# WEARABLE SENSOR TECHNOLOGY PROTOTYPES

While numerous سنسورهای پوششی systems in design for the home health care field are available, only a few systems are being designed with application in the fire service as an intended field of use. This chapter explores the research and analysis of four different سنسورهای پوششی prototypes that have different designs using a combination of smart textiles, microcontroller boards or other sensing capabilities.

در حالی که سیستم های سنسورهای پوششی بی شماری در طراحی زمینه مراقبت از منزل در دسترس هستند ، تنها تعداد کمی از سیستم ها با کاربرد در سازمان آتش نشانی به عنوان یک زمینه استفاده در نظر گرفته شده است. در این فصل به تحقیق و تحلیل چهار نمونه اولیه سنسورهای پوششی می پردازیم که دارای طرح های مختلفی با استفاده از ترکیبی از پارچه های هوشمند ، تابلوهای میکروکنترلر یا سایر قابلیت های سنجش هستند.

**A. ANALYSIS OF سنسورهای پوششی PROTOTYPES**

سنسورهای پوششی is no longer a conceptual idea that is years in the future. Most Americans are aware of it, and hundreds each day are joining the growing number of citizens wearing it.[[1]](#footnote-1) The most common forms of wearable technology are smart watches and fitness bands that have exploded onto the scene in the last few years. However, many of these wearable devices are, in reality, nothing more than digital pedometers that count the wearers’ steps taken, or heart rate monitors that count the pulse. Although technology does communicate these readings via Bluetooth to the wearers’ phone or laptop, it does not meet the standards of the سنسورهای پوششی being explored for use in the fire service.

سنسورهای پوششی دیگر یک ایده برای سال های آینده نیست. بیشتر مردم از این امر آگاه هستند و هر روز صدها نفر به تعداد افرادی که از این تکنولوژی استفاده می‌کنند می پیوندند. رایج ترین اشکال تکنولوژی پوشیدنی ساعتهای هوشمند و باندهای بدنسازی هستند که در چند سال گذشته موقع استفاده از کار افتاده اند یا باعث ایجاد خساراتی شده‌اند . با این حال ، بسیاری از این دستگاه های پوشیدنی ، در اصل ، چیزی بیش از گام شمار دیجیتال نیستند که گام های استفاده کنندگان را گرفته یا مانیتور ضربان قلب که نبض را می‌شمارند . اگرچه این فناوری این واکشی‌ها را از طریق بلوتوث به تلفن یا لپ تاپ متقاضیان برقرار می کند ، اما استانداردهای سنسورهای پوششی مورد بررسی برای استفاده در سرویس آتش نشانی را برآورده نمی کند.

What distinguishes the سنسورهای پوششی being designed for the fire service is not only its ubiquitous design, but also its ability to sense and react to the changing needs of the wearer, and the quality of the diagnostics it can provide.[[2]](#footnote-2) It will also have the ability to transmit data over great distances; thus, improving service and timeliness of response to the wearers’ physiological needs. The use of non-invasive sensors and smart textiles are particularly well suited for human use in that they offer painless measurements without the risk of infections or the need for advanced medical training to don the sensors properly.[[3]](#footnote-3) However, the سنسورهای پوششی themselves do present a very highly complex system due to the inherent difficulty in measuring physiological signs from the body’s exterior.[[4]](#footnote-4)

آنچه که سنسورهای پوششی را برای سرویس آتش نشانی متمایز می کند ، نه تنها طراحی همه جانبه آن ، بلکه توانایی حس و واکنش در برابر نیازهای کاربر و کیفیت تشخیصی که می تواند ارائه دهد را دارد . همچنین امکان انتقال داده از مسافت های بزرگ را برای بهبود خدمات و پاسخگویی به نیازهای فیزیولوژیکی استفاده کنندگان نیز خواهد داشت . سنسورهای هوشمند پوششی برای کاربر بسیار مناسب است زیرا استفاده از آن نیازمند آموزش حرفه ای دانش پزشکی نمی‌باشد ومی‌توانند براحتی از آن استفاده کنند. با این حال سنسور‌های پوششی دارای مشکلات و چالش‌های بسیار زیادی در اندازه گیری علائم فیزیولوژیکی از قسمت بیرونی بدن می‌باشد و سیستم پیچیده‌ای را ارائه می‌دهد.

The choice of which noninvasive device to use must be the one that meets the specific criteria needed while still being unobtrusive. Almost all past commercial wearable technology with applications in the health monitoring field have only been able to register a single physiological parameter.[[5]](#footnote-5) It has resulted in transmitted information that was both incomplete and did not provide detail about other critical physiological and environmental considerations. For سنسورهای پوششی to be useful in the fire service, the garments and systems must be able to register multiple parameters simultaneously.[[6]](#footnote-6)

انتخاب دستگاه غیر تهاجمی یا موضعی برای استفاده باید از مواردی باشد که معیارهای خاص موردنیاز را برآورده کند. تقریباً تمام فناوریهای پوشیدنی تجاری گذشته با کاربردهایی در زمینه نظارت بر سلامت ، تنها قادر به ثبت یک پارامتر فیزیولوژیکی واحد بوده اند. این امر منجر به انتقال اطلاعاتی شده که ناقص بوده و جزئیاتی در مورد سایر ملاحظات مهم فیزیولوژیکی و محیطی ارائه نکرده است. برای اینکه سنسورهای پوششی در سرویس آتش نشانی مفید باشد ، پوشاک و سیستم ها می توانند چندین پارامتر را به طور همزمان ثبت کنند.

سنسورهای پوششی garments have been produced that implement numerous different styles. The most common are the systems based on microcontroller boards, those based on the use of “smart textiles,” and multi-sensor created mote-based BANs. However, as technology has improved, many of the prototype systems being tested today are hybrids of those systems. They include components of many systems banded together for heightened capabilities and communications. In the next few paragraphs, several products that have been or are being developed in سنسورهای پوششی are reviewed for their possible use within the fire service.

پوشاک سنسورهای پوششی تولید شده است که سبک های مختلفی را اجرا می کند. رایج ترین انها سیستم ‌های متقر شده بر بردهای میکروکنترلر می‌باشند، که از از لباس‌های هوشمند و حسگرهای حرکتی تشکیل شده اند . با این حال ، با پیشرفت فناوری ، بسیاری از سیستم های نمونه اولیه که امروزه مورد آزمایش قرار می گیرند ، ترکیبی از آن سیستم ها هستند. آنها شامل اجزای بسیاری از سیستم هایی هستند که برای افزایش قابلیت ها و ارتباطات در کنار هم قرار گرفته اند. در پاراگرافهای بعدی ، چندین محصول که در سنسورهای پوششی تولید شده اند یا در حال تولید هستند ، برای استفاده احتمالی آنها در سرویس آتش نشانی بررسی می شوند.

**1. Georgia Tech Wearable Motherboard, aka “Smart Shirt”**

The original project in the field of wearable technology was funded by the U.S. Department of the Navy in 1990. It was based on a proposal by Georgia Tech to create the world’s first truly “smart textile.”[[7]](#footnote-7) The intent of the program was the development of a textile and garment that would allow for the detecting of possible garment/body penetration by projectiles, on the battlefield, and the subsequent monitoring of the wearers vital signs.[[8]](#footnote-8) The research at Georgia Teach resulted in the development of the first wearable mother-board or “intelligent” material ever produced.[[9]](#footnote-9) The پوشاک هوشمند اورژانسی, or the “smart shirt,” in its original design, used optical fibers to detect penetrating wounds with sensors and interconnections to monitor the body’s critical functions constantly under combat conditions.[[10]](#footnote-10)[[11]](#footnote-11) Although the risk of penetration injury is much less in the fire service, the capability to monitor a firefighters’ vital signs during fire ground operations presented as a significant benefit available from the پوشاک هوشمند اورژانسی system. (See Figure 1.)

Figure 1. The Georgia Tech Wearable Motherboard



پروژه اصلی در زمینه فناوری پوشیدنی در سال 1990 توسط وزارت امور خارجه نیروی دریایی تأمین شد. این بنا به پیشنهاد جورجیا تکن برای ایجاد اولین "پارچه هوشمند" در جهان بنا شده است. هدف از این برنامه تولید پارچه و پوشاک بوده که بتواند نفوذ پذیری و نشانه های حیاتی پوشنده را بدست بیاورد. این تحقیق در جورجیا تدریس منجر به تولید اولین مادربرد پوشیدنی یا ماده "هوشمند" شده است که تاکنون تولید شده است.

GTWM پوشاک هوشمند اورژانسی - Smart Garments for Emergency Operators یا "پیراهن هوشمند" در طراحی اصلی خود از الیاف نوری برای تشخیص زخم های نفوذی با سنسورها و اتصالات اتصال برای نظارت بر عملکردهای مهم بدن به طور مداوم در شرایط جنگی استفاده می کرد. اگرچه خطر آسیب دیدگی در سازمان آتش نشانی بسیار کمتر است ، اما امکان نظارت بر علائم حیاتی آتش نشانان در حین عملیات آتش نشانی به عنوان مزیت قابل توجهی از سیستم پوشاک هوشمند اورژانسی ارائه می شود. (شکل 1 را ببینید)

The پوشاک هوشمند اورژانسی was the first garment that used “smart textiles.” However, as development continued and fine-tuning took place, it was realized that the use of “smart textiles” alone did not cover all the potential needs of the military or private users. In response, the پوشاک هوشمند اورژانسی design team developed the first hybrid system comprised of “smart textiles” but which allowed for the addition of other sensors to the garment so as to meet the needs of the wearer.[[12]](#footnote-12)

پوشاک هوشمند اورژانسی اولین پوششی بود که از "پارچه های هوشمند" استفاده می کرد. با این حال ، همچنان که توسعه ادامه داشت و تنظیم دقیق صورت می گرفت ، دریافتند که استفاده از "منسوجات هوشمند" به تنهایی تمام نیازهای بالقوه ارتش یا کاربران خصوصی را پوشش نمی دهد. در پاسخ ، تیم طراحی پوشاک هوشمند اورژانسی اولین سیستم ترکیبی متشکل از "منسوجات هوشمند" را توسعه داد اما امکان افزودن سنسورهای دیگر به این پوشاک را فراهم آورد تا بتواند نیاز مشتری را برآورده سازد.

