabinets to provide built-in steps or a stool. Imagine a foot-operated, pullout and pop-up step hidden in the kick space of kitchen cabinets or between cabinets. Such a feature might eliminate flimsy plastic steps and stools improperly used.

Teams are encouraged to compare traditional Western residential design with European and Eastern design. Teams are encouraged to not accept current preconceptions of furniture and kitchen structure. Teams will investigate factors like the coefficient of friction between various surfaces and materials and apply that knowledge to the design of common household items. Teams are encouraged to use space, objects, and furniture more efficiently to ensure safe activities for people of all ages, especially older adults.

TEAM FUNCTIONS, SKILLS, AND TASKS.

Civil Engineering / Architecture (CE/A) and Electrical / Computer Engineering (ECE) analyses shall integrate human factors engineering design guidelines, knowledge, and principles into the design of human interfaces in a home to resist falling. Management and Engineering for Manufacturing (MEM) shall perform systems engineering functions to coordinate CE/A and ECE efforts as well as developing business strategies, risk analysis, sales plans, and commercialization.

The following figure identifies some of the functions, skills, and tasks for each team.



A systems engineering approach is strongly encouraged by the co-sponsors. This includes fundamental systems engineering tools and techniques like trade studies, requirement traceability, functional block diagrams and flow down, Concept of Operations (CONOPS), schematic diagrams, and risk management.

An interdisciplinary approach to problem solving usually results in a better learning experience since each engineering discipline is exposed to different perspectives. Technical advisors and co-sponsors will provide systems engineering advice and other technical guidance on problem solving.

STUDENT TEAMS.

This Senior Design is offered to the College of Engineering at the University of Connecticut. Teams in Electrical and Computer Engineering (ECE), Management and Engineering for Manufacturing (MEM), and Civil Engineering/Architecture (CE/A) might be interested in this project for the following reasons. For this project, emphasis is on the construction, structural, and architectural aspects of home design, as well as structural loads imposed on objects by the human body.

ECE expertise is needed for hardware and software development and integration. MEM student expertise is needed to develop the risk, cost, marketing, manufacturing, and other business plans. A CE/A student might be interested in construction techniques and analyzing the architectural aspects of residential design that contribute to accidents and designing features which might improve accessibility and prevent falling accidents.

Experience and knowledge gained in this senior design is extremely pertinent in today's professional job market. This project requires applying knowledge in systems and civil engineering as well as user interface (UI) to achieve objectives. These disciplines are consistently ranked in the top 10 for 2020.

ADVISORY PERSONNEL

Electronic and Computer Engineering Technical Advisor: Professor Yaakov Bar-Shalom. Professor Bar-Shalom is recipient of the 2008 IEEE Dennis J. Picard Medal for Radar Technologies and Applications and Connecticut Medal of Technology (2012).

Electronic and Computer Engineering Senior Design Advisor: Professor Liang Zhang

Civil Engineering Senior Design Advisor: Professor Alexandra Hain

Management and Engineering for Manufacturing Senior Design Advisor: Professor Craig Calvert

Mechanical Engineering Senior Design Advisor: Professor Frank Cunha

Co-Sponsor: Richard C. Davids is a retired Senior Staff Human Factors Engineer, Lockheed Martin, in Sunnyvale, California.

Co-Sponsor: Michael K. Bartosewcz is a semi-retired electro-optics and systems engineer whose work experience includes Lockheed Martin, L-3, and Ball Aerospace.

MOTIVATION FOR PROJECT.

The societal and financial impact of adults falling and injury at home is substantial. The motivation for this project is quite personal yet the circumstances are common for nearly everyone.

Several years ago, Mr. Davids' mother lived at a nursing home for dementia patients. She fell in the middle of the night and remained wedged between the door and wall. No one knew she was stuck. Another time she climbed out of a crib, fell to the floor, and laid there for several hours before someone rescued her. Mr. Davids' aunt Helen fell in a doorway at her home and was unable to get up for 3 days until relatives arrived to check up on her. These accidents are not uncommon in homes and managed care facilities.

The sensor system might be ceiling, wall, or baseboard mounted at critical points in the home where slips, trips and falls are likely. The device might use sound or auditory cues to activate the system, also. It is imperative that CE/A and ECE teams work together to identify optimal locations and capability.

