Purdue ECE Senior Design Semester Report
(Team Section)

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2019
Advisors	Mithuna Thottethodi, Todd Wild
Team Number	2
Project Title	The Guard DAWG System

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Evan Miller	CompE	Embedded Systems	May 2019
Yash Nain	CompE	PCB Design, Electrical Eng	May 2019
Ian Sibley	CompE	Software design and test	May 2019
Viktoryia Zhuleva	CompE	Embedded Systems	May 2019

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Provide a general description of the product to be delivered by this design project.

The Guard DAWG System is a security system that uses a door mounted camera to verify registered users using facial recognition software. The product is target at residential and commercial properties that want to increase security as a face isn't as replicable as a physical key. It also provides the benefit of convenience of not having to carry around a physical key.

The system uses three different computing resources including a microcontroller, and single board computer, and a remote server to interface with electrical components and process a resource heavy recognition algorithm. The system will have two user facing components: the door mounted camera and an alphanumeric keypad. The keypad will allow the user to press a button to start the recognition process or a password in the event that the system loses internet connection. If the user wants to start facial recognition, it signals to the single board computer to capture an image and send it to the remote server to be processed. After processing, the remote server sends a response back to the single board computer which in turn tells the microprocessor to unlock the door.

(b) What is the purpose of this product? For whom is it intended?

The purpose of the Guard DAWG System is to enhance security over a traditional lock and key mechanism. A user's face is much more unique and harder to duplicate than a physical key. This also gives the property owner more control over who has access to the property. Additionally, a tenant will no longer have to carry around a physical key. There is a growing market for smart home devices that emphasize security and privacy, and our system attempts to solve this to some degree.

(c) Describe how the engineering design process used to create your product was utilized in this project. Include how you were able to develop and conduct appropriate experiments, analyze and interpret data, and use engineering judgment to draw conclusions related to the development of your product.

The engineering design process started ideation and scoping by identifying a problem we as a team wanted to solve in a relatively short time frame. From there, we narrowed down proposals by examining existing solutions that solve similar problems and by identifying technologies we could utilize. After this initial ideation, we constructed success criteria that we deemed necessary for a viable project and characterized how we should move forward with development. From there we established a plan for a bottom up approach that involved prototyping smaller components individually and then slowly integrating them into the larger system. This allowed us to easily identify points of failure and bugs later on the in the top level system integration.

A major part of our design relied on our selection of components. We wanted to have reliable, cost effective components that would allow us to be flexible in our design. As such, we chose our microcontroller that had more than enough processing capability and a single board computer (Raspberry Pi) for its community backing. We ordered other parts from reliable manufacturers and began unit tests for to establish reliability.

(d) Describe the design constraints, and resulting specifications, incorporated into your product (list a minimum of 3).

One of our major constraints was making sure we had enough computing power to run the recognition algorithm quickly to provide a seamless experience. As such, we used a Raspberry Pi for capturing and preprocessing images and a remote server to run the algorithm as it wasn't feasible to run the algorithm on a microcontroller. Another major constraint was selecting a microcontroller as several factors we part of that decision making process. We had to make sure there were enough GPIO pins, support for common protocols like UART and SPI, and was fast enough to keep up with the rest of the system. As a result, we chose a MSP432 because it fit that criteria while also being cost effective over competing products. Our third major design constraint was time. The project is intended to deliver a real prototype of a viable product in only a few months and as such we had to make design decisions quickly. In order to deal with this, we used a Gantt chart to map out when we want to accomplish certain milestones in development. As a result, our product is using board that has been revised twice with every major component and subsystem tested with time to spare in case anything goes wrong. We had several other constraints but these are the main issues our team grappled with the most.

(e) Describe how each of the following factors influenced your design specifications and constraints.

Health, Safety, Safety, and Welfare: The purpose of the Guard DAWG System is to provide security and safety to residential and commercial homes. As such, we designed our system to improve on the security of a traditional lock and key so the user can have peace of mind. Our design accounted for network and electrical outages to make sure a tenant or owner always has access to their home. If taken to market, the system would first have to pass tests.

Global: The Guard Dawg System was intended to be sold in the U.S. and Europe and we have reviewed the environmental and safety standards required to bring it to market. If we wanted to make the system for sale in more markets we would have to first make sure that all requirements and tests are accounted for. There are not any major concerns about the product being used globally.

Cultural: There are several facial algorithms used to detect faces and we wanted one that performed well regardless of skin color and race. We understand there are limitations in the camera technology we are using but the Guard DAWG system is intended for everyone and as a team have made measures to ensure that this holds.