The fire service can take advantage of this capability by adding sensors to detect and measure carbon-monoxide and carbon dioxide levels or monitor oxygen levels in a room. This data, paired with the firefighters’ vital signs, could be communicated wirelessly to the IC where the data could be continuously observed providing appropriate information to the firefighters and their supervisors from which critical decisions, such as the need to evacuate the structure, may be made.

سرویس آتش نشانی می تواند با اضافه کردن سنسورها برای تشخیص و اندازه گیری میزان مونوکسید کربن و دی اکسید کربن یا نظارت بر میزان اکسیژن در یک اتاق از این قابلیت استفاده کند. این داده ها ، همراه با علائم حیاتی آتش نشانان ، می توانند به صورت بی سیم به IC منتقل شوند ، جایی که می توان داده ها را بطور مداوم مشاهده کرد و اطلاعات کافی را در اختیار آتش نشانان و سرپرستان آنها قرار داد تا تصمیمات مهم گرفته شود .

The design of the پوشاک هوشمند اورژانسی was a monumental advancement in the combining of textiles and computing. The Georgia Tech research and development in سنسورهای پوششی have brought about a shift of thought from solely of textiles to an understanding of “fabric is the computer.”[[13]](#footnote-13) The development of interconnected technology now allows for a flexible and wearable system that allows sensors to be connected that can monitor a variety of vital signs, including: heart rate, respiratory rate, EKG, pulse oximetry (saturation of peripheral oxygen or SpO2), and temperature, to name but a few. [[14]](#footnote-14)

طراحی پوشاک هوشمند اورژانسی پیشرفت مهمی در ترکیب پارچه و محاسبات بود. تحقیقات و پیشرفت Georgia Tech در سنسورهای پوششی تغییر تفکر را فقط از منسوجات به درک "پارچه کامپیوتر است" منتقل کرده است. توسعه فن آوری به هم پیوسته اکنون امکان ایجاد یک سیستم قابل انعطاف و پوشیدنی را فراهم می کند که به حسگرها متصل می شود و می تواند انواع علائم حیاتی از جمله ضربان قلب ، ضربان تنفس ، ECG ، پالس اکسیمتری و دما را کنترل کند.

The current پوشاک هوشمند اورژانسی allows these sensors to be plugged in anywhere on the shirt, although most specific sensors must be in specific locations for ideal data recovery, and are easily plugged into the پوشاک هوشمند اورژانسی garment. Once the desired sensors are in place, the flexible sensor bus (which is designed into the garment) directs the data from the sensors to a smart shirt controller that is also a component of the garment.[[15]](#footnote-15) The controller then wirelessly communicates the information to a device, such as a PDA or personal computer, or over the Internet if it is using an appropriate communication protocol. This system allows the پوشاک هوشمند اورژانسی to fulfill the roles of being both an information system that permits computing and a system capable of monitoring and collecting the vital signs of the individual wearing it.

پوشاک هوشمند اورژانسی فعلی اجازه می دهد تا این حسگرها به هر جای پیراهن وصل شوند ، اگرچه بیشتر سنسورهای خاص برای بازیابی اطلاعات ایده آل باید در مکان های خاصی باشند و به راحتی در پوشاک پوشاک هوشمند اورژانسی متصل می شوند. پس از نصب سنسورهای مورد نظر ، اتوبوس حسگر انعطاف پذیر (که به داخل پوشاک طراحی شده است) داده ها را از حسگرها به یک کنترل کننده پیراهن هوشمند هدایت می کند که آن هم جزئی از پوشاک است. سپس کنترلر بصورت بی سیم اطلاعات را در صورت استفاده از پروتکل ارتباطی مناسب به یک دستگاه از قبیل PDA یا رایانه شخصی یا از طریق اینترنت منتقل می کند. این سیستم به پوشاک هوشمند اورژانسی اجازه می دهد تا نقش های یک سیستم اطلاعاتی را که امکان محاسبات را فراهم می کند و همچنین یک سیستم قادر به نظارت و جمع آوری علائم حیاتی فردی که آن را پوشیده است ، انجام دهد.

Since the goal of the پوشاک هوشمند اورژانسی was to design a functional and wearable information collecting garment, user requirements for the system were established early in the process.[[16]](#footnote-16) These requirements included factors, such as functionality, usability, wearability, durability, manufacturability, maintainability, affordability, and connectivity.[[17]](#footnote-17) In its original design, the functionality of the پوشاک هوشمند اورژانسی included the ability to detect a penetration of the garment. However, for the fire service, the functionality is less demanding and requires only the expectation that vital signs will be accurately monitored and communicated, as well as that any added sensors will also function and communicate as needed. Requirements for the fire service include the ability to provide thermal protection, resist electromagnetic interference (EMI), offer hazard protection, and provides flame and heat mitigation.[[18]](#footnote-18)

از آنجا که هدف از پوشاک هوشمند اورژانسی طراحی یک اطلاعات جمع آوری شده از پوشاک و پوشیدنی بود ، نیازهای کاربر برای سیستم در اوایل فرآیند برقرار شد. این الزامات شامل عواملی از جمله قابلیت های استفاده ، قابلیت استفاده ، پوشیدگی ، دوام ، تولید ، حفظ و نگهداری ، قیمت مناسب و اتصال می باشد. در طراحی اصلی خود ، عملکرد پوشاک هوشمند اورژانسی شامل قابلیت تشخیص نفوذ در پوشاک بود. با این حال ، برای سرویس آتش نشانی ، عملکرد کمتری خواستار است و فقط انتظار این را دارد که علائم حیاتی با دقت کنترل و ارتباط برقرار شود ، همچنین هر سنسور اضافه شده نیز در صورت نیاز عملکرد و ارتباط برقرار خواهد کرد. موارد مورد نیاز برای سرویس آتش نشانی شامل امکان محافظت از حرارتی ، مقاومت در برابر تداخل الکترومغناطیسی (EMI) ، ارائه حفاظت در برابر خطر ، و کاهش شعله و گرما می باشد.

Wearability mandated that the پوشاک هوشمند اورژانسی not be burdensome in its weight, be breathable, comfortable to wear, and be quick to don and to take off. Additionally, it must provide easy access in the event the wearer needs medical treatment. It is critical that wearers not be hampered in any way from performing their jobs because of the presence of the پوشاک هوشمند اورژانسی garment. Studies have found that they have succeeded in that objective.[[19]](#footnote-19) In an effort to improve wearability, the پوشاک هوشمند اورژانسی is made of a polypropylene fiber for comfort, spandex for ensuring a proper snug fit, and Nega-Stat™ for dissipating static.[[20]](#footnote-20)

The durability of the پوشاک هوشمند اورژانسی is another critical component of its use. According to the Georgia Tech literature on their wearable motherboard garment, it “should have a life of 120 combat days and withstand repeated flexure and abrasion.”[[21]](#footnote-21) Due to the humidity to which the پوشاک هوشمند اورژانسی will be exposed from the environment in which it is used, as well as a result of the anticipated perspiration of the wearers, the systems and technology used within it were made to be corrosion resistant.[[22]](#footnote-22)

پوشیدگی مقرر می کند که پوشاک هوشمند اورژانسی در وزن خود سنگین نباشد ، تنفس شود ، راحت لباس بپوشد و سریع به دان و پیاده روی برسد. علاوه بر این ، در صورت نیاز به استفاده از معالجه پزشکی ، دسترسی آسان باید داشته باشد. این امر بسیار حیاتی است که به دلیل وجود پوشاک پوشاک هوشمند اورژانسی ، از پوشیدن لباس به هیچ وجه در انجام کار خود جلوگیری نشود. مطالعات نشان می دهد که آنها در این هدف موفق شده اند. در تلاش برای بهبود پوشیدگی ، پوشاک هوشمند اورژانسی از فیبر پلی پروپیلن برای راحتی ، اسپندکس برای اطمینان از تناسب مناسب و Nega-Stat ™ برای از بین بردن استاتیک ساخته شده است.

دوام پوشاک هوشمند اورژانسی یکی دیگر از اجزای مهم استفاده از آن است. طبق ادبیات جورجیا تکنیک درباره پوشاک مادربردهای پوشیدنی آنها ، "باید عمر 120 روزه داشته باشد و در برابر انعطاف پذیری و سایش مکرر مقاومت کند." با توجه به رطوبت که پوشاک هوشمند اورژانسی در معرض محیطی که در آن استفاده می شود ، و همچنین در نتیجه تعریق پیش بینی شده از پوشیدگان ، سیستم ها و فناوری به کار رفته در داخل آن ساخته شده تا در برابر خوردگی مقاوم باشند.

The ability to manufacture the پوشاک هوشمند اورژانسی will be another consideration, as eventually, the designers of this garment estimate it will need to be manufactured in large quantities to meet widespread demands. Garments must be designed to be compatible with the standard clothing and equipment worn by the specific individual.[[23]](#footnote-23) Durability is important, but no more so than the ability of the garment to withstand daily use and necessary cleaning. The ability to maintain the پوشاک هوشمند اورژانسی is a critical consideration for the hygiene and comfort of the wearer. It must to be able to withstand routine cleaning, be able to dry quickly and be easily repairable if it sustains minor damage.

توانایی تولید پوشاک هوشمند اورژانسی مورد توجه دیگری خواهد بود ، زیرا در نهایت طراحان این پوشاک تخمین می زنند که برای تأمین نیازهای گسترده ، نیاز به تولید مقادیر زیادی دارد. پوشاک باید طوری طراحی شود که با لباس استاندارد و تجهیزات پوشیده شده توسط فرد خاص سازگار باشد. دوام مهم است ، اما بیشتر از توانایی لباس در تحمل استفاده روزانه و تمیز کردن لازم نیست. توانایی حفظ پوشاک هوشمند اورژانسی برای بهداشت و راحتی مصرف کننده یک نکته مهم است. باید بتواند در مقابل تمیز کردن معمول مقاومت کند ، در صورت آسیب های جزئی صدمه ببیند و به سرعت قابل تعمیر باشد.