Where people fall is not where you might think they fall. Over eighty percent (80%) of falls occur in the living room, bedroom, and kitchen, typically on the ground floor. Falling getting out of a chair or bed is less likely. Falls are less likely in bathrooms and on stairs, also.

COMPETITION.

There are several commercial client-activated medical alert systems available for use in managed care facilities. However, these systems require the user to wear a device and/or activate it if the user moves or falls. They must be adjusted and set in place routinely by a caregiver. They are expensive. Wearable devices can be intrusive, also. Likewise, requiring the user who may be incapacitated to press a small button to activate an auditory alarm or electronic message is presumptive. This project will by-pass the need for the client to activate an alarm and notify a responder of a questionable or hazardous condition.

A company called 'Smart Caregiver' sells motion and pressure sensor devices that sound an alarm to notify a caregiver (within 30 feet) that someone needs attention. These devices are used in institutions and not in the primary home.

Preliminary research reveals that there is not a readily available, in-home device that uses either Infra-Red (IR) technology and/or motion detection or sound sensors to detect a human body on the floor and notify a caregiver. The human body thermal image is unique and within a narrow bandwidth, so such a device is less likely to produce a false positive. Developing such an ambient, non-intrusive device will reduce injuries in older adults who live alone and may not have immediate assistance. This device will be a life saver.

APPROACH.

Teams will research slips, trips, and falls and how these types of accidents happen and why. What is a slip? What is a trip? What are the architectural aspects like surface treatments, lighting, and house construction that might be pre-conditions for accidents? Can standard kitchen cabinets be modified to enable users to reach objects without climbing on step ladders and stools? What are the less obvious causes like age, fragility, and impairment?

Teams will research the advantages and disadvantages of current motion detection technology, including medical alert systems and wearable devices. Teams will investigate comparative cost, manufacturing, and marketing issues, location of devices, price points, form factor, usability, power usage, and Wi-Fi capabilities. Teams will research, design, and test at least one ambient surveillance device and test it in locations of your choice in a residential house.

The advisors and co-sponsors will assist in identifying preliminary system and conceptual design requirements. An example of a system requirement for ECE is “The sensor device physical envelope shall not exceed a 6-inch diameter, 3-inch-high disk.” An example of CE/A system requirement is “Human factors criteria shall be incorporated into notional kitchen, stairs, and living room arrangements.” An example of a system requirement for MEM is “MEM shall perform cost control to achieve a unit material cost of less than $99 per sensor unit.”

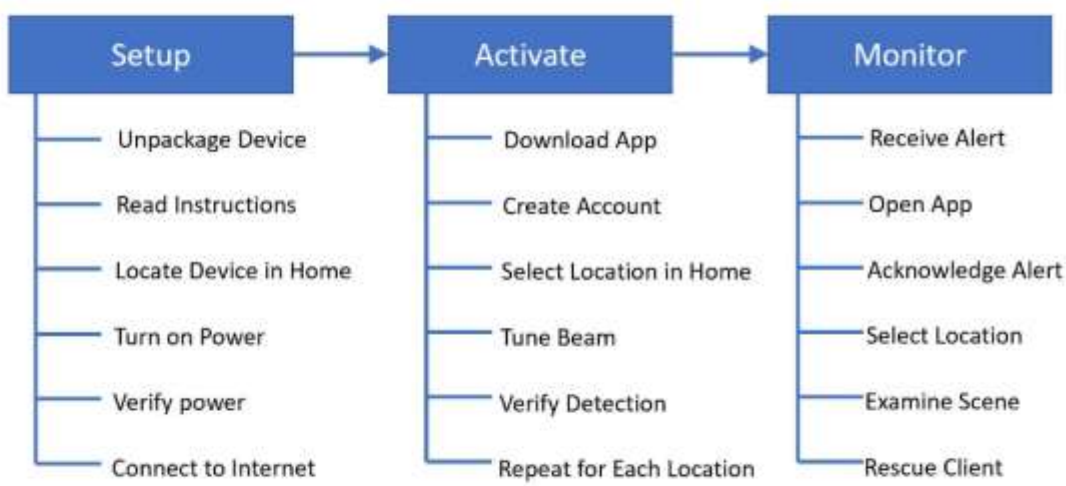
CONCEPT OF OPERATIONS.

One classic systems engineering analysis is the Concept of Operations (CONOPS). It is particularly useful in the project. The CONOP identifies what, when, how, and where various functions occur.