Social: We acknowledge society's growing concern with privacy and technology and made sure that we have security measure in place to protect user's digital information. The camera is not always capturing images and any major action is triggered by user interaction. Further, the user is in control of who is registered in the system. We hope that our system instills trust in security technology moving forward.

Environmental: In order for our product to be sold in the U.S. or Europe, it has to pass certain environmental tests. Our design does not use any harmful materials and should have a low environmental impact.

Economic: The design process involved picking low cost development components. The design can be modified later to improve manufacturing costs. If taken to market, our design has a target audience that would be willing to purchase the product at a healthy margin. Costs were also taken into consideration throughout development process as we had a limited budget and limited time.

(f) Describe the appropriate engineering standards incorporated into the creation of your product.

In order for the Guard DAWG System to be sold in the U.S., it needs to be in compliance with the Federal Communications Commission (FCC) because it has an internal oscillator operating above 10kHz. Our system operates well above 10kHz and would be considered a Class B digital device. As such, it would needed to be sent to an FCC accredited laboratory to receive certification. We also want to sell our system in Europe and would need RoHS compliance and get a CE marking. RoHS compliance means we don't use hazardous materials in our product. A member state of the EU would test the product independently. The CE marking means our product adheres to the health, safety, and environmental standards required by all products bought or sold in the EU. We can test for a CE marking at the same lab as the FCC testing.

(g) Describe the final status of your product.

The final status of our product resembles a viable prototype. The system is mounted on a mock up of a door and achieves the intended functionality of unlocking a push bar after verifying a registered user's face. They system we built has wireless connection between a MSP432 microcontroller and a Raspberry Pi via Bluetooth, and between the Raspberry Pi and a remote laptop over Wifi. The Raspberry Pi and MSP432 have a mechanical enclosure preventing any exposed connections. A user is able to start facial recognition with the keypad and see a status indication via LEDs.

(h) Describe the makeup of your project team and how you were organized to establish goals, plan tasks, and meet the objectives of this project.

The team was lucky enough to have a wide range of experiences that were vital to our overall success. We had members with different class, internship, and club experiences that proved to be helpful in making key design decisions. Although we established roles for the sake of the project, everyone helped in different areas depending on what was asked of us. We decided as a group the scope of the project and what we wanted to accomplish by defining our Project Specific Success Criteria (PSSC). From there, we made a Gantt chart to map out our development timeline. We made sure to have certain development processes happen in parallel for hardware and software to increase productivity. Planning was a key part of making sure we met success criteria and we held weekly meetings to make sure we were on track.

(i) Did your project require the production of any written documentation other than this document (i.e., manuals, educational materials, etc.)? If so, describe the types, composition, and nature of the audiences for whom these materials were intended.

The project has a User Manual that is written in English and is intended for the home owners and/or small businesses. It features the setup instructions that are very detailed and easy to understand. The manual also features usage instructions that describe the ways to interface with the system. And, finally, it has the list of common issues alongside with troubleshooting instructions to assist users in case of component failure.

(j) Describe the types, composition, and nature of the audiences in attendance for the final oral design review. Discuss how you prepared for this audience.

The audience for our final oral design review consists of a group of our peers as well as Professors and Teaching Assistants for the course. Knowing this, we prepared a technical presentation that outlines our major design decisions, what we were able to achieve, and a demo. Our audience should be able to understand most of what we will cover. It will also be considered a professional presentation and we planned to conduct ourselves accordingly.

Purdue ECE Senior Design Semester Report (Individual Section)

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Advisors	Mithuna Thottethodi, Todd Wild
Team Number	2
Project Title	The Guard DAWG System

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Evan Miller	CompE	Embedded Systems	May 2019

Individual Reflection: Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

(a) Describe your personal contributions to the project.

My personal contributions revolved around programming the microcontroller and testing different sensors used in our project. I interfaced with an alphanumeric keypad, a Hall Effect sensor, LEDs and a bluetooth module. I then integrated these sensors with the MSP432 microcontroller using GPIO, interrupts, and internal timers. I helped create the main algorithm that the microcontroller uses in our final system design. Outside of working with the micro, I helped with different debugging issues over the course of the project and did my best to be proactive with planning and documentation.

(b) Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

Programming the microcontroller and interfacing with different sensors was very similar to my embedded systems course (ECE 362). The main algorithm was a basic state machine coded in C and utilized skills I learned in both hardware and software classes (ECE 337, ECE 264). Working on a project in a team setting was also very similar to introductory engineering courses (ENGR 131, ENGR 132).