Another requirement for سنسورهای پوششی is ease of connectability. This connectability has a dual meaning with the پوشاک هوشمند اورژانسی, as it covers both the ability of the wearer to connect any additional sensors, and the garment’s ability to connect to its controller and wirelessly transmit data to desired locations.

یکی دیگر از نیازهای سنسورهای پوششی سهولت اتصال است. این اتصال با پوشاک هوشمند اورژانسی معنای دوگانه دارد ، زیرا هم توانایی پوشنده را در اتصال هر سنسور اضافی و هم توانایی این پوشاک برای اتصال به کنترلر خود و انتقال بی سیم داده ها به مکان های مورد نظر را در بر می گیرد.

The پوشاک هوشمند اورژانسی has been tested by the United States Navy and United States Army with very good results regarding its ability to collect and transmit the vital signs of its wears.[[24]](#footnote-24) The EKG leads used in the پوشاک هوشمند اورژانسی are the same type of electrodes found in both the pre-hospital and clinical setting. Instead of being part of the پوشاک هوشمند اورژانسی garment, the electrodes are placed on the wearer’s body and then worn under clothing as would be done when in normal use. After testing, the subject was then wired into an EKG at Crawford Long Hospital and another EKG was acquired in normal medical fashion. It was determined that the quality of the پوشاک هوشمند اورژانسی EKG and the hospital acquired EKG had almost no difference in their readability or accuracy.[[25]](#footnote-25)

پوشاک هوشمند اورژانسی توسط نیروی دریایی ایالات متحده و ارتش ایالات متحده با نتایج بسیار خوب در مورد توانایی آن در جمع آوری و انتقال علائم حیاتی لباسهای خود آزمایش شده است. سربهای EKG استفاده شده در پوشاک هوشمند اورژانسی همان نوع الکترودهایی هستند که در هر دو حالت پیش بیمارستانی و کلینیکی یافت می شوند. به جای اینکه جزئی از پوشاک پوشاک هوشمند اورژانسی باشید ، الکترودها روی بدن پوشنده قرار می گیرند و سپس تحت لباس پوشیده می شوند که هنگام استفاده معمولی انجام می شود. پس از آزمایش ، موضوع در EKG در بیمارستان کرافورد لانگ و یک EKG دیگر به روش پزشکی معمولی سیم کشی شد. مشخص شد كه كیفیت پوشاک هوشمند اورژانسی EKG و بیمارستان EKG به دست آمده تقریباً هیچ تفاوتی در خوانایی یا صحت آنها ندارد

The final consideration for any wearable sensor is the affordability of the system. The anticipated cost to produce the پوشاک هوشمند اورژانسی “smart shirt” is in the $35 range.[[26]](#footnote-26) This estimated cost does not include the need to have laptops or other devices that can receive the data communicated from the garment.

توجه نهایی برای هر سنسور پوشیدنی ، قیمت مناسب سیستم است. هزینه پیش بینی شده برای تولید "پیراهن هوشمند" پوشاک هوشمند اورژانسی در محدوده 35 دلار است. این هزینه برآورد شده نیازی به داشتن لپ تاپ یا دستگاه های دیگری ندارد که بتوانند داده های دریافت شده از پوشاک را دریافت کنند.

**2. ProeTEX**

Following the creation of the پوشاک هوشمند اورژانسی, the European Commission recognized this developing branch of research as having the potential to significantly impact in the information, communications and technology field.[[27]](#footnote-27) The European Commission began funding studies researching the applications of wearable electronics in the medical field and in worker surveillance. One of these studies resulted in a European-integrated committee called ProeTEX, which was tasked with the creation of a “smart” garment that would incorporate sensors, communication, data processing, and power management devices that would be directly integrated into the textile structure of the garments.178 The goal was to design this system specifically for emergency and disaster intervention responders, firefighters, and civil protection rescuers. ProeTEX was officially started in February 2006 and was made up of a collection of 23 partners from eight European countries.[[28]](#footnote-28) Included in that consortium were 22 industrial companies, universities, and research centers throughout Europe.[[29]](#footnote-29)

پس از ایجاد پوشاک هوشمند اورژانسی ، کمیسیون اروپا این شاخه در حال تحقیق را به عنوان توانایی بالقوه تأثیرگذاری در حوزه اطلاعات ، ارتباطات و فناوری به رسمیت شناخت. کمیسیون اروپا مطالعات بودجه ای را برای تحقیق در مورد کاربردهای الکترونیک پوشیدنی در حوزه پزشکی و نظارت کارگران آغاز کرد. یکی از این مطالعات منجر به ایجاد کمیته یکپارچه شده اروپایی به نام ProeTEX شد که وظیفه آن ایجاد یک پوشاک "هوشمند" بود که سنسورها ، ارتباطات ، پردازش داده ها و دستگاه های مدیریت انرژی را در اختیار داشته باشد که مستقیماً در ساختار نساجی ادغام شوند. هدف این بود که این سیستم به طور ویژه برای پاسخ دهندگان مداخله اضطراری و حوادث ، آتش نشانان و امدادگران حفاظت از مدنی طراحی شود. ProeTEX در فوریه 2006 رسماً آغاز شد و از مجموعه 23 شریک از هشت کشور اروپایی تشکیل شده است. در این کنسرسیوم 22 شرکت صنعتی ، دانشگاه و مراکز تحقیقاتی در سراسر اروپا حضور داشتند.

The ProeTEX committee realized in the early development of its product that structural firefighters have different needs when compared to other disaster responders, since they perform the majority of their work in smaller areas generally with specific boundaries. In addition, large numbers of firefighters generally do not need to be monitored concurrently. Often their interventions, such as forcible entry, establishing ventilation, and fire attack, can be tracked visually.[[30]](#footnote-30)

کمیته ProeTEX در ابتدای تولید محصول خود فهمید که آتش نشانان سازه در مقایسه با سایر پاسخ دهندگان به حوادث ، نیازهای متفاوتی دارند ، زیرا آنها اکثر کارهای خود را در مناطق کوچکتر عموماً با مرزهای خاص انجام می دهند. علاوه بر این ، تعداد زیادی از آتش نشانان به طور کلی نیازی به نظارت همزمان ندارند. اغلب مداخلات آنها از قبیل ورود اجباری ، ایجاد تهویه و حمله به آتش سوزی قابل مشاهده است.

Nonetheless, the working environment for structural firefighters can be extremely dangerous due to the presence of fire, toxic gases, and explosions. It was determined that all these fire ground tasks and environmental dangers would need to be monitored by any system designed for use by the fire service, and should automatically generate alarms to the firefighters should extreme conditions be detected.

با این وجود ، محیط کار برای آتش نشانان سازه به دلیل وجود آتش ، گازهای سمی و انفجار می تواند بسیار خطرناک باشد. مشخص شد که تمام این کارها در زمینه آتش نشانی و خطرات محیطی باید توسط هر سیستمی که برای استفاده توسط سازمان آتش نشانی طراحی شده است ، کنترل شود و در صورت ایجاد شرایط شدید ، باید بطور خودکار آلارم برای آتش نشانان ایجاد شود

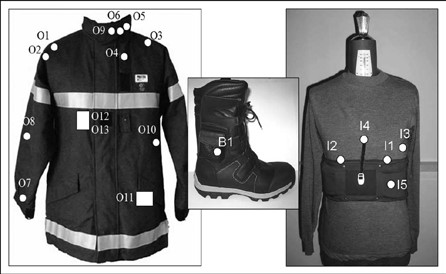
From discussions that the ProeTEX committee had with fire services throughout Europe, they were able to create a list of end-user specifications to help guide the development process.182

از بحث هایی که کمیته ProeTEX با خدمات آتش نشانی در سراسر اروپا داشت ، آنها توانستند لیستی از مشخصات کاربر نهایی را برای کمک به راهنمایی در روند توسعه ایجاد کنند.

According to the end-user requests, the desired monitoring parameters included the “heart rate, respiratory rate, body temperature, blood oxygen saturation levels, environmental temperatures, concentration of toxic gases, such as carbon monoxide and carbon dioxide, operators’ activity, and the operator’s absolute position and speed.”[[31]](#footnote-31) To meet the desires of the end users, ProeTEX designed its system to be made up of three sub-systems: an inner garment (IG), outer garment (OG) and a pair of boots.[[32]](#footnote-32) (See Figure 2.) Each subsystem has at least one sensor linked to micro-processors that receive the data and send it to the system bus for transmission.

طبق درخواست کاربر نهایی ، پارامترهای مورد نظر شامل "ضربان قلب ، ضربان تنفس ، دمای بدن ، میزان اشباع اکسیژن خون ، دمای محیط ، غلظت گازهای سمی مانند مونوکسید کربن و دی اکسید کربن ، فعالیت اپراتورها و موقعیت و سرعت مطلق اپراتور. " برای پاسخگویی به خواسته های کاربران نهایی ، ProeTEX طراحی کرده است که سیستم خود را از سه زیر سیستم تشکیل می دهد: یک پوشاک داخلی (IG) ، پوشاک بیرونی (OG) و یک جفت چکمه. (شکل 2. را ببینید)

Figure 2. Overview of the Proe-TEX Prototype



The IG has a textile sensing component that is in direct contact with the wearers’ skin. Composed of two knitted stainless steel electrodes, these sensors are located to ensure a good EKG signal is achieved from the garment.[[33]](#footnote-33) In addition, the ProeTEX system has added a neoprene filler into the electrodes to improve the adherence needed to protect the skin/sensor connection even during strong physical activity.[[34]](#footnote-34) These sensors not only provide the EKG signal, but also are the sensors that record and transmit the heart rate of the wearer.

To monitor the respiratory status of the wearer, a piezoelectric sensor is wrapped in a removable band that senses the stretch and recovery of the band to reflect the respiratory action of the wearer.[[35]](#footnote-35) The band is adjustable to ensure the wearers are able to position the band in the correct location and that it is tight enough to stretch and recoil accurately. A temperature sensor is also built into the garment, designed to contact the wearers under their left arms, which provides a continuous read of the wearers’ skin temperature.[[36]](#footnote-36)

IG یک مؤلفه سنجش نساجی دارد که در تماس مستقیم با پوست پوشیدگان است. این سنسورها متشکل از دو الکترود استنلس استیل گره خورده ، برای اطمینان از دستیابی به سیگنال خوب EKG از این پوشاک هستند. علاوه بر این ، سیستم ProeTEX برای بهبود چسبندگی مورد نیاز برای محافظت از اتصال پوست / حسگر حتی در حین انجام فعالیت بدنی قوی ، یک پرکننده نئوپرن را به الکترودها اضافه کرده است. این سنسورها نه تنها سیگنال EKG را ارائه می دهند بلکه سنسورهایی هستند که ضربان قلب کاربر را ضبط و انتقال می دهند.