Setup of this sensor device most likely requires a smart phone interface. Since this electronic device must be installed, set up, and monitored, Teams are encouraged to consider what user interface might be used on a smart phone to setup the IR device much like the 'WEMO' a WIFI smart plug. Teams should prototype the functions that the user interface must perform like download app, setup app, create account, and how to control the electronic IR device. For instance, Teams should consider how to indicate status of the IR device to the user. Teams are encouraged to prototype the user interface and functions using a free graphical user interface simulation tools like

NOTIONAL FUNCTIONAL BLOCK DIAGRAM.

The following notional functional block diagram identifies the preliminary major and minor functions for operating Home Body in a client's home. The major functions are setup, activate, and monitor. Each of these major functions are broken down into at least five (5) secondary sub functions. The CONOPS for client use and the functional block diagram are closely related. Once the major functions and subfunctions are identified, then a story can be written that describes the who, what, when, where and how each of these functions is accomplished.



TECHNICAL ELECTRONIC AND COMPUTER REQUIREMENTS:

Teams shall be familiar with programming language for Arduino or raspberry Pi microprocessors including Python, or similar language, as well as small device power management, wireless link, and messaging. Teams should be familiar with small electronic board setup, test, and integration. Teams are encouraged to use Adafruit components. These DIY Adafruit components are inexpensive, easy to program and available online.

The problem domain is quite complex. For instance, teams will be expected to identify and discriminate between benign and potentially lethal situations. For instance, how can this device discriminate between someone who is resting on the floor from someone who has fallen and cannot get up or is unconscious? Software code must be developed that discriminates between the two, perhaps based on a time variable or motion variable.

A potential approach to detecting the fallen person is to use an automatic target recognition algorithm using a rectangular target search area. Areas like a bed or a couch would be out of bounds for this algorithm since the person could just be lying down on the floor to sleep or rest.

A frame grabber will be required to implement the automatic target recognition algorithm. The rectangular target area would be implemented in python software. Another block of python code will be triggered by the detection of a stationary human body and thresholded in the infrared (IR) rectangular target box. An interface to the Internet is required to transmit a distress message to the responder.

Mr. Bartosewcz will assist the teams in decision making and implementation of solutions in the IR problem domain. Professor Bar-Shalom's expertise in multi-target, multi-sensor solutions is extremely pertinent and critical to achieving an optimal solution.

NOMINAL TOPICS TO BE ACCOMPLISHED BY TEAMS.

The following list of topics and details are recommended to guide project development. These topics should be covered in end of semester reports in conjunction with senior design reporting requirements.

TOPIC	DETAILS
Motivation	Slips, Trips, and Fall statistics in the home and common causes.
System Benefits	Fewer fatalities, fewer ER visits, safer home design
Project Goals for Sensor System	Optimize accuracy, reasonable cost, improve residential safety, minimum form factor, optimized usability, nominal Field Of View (FOV).
Project Goals for Infrastructure	Innovative designs to improve safety, reduce slips, trips and falls, improve accessibility for everyday tasks, integrate human factors into structural design.
Approach	Research slips, trips, and falls. Research motion detection. Develop CE/A, ECE, and MEM plans.
Requirements	Develop system and detailed design level requirements, system schematics, task, and function analyses.
Alternative technologies	Consider motion, pressure, and sound sensors. Compare Bluetooth vs. Wi-Fi connectivity.
Analyses	Perform trade off studies, radar charts, risk, CONOPS, functional analysis, task analysis, FOV, human error analysis.

TOPIC	DETAILS
Design solution	Provide general description and approach for preliminary design, schematics, cost, power, packaging, user interface for sensor setup, etc.
Detailed system design	Describe mechanical, electrical, sensors, and software detail design.
Experimentation	Conduct lab or full-scale experiments or Solidworks modeling. Use virtual modeling to understand construction methods.
Verification	Test, demonstrate, analyze / simulate, or inspect system and home safety ideas
Business Plan	Provide estimated manufacturing cost, market analysis, partnering, competition, intellectual property, commercialization, customer base, SWOT analysis, advertising,

Civil Engineering / Architecture (CE/A) Function, Ideas, and Questions to Answer.