(c) Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

I did not have any experience working with the MSP432 microcontroller and much of my new knowledge was gained by reading the User Guide provided by TI and looking at some of the provided examples. I hadn't worked with a microcontroller in almost three years and I definitely needed a refresher, so I went back and looked at ECE 362 courses. The strategy I employed to be comfortable with the microcontroller involved trying out a lot of different examples and building small applications which later lead to code that we used in our final design. I also became more adept in debugging as I would frequently run into issues that I had not predicted. Being able to set breakpoints and pin point where the code deviates from what was expected helped target issues and speed up fixes.

(d) Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

When designing a security system we have to think of all of the ways it can be broken. We have a moral and ethical responsibility to the end consumer to protect their home and their data. There are hacks and leaks happening all over in industry and it is our professional responsibility to try and prevent this from happening.

(e) Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product's impact in each of these four contexts?

Several factors went into our design considerations with respect to economic, environmental, societal, and global contexts. We checked that all of the components we bought and used did not have any hazardous materials. We bought components that were cheap but reliable, reducing the cost of our prototype. We wanted our product to be cost effective and affordable to for the consumer. We discussed adding encryption to our product to make it more secure, which would be very important in a societal context. The microcontroller has hardware acceleration for encryption and could be accomplished. I don't imagine our design making too much of a global impact but I can see smart homes becoming more common.

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Advisors	Mithuna Thottethodi, Todd Wild, Joseph Bougher
Team Number	2
Project Title	The Guard DAWG System

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Yash Nain	Comp.E	Hardware, Software	May 2019

Individual Reflection: Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

(a) Describe your personal contributions to the project.

I was the team member who was responsible for the hardware. I fully designed all of the iterations of the PCB, made most of the hardware choices (microcontroller, bluetooth module, door lock, etc.), and was responsible for hardware assembly and testing. I soldered all of our functional PCBs that we used for testing, and re-designed/fly-wired the components when we needed to make some adjustments. I was also able to provide Viktoryia and Evan, who were primarily responsible for the embedded software, with the tools needed for them to set up the microcontroller software at the beginning of the semester.

(b) Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

The most relevant skills for this project were not primarily obtained through coursework, but the ones that did were acquired through classes such as ECE 362 for microcontrollers and ECE 207/208/255 for electronic measurement techniques. I needed a basic understanding of embedded knowledge to correctly lay out the PCB, as well as the basics of circuit design. Dr. Meyer and George Hadley made sure that I included decoupling capacitors and reset buttons when I designed a PCB for ECE 362. In addition, we were able to craft tests to debug the system when we needed to get our systems working.

(c) Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

I acquired the requisite knowledge by asking people more knowledgeable than myself in embedded design, including Todd, Joe, and some graduate student friends. They were able to provide us with some direction in whittling down and refining our design, such as simplifying our power systems, laying out traces and polygons, and making our board easier to debug through the use of vias and LED's. In addition, I was able to reference the technical documentation and user manuals for our components to make sure that our design worked correctly, as well as other online resources such as Sparkfun and Autodesk reference guides. Most importantly, I applied the engineering design process when considering the overall system integration.

(d) Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

I needed to make sure that our design could be manufactured and maintained in an environmentally responsible manner, and to make sure that user security was of paramount importance in our design decisions. We wanted to ensure that the device was mechanically and electrically secure, so we strived for an IP65 rating for our component housings. Next, I needed to make sure that we informed our customers of the environmental impact of consumer electronics, so we discussed the proper installation and recycling procedures for disposal of the product at the end of its life cycle.

(e) Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product's impact in each of these four contexts?

The product developed throughout this project is a stepping stone for the future of smart products, in the way they continue to evolve over the coming years. Economically, we provide a relatively cheap, customizable product that can be easily modified for use in the public and private sector. Environmental impact was one of our primary concerns as well, so we took careful steps to make sure our product was manufactured in a reputable fabrication facility, and provided resources for proper device disposal in our environmental analysis. This product redefines the concept of home security by providing a truly ethically responsible device, that doesn't track information and sell it to the highest bidder, unlike our competitors. The user gets to decide who they want to let into their lives and their homes, and feel like their personal lives are safe. As more and more customers make use of our products, we are able to redefine the global debate on privacy and the environmental impact of consumer electronics.

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Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Ian Sibley	CompE	Software design and test	May 2019

Individual Reflection: Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

(a) Describe your personal contributions to the project.

My main contributions to the project mainly consisted of software and the physical housings and demo props for our product. My microcontroller contributions consisted largely of logic discussions and states with Viktoryia and Evan, though the most direct contribution was the addition of our MSP432's awareness of a Bluetooth connection, to avoid loading up the Bluetooth transmission buffer with unnecessary messages, and to avoid the process hanging if the Raspberry Pi either isn't yet connected, or drops connection for any reason.