برای نظارت بر وضعیت تنفسی پوشه پوشنده ، یک سنسور پیزوالکتریک در یک باند قابل جابجایی پیچیده می شود که کشش و بهبود باند را حس می کند تا عملکرد تنفسی فرد را نشان دهد. باند قابل تنظیم است تا اطمینان حاصل شود که پوشیدگان می توانند باند را در یک مکان صحیح قرار دهند و از کشش و بازگرداندن دقیق آن به اندازه کافی محکم باشند. یک سنسور دما نیز در داخل پوشاک ساخته شده است ، به گونه ای که برای تماس با پوشیدگان در زیر دست چپ خود طراحی شده است ، که خواندن مداوم از دمای پوست افراد پوشیده را ارائه می دهد.

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The OG, like the IG, contains sensors, but unlike the IG that is primarily focused on monitoring of the wearers’ physiological condition, the OG sensors monitor the environmental conditions in which the wearers are operating. The OG monitors such variables as the external temperature, the concentrations of carbon monoxide and carbon dioxide, as well as the location of the wearer within a building.[[37]](#footnote-37) In addition, the wearers’ posture, motion, and any falls can be observed through the addition of two accelerometers in the OG.190 The firefighters’ OG also contains one final sensor that measures the amount of heat radiating through the thermal barrier in the firefighters’ bunker coat to determine the risk of injury to the firefighter from heat exposure.[[38]](#footnote-38)

The core of the ProeTEX system is the professional electronic box (PEB) contained in the OG.[[39]](#footnote-39) The PEB receives all the wireless communications that come from the subsystems to allow the real time transmission of data recorded by all the sensors contained in the wearer’s garment, regardless of their location on the body in relation to the PEB. Information acquired by the PEB is simultaneously transmitted to the individual or system in charge of monitoring the wearers through the use of a “remote transmission system based on a Wi-Fi protocol.”[[40]](#footnote-40) Most civil protection and firefighting operational standards require a local coordinator of operations. This coordinator is often represented by an IC at a command post, which is ideally and most commonly located beyond the borders of the operational zone, but from a location at which all emergency responders can be overseen and directed. The command post is equipped with a software program operated on an interface with Google Earth®, which allows for multiple wearer data streams to be received. Locations of wearers can be depicted on a map of the operational area.[[41]](#footnote-41)

The ProeTEX system is powered by a commercial lithium ion polymer battery that allows for up to seven hours of autonomous operations.[[42]](#footnote-42) Also, a prototype flexible battery is specifically designed for the ProeTEX system, which will increase the usable time an additional two hours.[[43]](#footnote-43) The OG is outfitted with an alarm system that will alert the wearer, as well as the supervising agent, in the event a dangerous situation is detected. These alarms may include warnings for the presence of high levels of carbon monoxide (CO) or carbon dioxide (CO2), which would require the immediate evacuation of the area. These alarms, like all other communications from the ProeTEX system, are transmitted using a “long-range transmission module.”[[44]](#footnote-44)

While many firefighters already carry and utilize commercial handheld toxic-gas monitors and activity sensors to detect prolonged periods of immobility, both these capabilities are already part of the ProeTEX firefighter suits. A CO2 sensor is built into the boot’s upper section contained in a special pocket that leaves it capable of monitoring the air.[[45]](#footnote-45) The CO2 sensor was located in the boot because CO2 is known to be heavier than air and will accumulate at lower levels first. The CO monitor was placed in the lapel of the jacket because it has a vapor density very similar to air and unlike CO2, it will not settle to the ground, but will maintain its ability to float.199 To get ideal functionality of the toxic-gas sensors without exposing them to the hazards of the environment, the sensors are both placed on the outside of the OG. However, the sensitive electronics of the systems are safely located within the coat inside the thermal layer of the jacket to protect it from the heat and moisture common at fire grounds.

As with all new products and technology, cost will be an important factor to potential users. ProeTEX, which is still in its trials phase, is unable to be exact on its costs, but has estimated that a ProeTEX system with all of its component parts will run between $5,000 and $5,500 USD.[[46]](#footnote-46)

Unlike the پوشاک هوشمند اورژانسی, ProeTEX is much more than a garment worn under the usual clothing and equipment of the user. ProeTEX has developed an entirely new firefighter wearable system that includes multiple components that monitor the wearer, as well as the operational environment. According to Davide Curone, “It is now possible to have information infrastructures fully built into firefighting clothing that collect, process, and communicate data about the wearer and about the environment in which he or she is operating.”[[47]](#footnote-47)

**3. VTAMN**

The French company Medes, creator of the Vetement de Te’le’ Assistance Medicale Nomade (VTAMN) project set a goal to “reach a higher level of electronic integration in clothing than had been previously achieved by the پوشاک هوشمند اورژانسی.”[[48]](#footnote-48) Its objective was to create a biocloth that would be comfortable and washable yet which incorporates connections, wires, and micro sensors directly into the garment. The aim of the VTAMN project was to be able to measure physical activity, as well as physiological parameters during the wearers’ daily lives by creating a new design of sensor networks, as well as original distribution algorithms for sensor communication. The VTAMN system also was made to be able to request emergency services on its own through cellphone links to assist in the rescue of the wearer in extremis. It is able to guide rescuers to the location of the wearer through the use of the global positioning system (GPS) sensor in the garment.[[49]](#footnote-49)

The VTAMN project, which began in January 2001, strove to incorporate biosensors and bioactuators into the textile it was creating through weaving them into the fabric.[[50]](#footnote-50) The T-shirt component of the VTAMN garment uses dry EKG electrodes, a shock/fall sensor, a respiratory rate sensor, and two temperature sensors, as well as a GPS receiver. The ability to integrate and miniaturize microelectronics has allowed the development of micro sensors, such as the accelerometers and magnetometers that can be interwoven into the garment of the wearers to monitor their medical condition.[[51]](#footnote-51) The VTAMN system is set to analyze the wearers’ heart rate, respiratory rate, and activity level.

The VTAMN system is comprised of two main parts, the T-shirt and the belt. The T-shirt is comprised of the garment itself plus four EKG surface electrodes, a coil for respiratory status monitoring, two temperature sensors, and fall detection module, in addition to a wiring package, various interconnections, and the busses for the sensors.[[52]](#footnote-52) The belt retains the “connection for the wiring, the main electronics board, the global system for mobile communications (GSM) and GPS modules, the batteries, and the EKG electronics.”[[53]](#footnote-53) The data and power supply electronics are arranged in a “bus-like configuration” known as a “Body-LAN.”208

Different types of wires were explored during the design of the Body-LAN system in an effort to find which combination of wires would have the least power draw and create the least motion artifact. The final result was a blending of very fine stainless steel wires coated with silk.[[54]](#footnote-54) In an effort to maintain comfort and functionality, the EKG electrode wires were placed in the T-shirt via weaving while all the other wires were embroidered into place. The EKG subsystem is an adaptation from the system used in the 12 electrode Holtor monitor, which had long been the only technology available to monitor patients with suspected cardiac problems. For the VTAMN system, the Holtor monitor was simplified to record the cardiac rhythm using only four electrodes that are placed on the wearers’ anterior deltoids and just above the anterior iliac crests. With these placement positions, the EKG sensors deliver an “acceptable” signal.[[55]](#footnote-55)

Historically, “continuous monitoring of respiratory frequency is heavily plagued by motion artifacts.”[[56]](#footnote-56) Motion artifact is principally caused from sensor slippage while being worn, but if the sensors are tightly wrapped to the body to prevent slippage, they can become uncomfortable and even restrict breathing. The pneumograph subsystem in the VTAMN is an adaptation of a commercial pneumograph. Based on a two-coil design, this subsystem operates based on low amplitude impedance where changes in the chest volume result in differences in how the electricity flows through the chest cavity from one side of the coil to the opposite side of the coil.[[57]](#footnote-57) These changes in chest cavity conductivity result in readings of actual ventilation rate. The pneumograph belt is positioned on the wearer around the upper abdomen to prevent it from blocking the EKG sensor locations while still allowing it to perform its function with high accuracy.[[58]](#footnote-58)

The other sensors that comprise the VTAMN system are the temperature sensors and the fall sensor. (See Figure 3) For temperature readings, sensors are located in specific locations to ensure that the data being collected is accurate for its intended purposes. For temperature readings of the outside environment, a sensor is embedded on the outside of the shirt, while another sensor if placed within the shirt and given a special backing to isolate the measurements to ensure it only reads the middle layer and does not assess and radiation from the outside. The fall sensor is a “2 axis accelerometer with a microcontroller that is embedded on a flexible sensor board” and positioned within the belt.[[59]](#footnote-59)[[60]](#footnote-60)

Figure 3. Fall Sensor Location on VTAMN



Source: “VTAMN PROJECT (RNTS 2000): “Medical Teleassistance Suit,” 2005, http://george.medes.fr/home\_en/telemedicine/assistance\_to\_patients/vtamn.html.

In the development process, the VTAMN group made a conscientious effort to bring down the overall power demand of the system, originally done in an effort to reduce the size of the batteries required for the system, in hopes of being able to place the batteries in the T-shirt portion of the garment. However, as the batteries could not be reduced in size, and the power consumption could not be reduced further, a belt was added to the system to house the batteries.[[61]](#footnote-61) Once the belt was added to the system, the main electronics board and the GPS/GSM modules were added to the belt as well.[[62]](#footnote-62) The overall weight of the VTAMN system finished at 730g or just over 1.6 pounds with more than half of that weight coming directly from the rechargeable batteries, which have an operational life of over 18 hours.[[63]](#footnote-63)

The projected costs of the VTAMN system are unknown as this technology is still in research and development.