The CE/A team shall perform the structural, architectural, and environmental design, analysis, and modeling required to support the development of the Home Body device(s). The CE/A team is encouraged to research why and how slips, trips and falls occur in the home. What situational factors like distractions might precede as a fall? Investigate the age related and cognitive factors. Final analyses should concentrate on the physical factors that precede a fall.

Once analyses are complete, then CE/A team should design conceptual access aids like handholds, steps or stools that might improve access to objects. Can kitchen cabinets incorporate access aids like slide-out steps? Can handholds be built-in to cabinets to stabilize reaching objects above shoulder height? Why are cabinet door hinges vertical on left or right side? What if a cabinet door(s) was designed to fold down and becomes a step? How do you child proof such a cabinet door? How do you secure a step with a positive indication of engagement?

Although falls are less common on stairs, why is a banister usually on one side? How does a single banister impair ascending and descending a stair? How would double banisters aid ascend and descend while carrying an object? CE/A team is encouraged to model design improvements using Solidworks or other inexpensive architectural modeling software.

It is imperative that CE/A team members work closely with the ECE team to identify Field of View (FOV) and Line of Sight (LOS) in designing a fall-resistant kitchen or living room or other space. Scaled models may be constructed of cardboard to understand the interrelationships of FOV and LOS in low fidelity, inexpensive 3D models.

Teams are expected to use an inexpensive home design software package like 'Virtual Architect' or 'Punch! Home and Land' to model residential rooms like the kitchen, bedroom and living room. If teams use home design software, then virtual models of team's personal kitchen, living room or house can be used to evaluate sensor placement and safety features. Modeling your home enables you to perform construction design, cost estimating, locating load bearing walls, electrical outlets, appliances and more. These software packages usually include 'fly around' capability, panning and zooming, and ability to modify cabinets and other details in custom libraries. Since 'Punch' includes a custom workshop for modifying existing or creating new objects for animation, 'Punch' is recommended. Likewise, Solidworks might be used in conjunction with a human computer modeling program to integrate life size human body into the home model.

The following figure is an example of virtual modeling by Mr. Davids using 'Virtual Architect'. This inexpensive 3D modeling tool might be used to show sensor system locations, FOV and LOS. They are easy to learn and use plus give the user a better understanding of construction techniques and cost.

Figure 1 - Virtual kitchen model using Virtual Architect

CE/A team members are encouraged to consider hidden space that is built-in to cabinets by convention. How can you use this 'hidden' space for access aids? Likewise, vacant space under a bed or dresser might be used for sensors or sliding steps. Teams are encouraged to create novel and interesting ways of camouflaging the sensors. Can Home Body sensor be hidden in picture frame? Can it be plugged into a wall socket and provide optimal coverage?

Management and Manufacturing for Engineering (MEM) Function, Ideas, and Questions.

MEM/SE shall perform the systems engineering management, business planning, manufacturing, and logistics analyses. This function includes developing system and detailed requirements with the assistance of co-sponsors, allocating requirements to ECE and CE/A teams, tracking compliance to requirements, developing business and marketing plans, cost analyses, competitive analyses and other associated management and business functions.

Keep in mind that coverage is a consumer choice factor – not a strict technical factor. For instance, a buyer might decide to purchase only one per room based on price. Or based on guidelines, the consumer might purchase 3 sensors much like WiFi repeaters.

MEM team shall function as the systems engineering entity in this project. MEM shall initiate, coordinate, and conduct all team meetings with meeting itinerary, attendee list, action items, etc. Co-sponsors will assist in methods for conducting comprehensive meetings. One goal is to familiarize MEM engineers with systems engineering best practices in aerospace, construction, and energy business.

Electrical Computer Engineering (ECE) Function, Ideas, and Questions.

ECE student team is responsible for researching, designing, and testing a Home Body IR sensor system that detects a near motionless or motionless human form, analyses it against criteria, and transmits a message to a designated smart phone. ECE shall develop the Home Body sensor system using commercial off-the-shelf (COTS) hardware and software, especially open-source software.

ECE shall optimize FOV and LOS coverage considering cost, convenience, and usability of the device and system components. Sample locations for sensors in one or more notional room (kitchen, living room) layouts is expected with concomitant approximation of coverage. The goal is to approach the sensor system as a commercial product that would include a user manual for installation and use.