The rest of my software contributions had to do with our Raspberry Pi and connecting server code: setting up the application software on the Pi to take pictures, communicating over Bluetooth and transmitting both images over an internet connection as well as a JSON result string, and forwarding the identification result to the microcontroller via Bluetooth as either passed or failed.

Much of this on the Pi's side involved investigating how basic internet socket connections work, how to transmit information of different types back and forth securely (especially when the size is variable or unknown), transmission speeds and connection/error handling. Socket connections for Bluetooth were fairly similar, though newer and less robust in their implementations. The code for running the Pi Camera was also well documented and relatively straight forward, though investigations to the pros and cons of Python threading did take a small amount of time.

The server side involved, again, socket connection transmissions, but more importantly investigation into different facial recognition networks and attempts to tie them into the application process. Tying them into the process required organizing how they read faces from an image, writing and saving registered user encodings when possible, and comparing new captured images to the old stored images or feature encodings in an organized manner, with all of these differing for each of the three investigated options. The main factors boiled down to both speed and ease of application integration, as they were all around ~95% accurate in their documented recognition results, and proved more than accurate enough for our means in testing. Once this was done, and one network was selected, I refined and integrated the several separate systems alongside the recognition system into an application style design flow and structure, and got the process structure as autonomous as possible once run, becoming more autonomous as our microcontroller gained more Bluetooth capabilities.

For the physical components I made the 3D CAD models of the Raspberry Pi and Pi Camera housings and printed them out, and made sure they were also able to screw together to close as well as mount onto the door somehow, though these are still concept prototypes for mainly demonstration

purposes. I reduced the size of the pre-made door we acquired to better suit our needs, and mounted the push bar. Yash and myself will be the ones to finish mounting our functional prototype and its various component housings to the door for our final product demonstration.

(b) Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

Much of my dynamic knowledge that I applied to this project comes from external projects and application development experience from my extracurricular activities,summer pursuits and projects, and internships, as they were more extensively software-based and application-design based than my coursework, as well as being network related, whereas I've had only two or three courses covering application design and network communication in my degree path.

I have, however, capitalized on knowledge and structures gained through the basics of my more advanced coding courses, as well as the Object Oriented course that I've taken before in my pursuits for threading to attempt to increase the camera image transmission speeds. My AI course from last semester stands out strongly in my application of a facial recognition framework, especially since the one we wound up using after testing 3 different options was actually the same Python framework I wound up using for that class's semester project, so that familiarity was considerably helpful. Modular coding practices from the Software Engineering Tools Lab course I took last year were also helpful in simplifying our application structure, organizing code, and designing functionality for server vs Pi code, making software changes consist of simple and local edits more so than large, multi-file edits to change a single item. Dynamic problem solving from the Advanced Coding in C and Data Structures classes both have contributed significantly to my flexibility in problem solving for various issues along the way through the software design, iterations, and issue debugging, and my Intro to Digital Design and Microprocessor Systems and Interfacing classes both helped greatly in knowing the strengths and limitations of the microcontroller's capabilities, in my coding on our microcontroller itself, and in aiding bug and/or issue diagnosis discussions with Viktoryia and Evan at various points through the semester.

(c) Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

Between low-level socket communication, Bluetooth interfacing (especially from a Linux environment on a Raspberry Pi), \debugging Code Composer Studio project-based issues, and more, there were a generous amount of things scattered along the development of this project that I hadn't had exposure to before, though thankfully my experience with Purdue IEEE ROV group and some of my latter coursework at least gave me some related context for many of the items. The main exception being Code Composer Studio, as it required more diving into the inner workings of an IDE than I've had to do before.

My main mode of acquiring new knowledge followed the general pattern of research, piecewise testing, prototyping, and then final design and integration testing, for the different software pieces I slowly integrated and designed alongside Viktoryia's structuring of the microcontroller's code. This employed many of the engineering self-teaching principles and design processes I've picked up through my years here at Purdue, as well as the flowcharting principles taught here for initial designing and general documentation. I also consulted with others with relevant knowledge in the subjects and tools I was working with, and used forums from those who have pursued similar pieces to their software projects, as well as the API documentations of the various software libraries used, in the designing, debugging, and understanding of the various tools that were pieced together to create the resulting application.