**4. MagIC**

In 2005, an Italian research group created their first prototype of a wearable garment it called the MagIC (Maglietta Interattiva Computerizzata) system.[[64]](#footnote-64) (See Figure 4) The system was originally designed to gather cardiorespiratory data in elderly patients who lived in confined environments, such as nursing homes, hospitals, etc. It has now progressed in its design and function to include usage by those healthy individuals who seek to have their health monitored as well.

Figure 4. MagIC System Garment



Paolo Castiglioni et al., “MagIC: A Textile System for Vital Signs Monitoring. Advancement in Design and Embedded Intelligence for Daily Life Applications,” in *29th Annual International Conference of the IEEE Engineering in Medicine And Biology Society*, 2007, 3958–3961.

The primary component of the MagIC system is its Lycra and cotton vest that has been integrated with sensors, as well as a “portable electronic board” to store the data acquired by the sensors.[[65]](#footnote-65) The crucial issue in the design and development of the MagIC garment was in the choice of the textile and its technological capabilities. The designers had to create a way for the sensors to provide good connectivity on the wearer’s skin but not rely on adhesives to accomplish that connection.[[66]](#footnote-66) It was critical that the connections between the sensors and skin were also maintained during physical activity. It was determined that the simplest ways to achieve this goal was to increase the compression of the garment on the wearer. This approach prevented sensor movement on the skin and resulted in decreasing motion or signal artifact.[[67]](#footnote-67) The MagIC research group also concluded that the fabric and cut of the garment played a role in the amount of artifact created by permitting as much freedom of movement as possible without disturbing the sensors and their adherence. To balance the need for freedom of movement with the need for proper sensor adhesion, a large range of sizes of the MagIC system were produced.[[68]](#footnote-68)

When the MagIC research and design group expanded the use of MagIC outside the clinical monitoring of the elderly, changes to many of their original paradigms needed to be addressed. Once healthy subjects were brought into the target populace, the rates of potential motion artifact from movement, exercise, and other activities increased substantially. In addition, it was realized that the garment itself would be placed under much more extreme and stressful conditions requiring a reassessment of the garments durability.

In the original design, sweating was not considered to be an issue; however, it also needed to be addressed with the expanded use of the MagIC system. In its own research, MagIC documented, “Only during heavy or prolonged physical activity or while exposed to warm environments, the wearing of the garment may induce abundant sweating that soaks the vest. In these exceptional cases, the wet vest may be unpleasant for the subject, although this fact does not interfere with signal quality.”[[69]](#footnote-69) MagIC has begun addressing the problem of sweating and comfort by testing new yarns and textiles to permit better evaporation in subjects exposed to environments like those frequently faced by firefighters.

The EKG read is made using two woven electrodes composed of conductive fibers. Despite the few number of electrodes used, the data recovered from this electrode design have shown the MagIC EKG signal “provided readable signals more than 99% of time when the patient was laying supine and 95% of the time when the patient was actively moving.”224 In all instances of readable signal recovery, the data allowed for the identification of all abnormal cardiac rhythm disturbances.

The respiratory sensing capabilities of the MagIC system come from the textilebased piezoresistive transducer that measures the respiratory rate through changes in the thoraxes volume.[[70]](#footnote-70) The transducer is a “thin elastic cord made of textile yarn” able to conduct an electrical impulse, which is surrounded in an elastic core.[[71]](#footnote-71) As a breath is taken, the movement of the chest results in a change in the volume of the thorax. This change in volume created by the respiration results in the cord stretching and a consequent alteration in its resistance indicates a breath has been taken.[[72]](#footnote-72) Connections made by the conductive fibers, the respiratory data, as well as the EKG data, are fed to an electronic board that is securely positioned on the vest.[[73]](#footnote-73)

The wearers’ movements and activity level is the final measurable data acquired by the MagIC system. MagIC is able to detect movement and activity level through the imbedded three axis accelerometer in the vest.[[74]](#footnote-74) The electronic board then stores the signals from the accelerometer or a memory card and can then transmit that data via Bluetooth or Zigbee to a computer or personal digital assistant (PDA).230 This data is currently only available for display on time plots, which makes the information difficult to assess and less useful in monitoring real-time activity.

As with all wearable technology, a critical component of the MagIC system is its power supply. The MagIC system uses a 3.6V rechargeable battery with an estimated life of over 60 hours.[[75]](#footnote-75) This estimation is based on all data being stored in the electronic board and does not account for transmitting the data from the garment to an external device.

Although MagIC has been in development for over 10 years, because of the number of changes and prototypes that have been developed, the MagIC designers have not yet been able to estimate a cost for their product. A response to questions regarding the estimated costs for the MagIC system by its designers went unanswered when requested by this author.

**B. SUMMARY**

Many different styles and designs of wearable sensor systems have been made. The پوشاک هوشمند اورژانسی, ProeTex, VTAMN and MagIC systems are the four most developed systems that have marketed themselves as having been designed for use within the fire service. While each of these systems has its advantages, each also has its draw-backs and limitations. Based on this research, it is clear that power consumption concerns created by weight and size limitations are a hurdle that each system shares. Although some of these systems have advertised battery life spans that lasts a sufficient amount of time for firefighting operations, the primary reason for their prolonged battery life is the decreased number of sensing capabilities and communication capabilities. Those systems that have the shorter battery lifespans have a corresponding larger number of sensing and communication capabilities.

Table 1 illustrates the point comparison between the four سنسورهای پوششی systems analyzed in this research. It demonstrates the capabilities and limitations of each system.

Table 1. Point Comparison between the FOUR سنسورهای پوششی Systems

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Evaluation Criteria |  | Georgia Tech Wearable Motherboard | ProeTEX System | VTAMN System | MagIC System |
| Wearability: | | | | | |
|  | Comfort | Yes | Yes | Yes | No |
|  | Skin Irritation | No | No | No | Some |
|  | Lightweight | Yes | Yes | No | Yes |
|  | Breathable | Yes | Yes | Yes | Some |
|  | Moisture Absorption | Yes | Yes | Yes | No |
|  | Easy to Don & Doff | Yes | Yes | Yes | Yes |
|  | Easy Access to Body | Yes | Yes | Yes | Yes |
|  | ROM Limitations | No | No | No | No |
| Durability: | | | | | |
|  | Flexural Endurance | Yes | Yes | Yes | Yes |
|  | Tear Resistance | No | Yes | No | No |
|  | Abrasion Resistance | No | Yes | Yes | Yes |
|  | Heat Resistance | Yes | Yes | No | No |
|  | Moisture | Yes | Yes | Yes | No |
| Evaluation Criteria |  | Georgia Tech Wearable Motherboard | ProeTEX System | VTAMN System | MagIC System |
| Wearability: | | | |  |  |
|  | Resistance |  |  |  |  |
| Maintainability: | | | |  |  |
|  | Launderable | Yes | Yes | Yes | Yes |
|  | Software Upgrades | Yes | Yes | Yes | unk. |
|  | Rechargeable Battery | Yes - unk | Yes 9 hrs | Yes 18 hrs | Yes 60 hrs |
| Functionality: | | | |  |  |
|  | Monitor Vital Signs | Yes-full | Yes-  full | Yes-  full | partial |
|  | EKG Capability | 4-lead | 2-lead | 4-lead | 2-lead |
|  | Communicate with  External Device | Yes | Yes | Yes | No |
| Additional Sensing Capabilities: | | | |  |  |
|  | CO/CO2  Monitoring | Optional | Yes | No | No |
|  | Activity  Monitoring | No | Yes | Yes | Yes |
|  | True RR Reading | No | Yes | Yes | Yes |
|  | Fall Detection | Optional | Yes | Yes | Yes |
|  | GPS | No | Yes | Yes | Yes |

The next chapter discusses the specific uses of سنسورهای پوششی within the fire service including scenarios.

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# WEARABLE SENSOR TECHNOLOGY IN THE FIRE SERVICE

سنسورهای پوششی has the capability to decrease LODDs from cardiac events because of its ability to monitor and communicate the physiological functioning of firefighters continuously while they are in the performance of their jobs. It has been well documented that firefighters are exposed to numerous cardiac risk factors while on duty in addition to the known risk factors of modern Americans.[[76]](#footnote-76) سنسورهای پوششی s offer a technology that can ensure that any cardiac abnormalities or unacceptable limits of physiologic function will be immediately detected and that both the firefighter and the IC are alerted to initiate medical care. Some سنسورهای پوششی s also have the added capabilities of being able to monitor the environmental conditions and track the location and movement of the wearer.[[77]](#footnote-77) Environmental monitoring of the area in which firefighters are working assists in protecting them from unique detrimental environmental conditions that could increase the risk of sudden cardiac death (SCD). Location tracking can be used to protect the firefighter from areas of known danger and make rescue more rapid in the event of a collapse or becoming trapped.

The first section of this chapter focuses on the key uses of wearable sensor technology including physiological monitoring, hazardous environmental monitoring, and firefighter location tracking. The second section explores the challenges and concerns of the stakeholders for سنسورهای پوششی , including privacy, security, legal considerations, health information privacy, and finally union concerns and considerations. Next, the costs of سنسورهای پوششی are described that include the estimated financial costs associated with سنسورهای پوششی systems, but attempts to factor in the direct and indirect costs of a firefighter’s LODD. Training considerations are also explored. This chapter concludes with a set of scenarios that demonstrates how سنسورهای پوششی in the fire service can be of value and positively change the unacceptable LODD rates in the fire service.

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**A. KEY USE AREAS OF WEARABLE SENSOR TECHNOLOGY**

The need for physiological monitoring of firefighters has been made clear by the consistent LODD toll suffered by the collective U.S. fire service. Annually, the U.S. fire service has over 100 firefighter LODDs, and the leading cause of death is from CHD.[[78]](#footnote-78) While firefighters must be aware of their susceptibility to the same cardiac risk factors that most Americans face, such as hypertension, poor diets, a sedentary lifestyle, and stress, they have additional risk factors that put them at an even higher risk of CHD and sudden cardiac events.