That one device in the optimal location might provide very good coverage of the room. We assumed that each sensor device would have one IR camera. What if the sensor device had two opposing IR cameras? Will FOV and LOS be doubled? The sensor device is envisioned as about the size of a ceiling mounted smoke detector and should be considered the maximum envelope.

TRADEOFF STUDIES.

All system design projects involve tradeoffs. In Home Body, a major tradeoff study involves coverage. For instance, 100% coverage of a large room might require 5 sensors. If each sensor costs $100, then the price for covering one room at 100% could cost the consumer $500 for devices alone. Depending upon the room arrangement, one sensor might provide 50% coverage of the vulnerable floor space. This senior design requires teams to identify vulnerable areas and recommend placements in something like a user manual. Likewise, coverage is considered a consumer choice since it involves several factors like unit price, FOV, and room arrangement.

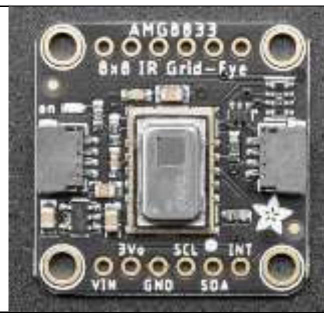
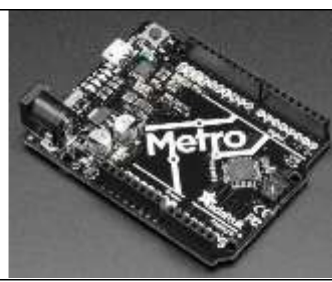
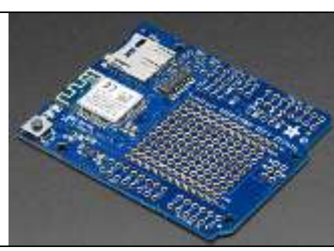
Teams must analyze several nominal layouts and determine the optimal locations for one, two and three sensors per room or area (staircase). One expected outcome of this project is a set of guidelines for locating one or more sensors based on typical room arrangements. Thus, whole room coverage is really a consumer choice rather than a technical requirement. The goal for

ECE is to maximize or optimize coverage at a reasonable per item cost commensurate with sensor complexity, reliability, usability, and durability.

Field of view or coverage is only one of many tradeoff studies. Suggested tradeoff studies involve deciding between battery operated or AC operated, camera characteristics and capabilities, frame storage, packaging, component cost, reliability, and connectivity. Good system design is a balance of many factors.

IR SENSOR SYSTEM NOTIONAL PARTS LIST.

The following components are suggested based on review of open-source electronics prototyping platforms and ease-to-use hardware and software. The following selected components are available from Adafruit. A catalog photo, model number and retail price are included.

ITEM	CATALOG PHOTO	MODEL	RETAIL PRICE ($)
Thermal camera breakout		AMG8833	44.99
Microcontroller		METRO 328	17.50
WiFi shield		WINC1500	24.95

ITEM	CATALOG PHOTO	MODEL	RETAIL PRICE ($)
Microcontroller (alt)		HUZZAH32-ESP32 Feather	19.95
Lithium-ion polymer battery		3.7v, 500 mAH	7.95
Display		TFT LCD display	24.95
Miscellaneous items		Case, breakout pins, cables.	50.00

LINKS AND RESOURCES.

Internet of Things and Do It Yourself Products, Software, and Ideas

https://www.adafruit.com/product/3538

Falls in the Elderly

https://www.lively.com/health-and-aging/elderly-falls-statistics/

Detection and Tracking of Human

https://ieeexplore.ieee.org/document/8342790

Slip and Fall Quick Facts

https://nfsi.org/nfsi-research/quick-facts/

Stop the Slip – Reducing Slips, Trips and Falls

https://www.amazon.com/Stop-Slip-Reducing-Slips-Trips/dp/0998354910

Smart Caregiver – Fall Prevention and Wandering

https://smartcaregiver.com/

SPIE Digital Library

https://spie.org/Publications/Book/2542435?SSO=1

Automatic Target Recognition

https://en.m.wikipedia.org/wiki/Automatic_target_recognition

Target Detection Using Image Processing Techniques

https://www.researchgate.net/publication/283517014_Target_Detection_Using_Image_Processing_Techniques

Human Factors Engineering Guidelines

http://www.deepsloweasy.com/html/hferesources.htm

EXPECTED COMMUNICATIONS AND REPORTS.