(d) Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

Our responsibilities as a security system require our rigorous testing of our system in a full-integration setting, as well as with individual pieces, in order to make sure that our product is as reliable as possible, and neither keeps out registered and valid users, nor lets in invalid users and allows for vulnerability, damage, or harm to befall the people and possessions inside of a building using our product. The users of this product trust both its reliability in proper functioning and its security in being tamper- or bypass-proof. It is in everyone's best interest to make sure this product is thoroughly tested and iterated to mitigate vulnerabilities and bug failure propagations through the system. To keep users safe and happy, we must be responsible and diligent in our pursuits to a well-rounded and durable design, especially in a rigorous testing to ensure our products reliability in all of these aspects.

(e) Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product's impact in each of these four contexts?

Adding AI to the security of your home, even in this "simple" way of recognition rather than a more home-orchestration approach, will potentially impact society at least in terms of comfort with AI existing in everyday life. This propagates the potential for these powerful tools to aid society in more aspects of everyday life throughout the globe. With that potential comes an inevitability for the imperfections of AI to show glaringly in the eye of the public, both in terms of not only basic services and security, but also in life or death scenarios, as we're already seeing in vehicles, and will likely see in medical applications as well not too long from now. It is difficult to tell the more short-term implications besides increased comfort with AI, however. Ideally, this product throws other security systems into economic disarray as they fight to compete against the hottest item on the market, but likely this product's ripple in the economic pool will likely go without being too unnoticed, at least in the beginning.

To confirm and investigate some of these claims and speculations, it would be wise to conduct both an analysis of similar products from the past, and reactions to other AI products of the past when newly introduced to the public, and investigate the initial and long-term reactions of the public in how they're used, accepted, and trusted, and how those patterns change over time. Additionally, a randomized polling of the populous on their thoughts on a product like the Guard DAWG System, and a consulting of experts in the field of economics and sociology for the more grand potential effects, would likely be excellent resources for a more in-depth projection of this product's effects.

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Viktoryia Zhuleva	CompE	Embedded Systems	May 2019

Individual Reflection: Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

(a) Describe your personal contributions to the project.

My main focus throughout the semester was working on the Embedded System for our project. I was responsible for the Bluetooth integration, UART communication as well as system testing. I was responsible for setting the IDE for our micro and configuring all the parameters needed for the development board to be working properly. I did a lot of research online on TI's website as well as other website that helped us figure out the bluetooth communication between HC-05 and MSP432. I wrote code for the HC-05 driver, UART driver (with the reference to the external resource), and the keypad and lock handling (partially with Evan). After primary code was finalized, I performed tests for various parts of the system and integrated them together. I also helped to test the PCB during the programming and system integration phases. To add, my other responsibility was maintaining the team website and tracking team progress report completion for individual members. I also was responsible for micro code version control (through Github) along with both Ian and Evan.

(b) Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

I was able to utilize my knowledge from ECE 362 (Microcontroller Systems Design and Interfacing). I learned to how to write embedded C code and how to setup an IDE for the micro. Taking ECE 40862 (Software for Embedded Systems) taught me to look through the micro documentation effectively. Classes like ECE 202 (Linear Circuit Analysis II) and ECE 255 (Intro to Electronics Analysis and Design) gave me the circuit knowledge that I needed to understand the PCB design and component placement.

(c) Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

I have learned how to solder better in lab as well as some of the PCB design techniques that enabled me to help Yash in his PCB design tests and soldering. I primarily watched the demos of the instructors like Todd or Joe to get better.

(d) Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

When the project work is shared between teammates and certain expectations/plans do not align perfectly with every team member, it can be frustrating. I have learned to take responsibility for the design ideas and formats that I proposed in order to remain on the same page with everyone else. As a systems engineer, I made sure I communicated the system interfacing and design between electrical and software sides of our group to make sure the product is put together correctly. I also was responsible for keeping the team's progress reports in check to make sure everyone submits them before the deadline.

(e) Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product's impact in each of these four contexts?

Economically our project is comparable to the similar products in the market like Nest or Yale Lock. It does not require any expensive materials associated with it and can even provide more functionality for the similar price point. Environmental impact is insignificant in terms of hazardous materials. We are not using lithium ion batteries or any other materials that would threaten the surrounding nature or people's health. The 3D-printed components that we made our housing from are not endangering the nature or people either. In terms of societal impact, we want to establish and preserve system's security features such as personal user information integrity. For that reason, we have password protected connections between the system's components. To mention, the photos used for the user recognition are store on the secure server that requires password authentication to access it. In terms of global context, our project is complaint with the U.S. and European standards of security and material usage. As mentioned above, our system does not use any hazardous material and keeps user information guarded by employing password protection standards.