Despite the numerous programs and projects that have aimed to decrease the number of LODDs, no significant changes have been seen in firefighter behavior or the number of firefighters dying while on duty.[[79]](#footnote-79) Additionally, a clear connection has been established between the work firefighters do and the increased risk of cardiac events, such as heart attacks, strokes, and cardiac death.[[80]](#footnote-80) The combined effects of the repetitive “sympathetic nervous system activation, intensive physical work, heat stress, dehydration, and environmental conditions leads to a significant cardiovascular strain.”[[81]](#footnote-81) As firefighters face these conditions on a routine basis doing their jobs, it is likely that these multiple stressors function to precipitate cardiac events in firefighters.

The physiological tests and parameters of firefighters that should be monitored are the EKG, heart rate (HR), body temperature, blood oxygen saturation (Sp02 or Sa02), respiratory rate (RR), movement, and body position of the wearer.

The EKG potentially provides the most important data on cardiac status that can be acquired outside of a medical facility to recognize the development of cardiac distress.[[82]](#footnote-82) “Any irregularity in the heart rhythm or damage to the cardiac muscle” causes an alteration in the normal electrical flow pattern within the heart, which will present on the EKG as abnormalities in the electrical pattern and indicate the presence of cardiac distress or myocardial death.[[83]](#footnote-83)

While EKGs can often reflect the true HR of the wearer, as described in the previous paragraph, the HR and the EKG will differ at times. To ensure an accurate HR count is maintained, the need to monitor the HR in a way separate from the EKG must be employed. The monitoring of the firefighters’ HR is not simply to see if it is present or absent, but to gauge its rate, rhythm and regularity, and grasp that the HR is one in a set of vital signs that need to be compared in relation to one another to come to an understanding of the physiological functioning of the wearer.

During actual firefighting operations, HRs of firefighters can be between 150–190 beats per minute.[[84]](#footnote-84) In many cases, these rates exceed the “age predicted” and the measured maximal heart rates based on baseline tests of the firefighters.[[85]](#footnote-85) Not only does the speed at which the heart is beating need to be considered, but the fact that while firefighting, many changes take place in the circulatory system as a whole that can alter the speed with which the heart beats, as well as the overall functioning of the body. In the early phases of firefighting, a significant percentage of the firefighters’ cardiac function is rerouted to the “cutaneous circulation and working muscles.”[[86]](#footnote-86) As a result of these changes in the heart’s functionality, its demand for oxygen increases, as well as the amount of stress placed on the heart.[[87]](#footnote-87) The movement of blood to the cutaneous level is done primarily as a means to improve thermoregulatory control by allowing the blood to cool, as it is nearer the surface of the body where evaporative cooling can occur.[[88]](#footnote-88) However, in the case of firefighters, this attempt by the body to control its thermoregulation is often defeated by the microenvironment created by the clothes the firefighters wear. For this reason, the need to monitor the body temperature of firefighters is important in decreasing firefighter LODDs.245

The highly encapsulating and insulating properties of the firefighters’ protective ensemble, better known as “bunker gear,” prevents evaporation, and thus, the natural cooling capacity of the body, which becomes especially true when the atmosphere around the firefighters exceed 698 degrees Fahrenheit.[[89]](#footnote-89) At this temperature, the thermal stress experienced by firefighters comes primarily from the microenvironment that exists in the void space between the wearers’ body and the bunker gear and the inability of the accumulated head to be evaporated or otherwise removed.[[90]](#footnote-90) The result is that sufficient quantities of “metabolic heat and humidity” are held within the firefighters’ bunker gear to cause significant thermal stress to the wearer.[[91]](#footnote-91)

The heat and humidity to which the firefighters are now exposed will increase their core body temperature and place them at greater risk for injury or death. Much of this increased risk stems from the fact that an increase in the firefighters’ “core body temperature” can result in “increased stress on the cardiovascular system through the redistribution of blood to the cutaneous circulation,” and to a contraction of plasma volume as a result of sweating.[[92]](#footnote-92) An increase in the HR and hearts demand for oxygen will also occur as a result of the decrease in plasma volume, which, when combined with pre-existing CHD could precipitate a cardiovascular event.[[93]](#footnote-93) It is because of these effects that much of the cardiovascular morbidity and mortality among firefighters “can be attributed to high incident radiant heat and metabolic heat stress resulting from physical exertion.”[[94]](#footnote-94)

Although the ability to track a firefighters’ movements and body position is not a measurement of physiological value, the ability to monitor the wearers’ movements and body position will be important in the use of سنسورهای پوششی in the fire service. On fire scenes, the سنسورهای پوششی wearers will rarely be inactive. Therefore, firefighters who become inactive while performing their job need to have their other monitored data assessed to ensure that their inactivity is not a result of a medical reason for. The ability to determine body position and movement will be helpful in justifying increases or decreases in HR and RR, based on the work being done or the conclusion of an assignment resulting in a few minutes of inactivity.

**B. PHYSIOLOGICAL MONITORING SCENARIO**

Engine 5 of the Central City Fire Department is on scene at a large commercial warehouse where fires are burning uncontrolled on the first and second floors. Upon receiving his unit’s assignment from the IC to take his crew and enter the first floor for firefighting operations, Capt. Tanner and each member of his crew grab the tools they will need, don their air packs, and turn on their سنسورهای پوششی garment. The IC confirms to Capt. Tanner that he is receiving all four members of Engine 5’s crew signals and clears them to make entry. After eight minutes working within the structure, Capt. Tanner begins to feel light-headed with chest tightness that he dismisses because he believes it might be the straps across his chest from his air pack. At the same time, the IC receives both an audible and visual alarm at the command post notifying him that Capt. Tanner’s heart rate has increased beyond his acceptable threshold and that he has begun to display multiple cardiac rhythm changes.

The IC calls for the withdrawal of Engine 5 for medical evaluation and has the on-scene paramedic unit, Medic 2, respond to the entrance from which Engine 5 will be exiting. Upon exiting the building, Capt. Tanner is assigned to a medical evaluation. The paramedics on Medic 2 perform a complete cardiac exam, including a 12-lead EKG where it is found that Capt. Tanner is experiencing a heart attack. Capt. Tanner is then given his first dose of fibrinolytic medications and is transported to the nearest emergency department. As a result of the rapid recognition of the سنسورهای پوششی system, and the work done by the paramedics and emergency room staff, Capt. Tanner only has a twoday stay in the hospital before he is released with no significant cardiac damage.

Most fire deaths are not caused by burns, but rather by the inhalation of smoke created during the fire.[[95]](#footnote-95) In almost all cases, the smoke incapacitates the victim so quickly that making an escape to a nearby exit is impossible. The synthetic materials that make up so much of a modern home and its furnishings produce dangerous substances when exposed to the high heat present during a fire.[[96]](#footnote-96) This toxic environment develops as a fire starts and grows within a building consuming all the available oxygen, which results in a slow burning fire known as a “smoldering fire.” During this smoldering phase, incomplete combustion occurs and the majority of the toxic gases are created.[[97]](#footnote-97) Smoke is made up of many ingredients, mainly unburned particles, partially burned particles, and completely burned substances that can be so small that they can be pulled into the respiratory system of anyone not wearing the correct respiratory protection.[[98]](#footnote-98) Of greatest concern for environmental monitoring is the presence of the toxic gases that are a major component of smoke, but can remain present even after the smoke is gone.

The most common toxic gas found at fire scenes is CO.[[99]](#footnote-99) CO can be deadly even in small quantities, as it replaces oxygen in the bloodstream, which occurs due to hemoglobin’s stronger chemical attraction to CO than to oxygen (O2). Traditionally in the fire service, a CO reading of below 35ppm has been the point at which firefighters have been permitted to remove all respiratory protection.[[100]](#footnote-100) However, CO has been proven to be a poor predictor of other chemicals presence at fire scenes.[[101]](#footnote-101) Therefore, the removal of respiratory protection based on the reading of a single gas leaves firefighters susceptible to exposure to other common toxic gases present at fire scenes.

During testing by the Office of the State Fire Marshal of Oregon, it was found that at fires in which testing samples were assessed, the levels of nitrogen dioxide (NO2), acrolein, CO, arsenic, and mercury, all exceeded levels the National Institute for Occupational Safety and Health (NIOSH) has established as producing immediately danger to life and health (IDLH).[[102]](#footnote-102) Chemicals found to be present at levels that were at NIOSH recommended exposure level—short term (REL-ST) were hydrogen chloride (HCl), benzene, formaldehyde, glutaraldehyde, hydrogen cyanide (HCN), and ozone (O3).[[103]](#footnote-103)

While some chemicals present at fire scenes do seem to predict the potential presence of other chemicals, no one individual agent has been found dependable enough to forecast the presence of all the hazardous agents present at a fire scene. As a result, سنسورهای پوششی should provide for active monitoring for the most common and most dangerous toxic gases to which firefighters will be exposed.

Two methods to monitor the environmental conditions within hazardous environments are *point source* monitoring, and *ambient* monitoring*.*[[104]](#footnote-104) In point source monitoring, a vacuum acquired sample is taken at the source of the contaminant or material. This handheld monitoring device is used to determine the presence of hazardous materials and hazardous environments. Ambient monitoring is performed by samples being taken in the immediate vicinity of the worker to test the environment in what is commonly called the “breathing region.” This monitoring is often part of the worker’s protective clothing and gives a more representative reading of the total atmosphere. Ambient monitoring is gas dependent because of the different vapor densities of the gases being looked for when monitoring the environment.[[105]](#footnote-105) With some gases sinking while others rise, ambient monitoring may not be as effective as point source monitoring for overall scene safety; however, it is ideal for individual responder safety.

**C. HAZARDOUS ENVIRONMENTAL MONITORING SCENARIO**

The fire at a three-story apartment building is now out and the job of digging through the debris and extinguishing any remaining small fires now begins for Engine 5. It has traditionally been the time when firefighters have stopped using their breathing apparatus since smoke is not visible and the air appears to be clear. With a سنسورهای پوششی system, like ProeTEX, which has the capability to determine the presence of toxic gases, Engine 5 will know that at this time, even though the air appears clear, actually, lethal levels of CO, CO2, and hydrogen cyanide are coming off the rubbish piles through which they are going to be sifting. As a result of that data provided to them by the sensors in their سنسورهای پوششی system, they leave their breathing apparatus on and complete their job without exposing themselves to the toxic chemicals that could have deadly consequences.