Teams are encouraged to meet weekly, if possible, to discuss progress. A short Weekly Activity Report is a good way to track progress and as a reference for end-of-semester reporting. Long term memory recall is easily corrupted, so teams are encouraged to document progress, ideas, and discussions on a routine basis. MEM team is expected to log meeting minutes.

Expected documentation include system and detailed design requirements, detailed schematics, procedures, a design review with action items, a test plan, lab reports, and a business and marketing plan. A set of guidelines for locating sensors is expected. These are strongly recommended reports dependent upon staffing and expertise. An end-of-semester report and a final report are expected consistent with UConn College of Engineering senior design requirements. UConn Senior Design project requirements take precedent over recommended documentation.

Co-sponsors recommend a monthly meeting with teams preferably by Zoom or Skype – whichever is more convenient. Mr. Bartosewcz lives in Wichita, Kansas and Mr. Davids lives in Kingston, Rhode Island. Therefore, electronic meetings are strongly advised. Mr. Davids may be available to travel to Storrs periodically.

RELATED UCONN ENGINEERING COURSES AND FOCUS AREAS.

The following courses described the 2021 undergraduate course directory appear applicable to the research, design, and development of Home Body. This list shows that the Home Body senior design involves many courses and areas of interest across mechanical, electrical, computer, civil, systems, and manufacturing engineering. Students who enrolled in these courses or are interested in the focus areas might enjoy working on Home Body.

4520. Digital Image Processing for Biomedical Engineering

4910W. Biomedical Engineering Design II

3224. Analysis and Design of Mechanisms

3225. Computer-Aided Design, Modeling, and Graphics

3263. Introduction to Sensors and Data Analysis

3265. The Engineering Process for Innovation and Value Creation

3315. Manufacturing 4P: People, Planet, Process and Profit

3500. Technology Innovation and Entrepreneurship

3100. Systems Programming

3200. Mobile Application Development

1151. Introduction to the Management and Engineering for Manufacturing Program

2212. Introduction to Manufacturing Systems Lab

Design and Manufacturing

Computer Aided Design

Occupational and Environmental Medicine

CO-SPONSOR RESUMES:

Richard C. Davids. Mr. Davids is a cancer survivor and retired senior staff human factors engineer with Lockheed Martin Missiles and Space Systems, Sunnyvale, California, 1974 – 2007. He applied human factors engineering principles and design standards to mobile shelters, large facilities, missiles, ships, planes, spacecraft, Office of the Secretary of Defense Crisis Coordination Center, transportation systems, railcars, missile and submarine support equipment, equipment racks, and computer human interfaces.

Mr. Davids worked with mechanical and electrical engineering, systems engineering, specialty engineering, manufacturing, training, logistics, parts, materials and processes, facility and field engineering, DOD, and special customers.

Mr. Davids taught Specialty Engineering, CONOPS, human factors engineering classes and is a Certified Human Factors Engineer #529. Since 2011, Mr. Davids has sponsored 13 Engineering Capstone, Honors, and Senior Design projects at the University of Rhode Island, University of

Connecticut, and Roger Williams University. His projects won both regional and international awards.

Contact Information:

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Michael K. Bartosewcz. Mr. Bartosewcz is a semi-retired systems and electro-optics engineer. Michael holds bachelor's degree in Electrical Engineering from the University of Vermont and master's in Physics, University of Vermont. He is a Certified Principal Engineer (CPE) CORE Training (completed at Lockheed Martin).

He has extensive experience in providing system level concept development for new EO/IR sensors, with focus on missile track/missile warning, space situational awareness, and earth imaging at high resolution, hyperspectral imagers (patent pending). He has hands-on experience in developing, integration and testing of space flight EO/IR hardware.

Mr. Bartosewcz has significant systems engineering and program management experience in the design/building/testing of end-to-end C4ISR systems including SBIRS High (ONIR), ABL, IKONOS, U-2 Multispectral Camera, Look Down Stabilized Gimbals and Battlefield Ordnance Awareness (MASINT) Programs. He is well versed in system architecture analysis and trade studies, as well as defining sub-system and component level requirements. Mr. Bartosewcz ran his own company, EO Space Systems, for 12 years.

Contact Information:

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Wichita, Kansas, 67206
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INITIAL BUDGET:

$500. Materials only. A cost-plus option may be available for unordinary material expenses.