**1. Location Tracking**

The ability for firefighters to move rapidly and safely inside a building during operations is critical for rescue, firefighting, and firefighter safety reasons. If firefighters are performing a search and rescue mission, the ability to move rapidly throughout the building and ensure that every room is searched could be the difference between locating a missing person and a casualty. In firefighting operations, being able to move quickly to the room of origin and extinguish the blaze rapidly decreases the chances of building collapse, stops fire damage, and removes the immediate threat to those who might still be in the building.

In regards to firefighter safety, the ability to know where to go to locate a trapped or injured firefighter and the fastest route to get there could be the difference between life and death. Although technology like thermal imaging does provide improved visibility to firefighters in smoke filled environments, it does not provide firefighters with location tracking or overall scene coordination to move in the most efficient direction for the building in which they are operating. Although no current location tracking technology is on the market for structural firefighters today, promising research is being done that could make this technology available within the next decade.[[106]](#footnote-106)

Navigation in a building during a fire is difficult regardless of the size of the structure. Due to the dense smoke created during a fire, visibility in a fire is generally only a few inches in any direction. Combine visibility constraints with the issues of an unknown structure layout, intense heat, and the threat of dangers, such as building collapse or holes in the floor, and the threats to firefighters in these environments become clear. The ability for firefighters and firefighting crews to be tracked will make their movements under these conditions safer and more efficient. Through a combination of command post (CP) guidance and heads-up display (HUD), firefighters in the future will have the ability to see their location overlaid on the floor plan of the building in which they are operating.[[107]](#footnote-107) This overlay will allow the firefighters and firefighting crews to make knowledge-based decisions on direction of travel, escape paths, and search and rescue patterns.

The current technology available for personal location tracking of GPS is not a viable option for structural firefighters due to the weak signal of GPS transmitters being insufficient to penetrate walls. A new technology in design for firefighter location tracking utilizes (UWB radio signals that can penetrate structures and allow signals to be picked up by the indoor positioning system (IPS) receiver.[[108]](#footnote-108) UWB radio is designed to be used for short-range and high data-rate links, which makes it ideal for سنسورهای پوششی usage. These UWB signals are transmitted over a very wide range of frequencies and are able to be picked-up by the IPS device, which can plot the signals location to within three feet of its actual location.266

This technology, although still in development, will need to be tested to ensure that it is able to detect and accurately track firefighters within the harsh conditions in which they work. This new technology will also need to be able to determine the body positions of the firefighters and determine their location despite the unique body positions firefighters generally move in, such as crawling. The use of accelerometers and gyroscopes may solve some of these issues because of their ability to communicate the actual position of the firefighter within the building. In the event of a floor collapse where the firefighters’ position would be a mystery with modern technology, سنسورهای پوششی like ProeTEX, would be able to communicate not only the firefighters’ current location within the building, but also their anatomical position and any movement from the firefighters. Testing in real-world situations will be the best means to ensure this technology is truly able to add the benefits expected of it.

**2. Location Tracking Scenario**

A fire in a four-story apartment complex has resulted in Engine 5 being assigned to perform firefighting operations on the third floor. At the command post, the IC is alerted that Capt. Tanner of Engine 5 is having EKG changes, as well as respiratory and heart rate changes that have caused his سنسورهای پوششی garment to notify the IC. Despite his attempts to contact Engine 5 and Capt. Tanner over the radio, he has no success in reaching them. Due to the seriousness of this event, a MAYDAY operation is started with a rapid intervention crew (RIC) being activated to perform a search and rescue for Capt. Tanner and the rest of Engine 5. In the past, the RIC crew would be told of the original assignment location of Engine 5 and from that knowledge alone would have to perform a search without the ability in most cases to see clearly due to thick smoke. However, thanks to the GPS component of Capt. Tanner’s سنسورهای پوششی , the IC is able to know the location of Capt. Tanner in the building along with each of the other members of Engine 5. The RIC crew is steered directly to Capt. Tanner’s location where he is evacuated from the structure and turned over to the medical crew who were awaiting his exit.

**D. STAKE HOLDER CHALLENGES AND CONCERNS**

While the potential benefits of سنسورهای پوششی in the fire service are numerous, and the technological developments needed for سنسورهای پوششی to provide the needed services are still being achieved, fire departments and the collective fire service must consider residual considerations prior to implementing سنسورهای پوششی that discussed in the next section, which explores the privacy, security and legal considerations of سنسورهای پوششی . As part of the legal discussion, this research addresses how سنسورهای پوششی can be used in consideration of the HIPAA laws, and what labor union concerns exist regarding the use of this technology by their members.

**1. Privacy, Security, and Legal Considerations**

With the use of سنسورهای پوششی , human lives are directly involved. Failure to protect the personal privacy of a سنسورهای پوششی wearer could negatively influence the life of that person. Many of the sensor network applications in سنسورهای پوششی rely on technology that can create security weaknesses like the unauthorized “eavesdropping” and “denial of service attacks” (DOS).[[109]](#footnote-109) Creating a complete list of potential methods of attack is by the nature of technology impossible. As soon as new technology is created to protect data, new attack methods are also created to try to break down firewalls and defeat protection technology. In addition, many types of attacks cannot be imagined by the designers until a technology system has been implemented and deployed. Therefore, protections will likely be a “band aid” post-production fixes. However, the most concerning types of attack that could be leveled against سنسورهای پوششی networks are “eavesdropping on medical data, modification of medical data, forging of alarms on medical data, DOS, and location tracking of the system users.”[[110]](#footnote-110)

The threat of eavesdropping occurs as the user’s medical information is acquired, communicated, and then achieved on the system.[[111]](#footnote-111) Those people trying to get access to this information illegally might try to break into the system electronically. This access can be done by snooping on radio communications that take place between the sensor motes and the recording data with which they are communicating. A second concern is when attackers are able to alter medical data during its collection, transmission, or storage.[[112]](#footnote-112) This kind of attack could result in false system reactions, or failures of the system to react when it should. Modifying data can also be used to trigger alarms by creating a fictitious message that does not alter the actual data but causes the real data to be missed or ignored that will result in the same type false alarms or alarm failures. This intrusion can be accomplished by creating fake messages instead of modifying regular ones, such as when medical data is modified.[[113]](#footnote-113)

DOS attacks are manifested by a “jamming” or “overloading of the system,” which results in the system being rendered unusable.[[114]](#footnote-114) System overloading during the attacks results in legitimate data coming from the sensor motes being unprocessed and abnormal conditions or emergencies being unrecognized.

Despite attempts to make the information transmitted by سنسورهای پوششی garments secure, all سنسورهای پوششی , like all cell phones, leave behind them an invisible wake of electronic markers. Even with systems that have been designed to operate with “localization of persons,” these electronic markers could still be gathered, grouped, and assessed to develop a very accurate location of the wearer’s location.[[115]](#footnote-115) A further threat present in the use of eHealth systems like سنسورهای پوششی , therefore, is the ability of persons or companies to track the activity of the wearers.[[116]](#footnote-116) In this kind of tracking, recorded data from the wearer can be analyzed to measure the amount of activity a person is getting by observing heart rate patterns and oxygen saturation readings. This kind of data would be very desirable by insurance companies who may be tempted to misuse the data resulting in an alteration or decrease in benefits for those people they deem to have an unhealthy lifestyle.[[117]](#footnote-117)

In an attempt to decrease the exposure to attacks on personal information of سنسورهای پوششی wearers, a security-minded approach to their use must be implemented that can be accomplished through implementing safeguard measures in three levels: administrative, physical, and technical.[[118]](#footnote-118)

At the administrative level, “security measures should be applied to check for security breaches by staff or those people responsible for operating the system.”[[119]](#footnote-119) Creating a “well defined hierarchy” of the users, coupled with stout identification confirmation protocols, may aid in preventing violations within security systems on the administrative side of the operation.278 In addition, a security measure at this level should include access mechanism that only allows authorized individuals to access the data.

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The physical level security will include developing systems to protect data or data streams in the system from being tampered with or stolen, but must also include the actual hardware and garments from being accessible. Designers of سنسورهای پوششی can assist in this by designing tamper resistant garments and systems. Another measure that can be taken is to ensure that only appropriately cleared and approved personnel be permitted to have physical contact with the system hardware or garments while they are in use to decrease the chance of tampering or theft.

Any technical level security will need to take place directly in the hardware, such as the sensors, servers, disks, or other types of devices used both in سنسورهای پوششی devices and the systems that read and collect information from them.[[120]](#footnote-120) If the network is designed in such a fashion that the data will be sent to central servers, technical security will also need to be used at the server side of the operation. Wireless networks like those in سنسورهای پوششی garments are very susceptible to hackers.280 Intrusion detection and prevention methods will need to be in place before a system goes into operation for the data transfers to be made with confidence.

As the Internet of Things (IoT) creates a world populated with “intelligent but invisible data collectors and communication devices, no part of our lives will be able to hide from digitization.”[[121]](#footnote-121) It has been suggested that the basic approach that should be taken in regards to the use of ubiquitous computing systems is the “principle of openness, or simply notice.”[[122]](#footnote-122) That principle directs that open content or data can be used, modified, and shared by anyone for any purpose.283

The EU data protection directive, better known as The Directive, refined and extended the fair information practices by making it no longer sufficient to simply announce that data collection is taking place; it now also requires explicit consent from

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the subjects whose data is being collected.[[123]](#footnote-123) Written contracts remain the most popular method of gaining a person’s unambiguous consent. However, in the modern world of electronic transactions, such overt consent can be difficult to obtain. The American legal system currently views any form of recording without the clear permission of those involved in the recording as “surveillance,” which is illegal except in certain law enforcement situations which, in most cases, still requires a court order.[[124]](#footnote-124)

While the EU’s Directive elevated the personal privacy protection expectations on businesses who desired to transfer personal information from U.S. to EU companies, the security practices in the United States still operate primarily off the 1974 U.S. Privacy Act and the Fair Information Practices (FIP) it inspired.[[125]](#footnote-125) One of the principles of the FIP is that secret record keeping should not occur. An attitude of openness and transparency was a key to the act. Individual participation expectations meant that any subjects of data collection should be able to see and correct any records kept about them by any organization to whom they have permitted access to personal data. The data that could be collected about any individual person was not permitted to be excessive when compared to the purpose for the collection.[[126]](#footnote-126) The quality of the data was also addressed in the FIP, which stated, “data should only be relevant for the purposes for which they are collected and should be kept up to date.”[[127]](#footnote-127) In addition, the information collected may be used exclusively by particular personnel and not be available to the public.289

The final practice mandated by the FIP was that record keepers must be accountable for being compliant with all the principles of the U.S. Privacy Act. Despite the laws that exist and the clear mandate by the U.S. Privacy Act, the rapid progress and commercial success of the Internet has challenged the laws and regulations written 40 years ago. “Laws are intended to regulate human behavior” according to David Post, a

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professor at the Beasley School of Law at Temple University, in an article in the *Stanford Law Review*.[[128]](#footnote-128) “The regulation of human behavior takes place through a complex interaction among four forces, four different regulators.”[[129]](#footnote-129) Three of these regulators are “law, markets, and social norms.”[[130]](#footnote-130) The fourth regulator, according to Post, is “architecture,” the united limitations of “physics, nature, and technology” that when combined, define the borders of the places where human behavior occurs.[[131]](#footnote-131)

What makes cyber space and سنسورهای پوششی a new dimension is that its construction is distinctively defined by code, or “the design of the hardware and software elements that comprise the operations” of this new place.294 The software and hardware of the Internet and many سنسورهای پوششی s create a set of constraints on how a person can function. The makeup of the restrictions will be different between systems, but they are understood as conditions for the سنسورهای پوششی wearers’ access the Internet and all that it permits. In some systems, a password is required to enter into the system, while in others, one is not necessary at all. In some situations, an electronic track is created that links the actions individuals take through “mouse droppings” back to them. The coding, software, and protocols set in the design of سنسورهای پوششی will constrain behavior by making some behavior possible within the system while limiting or forbidding other behavior. So, while system design has methods through which it can control the availability to breaches and security concerns, the U.S. federal government has taken strides to protect Americans who conduct business on the Internet.

The National Information Infrastructure Act of 1996 established a framework for dealing with computer crimes that may extend to some Internet crimes. The Electronics Communication Privacy Act (ECPA) of 1986 also has application, specifically section s2511 that prohibits “interception and disclosure of wire, oral or electronic

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communication.”[[132]](#footnote-132) However, s2511(2)g(i) states, “it shall not be unlawful for any person to intercept or access an electronic communication system that is configured so that electronic communication is accessible to the general public.”296 In other words, information communicated wirelessly may be legally acquired by anyone with the capability to intercept the signal. Wireless systems like سنسورهای پوششی once again become vulnerable to those seeking to collect, alter, or destroy the communications between the سنسورهای پوششی garments and the data collection base station. For systems like سنسورهای پوششی that require wireless communication to transmit sensitive personal health data, end-to-end security will be necessary to meet the demands of the users.

Threats of “tampering with data, DOS, physical tampering and eavesdropping” require more focused security interest in wireless communication networks than they do in other common networks.297 In technology journals and reports, authors have brought up concerns regarding the “privacy of an individual such as where the health data of a wearer should be stored,” and who can view the data.[[133]](#footnote-133) Also concerns have also been raised regarding who will be responsible for maintaining the data and who will be accountable for data security breaches. During an emergency, it may also be in the person’s best interest that information be disclosed, which will demand that the system be flexible enough to allow for data to be released without it being so porous that data is easily released or withdrawn without permission.

Data collected by سنسورهای پوششی networks will be made up of sensitive medical information, and the ownership of that information will not always be clear. It is likely that the fire department will own the sensors and the network devices, while the data being collected belongs to the wearer. Further, data must be available during emergencies to ensure proper care is given, but access must not leave an electronic trail that can lead to abuses and system vulnerability. To aid in protecting the information collected by سنسورهای پوششی systems, “proper encryption and authentication mechanisms” will be necessary to help guarantee the security of the information transmitted.[[134]](#footnote-134) Although it is important that all existing laws and codes of practice be considered, it is equally critical to recall that legal mandates can only succeed when properly teamed with the social and technical capabilities permitted by the realities of the system.[[135]](#footnote-135) As a result, it will be necessary to bring together specialist from the various fields involved including the medical, legal, and insurance fields to discuss various aspects of modern communication technologies to ensure that the population can fully embrace the potential available from this technology.

**2. Medical Information Privacy**

In 1996, the HIPAA was made public law.[[136]](#footnote-136) HIPAA required the Department of Health and Human Services to adopt “a national standard for electronic health care transactions and code sets,” as well as to establish regulations related to the security of medical data.302 This law resulted in comprehensive changes to the portability of health insurance information and established privacy rules to safeguard protected health information (PHI) and/or electronic personal health information (ePHI). The primary components of the HIPAA law can be broken down into three general rules: the privacy rule, the security rule, and the breach notification rule.303

The HIPAA privacy rule created a new set of laws created to establish a national standard to ensure that all medical records and personal health information were protected. HIPAA compliance is only required for “the protection of individually identifiable health information by three types of covered entities: health plans, healthcare clearinghouses, and those health care providers that perform health care transactions electronically.”[[137]](#footnote-137) The privacy rule dictates that appropriate barriers be put in place to guarantee the security of personal medical data, as well as to set limits and boundaries on acceptable “uses and disclosures” that can be made regarding the protected information without the consent of the patient.[[138]](#footnote-138) In addition, the privacy rule gives patients the legal right to access their own medical records, which includes the right to “examine, obtain copies of, and request corrections to their own health records.”[[139]](#footnote-139) The HIPAA law was made more important with the passing of The Health Information Technology for Economic and Clinical Health (HITECH) Act, which was signed into law on February 17, 2009.[[140]](#footnote-140) HITECH was enacted as part of the “American Recovery and Reinvestment Act.”[[141]](#footnote-141) Its purpose was to encourage the implementation and meaningful use of health information technology through the use of electronic health records (EHS).[[142]](#footnote-142)

Questions regarding the applicability of HIPAA laws for fire department employees as they relate to wearing of سنسورهای پوششی have varying answers depending on multiple specific operational and administrative considerations. If a fire department provides medical care as part of its service, it is mandated to comply with all HIPAA laws for the patients it treats. In that case, the answer to whether their employees’ PHI and/or ePHI must be kept secure is made clear by the definitions of the terms in the HIPAA law.

According to the Department of Health and Human Services HIPPA law, a “participant” means an employee or former employee who is or may become eligible to receive a benefit from a(n) (insurance) plan.[[143]](#footnote-143) This definition is the baseline for the determination that fire departments’ employees’ health information must be handled in compliance with HIPAA rules and regulations. However, if a fire department does not provide medical care as part of its service, then it may not be required to be HIPAA compliant, and thus, its employees PHI and/or ePHI may not be mandated to be HIPAA protected.

The HIPAA security rule created a national standard for the protection of individuals’ ePHI that is created, received, used, or maintained by healthcare clearinghouses, and health care providers that perform health care transactions electronically.[[144]](#footnote-144) As part of the security rule, it became mandatory that all HIPAA qualifying agencies create appropriate “administrative,” “physical,” and “technical” protective measures to guarantee “the confidentiality, integrity, and security of all ePHI.”[[145]](#footnote-145) By the definition given in the HIPAA law, PHI and ePHI are individually identifiable health information maintained or transmitted in any form by any entity covered by HIPAA.[[146]](#footnote-146) According to HIPAA, PHI and/or ePHI may not be used or revealed except when: “a) the individual who is the subject of the information has authorized its disclosure, b) the individual who is the subject of the information agrees or does not object to the disclosure and the disclosure is to persons involved in the health care of the individual.”[[147]](#footnote-147)

To be able to use سنسورهای پوششی in the fire service without risking violations of the variables that determine HIPAA compliance or non-compliance, the use of waivers by the firefighters would be required to put them in compliance with section (a) of the exemption rule. A waiver signed upon hiring that PHI will be recovered for the purpose of health monitoring while in active firefighting operations, may release the fire department from the mandate to make every effort to maintain the security and privacy of the employees PHI and/or ePHI. Additionally, as was discussed in the privacy and security section of this document, numerous technical safeguards can be put in place to assist in protecting PHI and/or ePHI while سنسورهای پوششی are in use.

The HIPAA breach notification rule demands all HIPAA mandated agencies and their partners must give notice to all affected individuals after an infringement takes place involving unsecured PHI or ePHI. Following the discovery of a breach, the individuals affected by the breach must receive notification as quickly as possible and notification is never permitted to exceed 60 days. As part of the notification, the affected individuals must be provided, “a brief description of the breach, a description of the types of information that were involved in the breach,” and “the steps affected individuals should take to protect themselves from potential harm.”[[148]](#footnote-148) Also, a “brief description of what the covered entity is doing to investigate the breach, mitigate the harm, and prevent further breaches, as well as contact information for the covered entity” must be provided.[[149]](#footnote-149) In some cases, individual states have established stricter timelines for breach notification. In those cases, the stricter timeline will be the enforced standard.

**3. Union Considerations**

A major concern for all career and combination fire departments (career and volunteer mixed) is the influence of the professional firefighters union. For most fire departments in the United States, the IAFF is their union organization.[[150]](#footnote-150) The IAFF represents more than 300,000 professional firefighters across the United States and Canada in over 3,100 locals.[[151]](#footnote-151) These professional firefighters account for the protection of over 85% of the population in the United States and Canada.[[152]](#footnote-152) As a result, the influence and power of the IAFF is substantial within the fire service. Although the stated purpose of the union is to focus specifically on issues related to pensions, collective bargaining, health care, staffing, occupational safety, compensation, and presumptive protections, they have often been brought in to fight for or fight against changes to the services fire departments will provide, or the methodology with which services will be provided.

The IAFF leadership has made it clear in its publications that they support the use of technological advancements that have a proven benefit towards their stated goal of improving firefighter cardiac health and decreasing firefighter loss of life.[[153]](#footnote-153) In previous labor/management issues that involved the security and transmission of personal medical information, the union leadership has taken a stance that clear and conscious language in contracts was sufficient provided it addressed the aftermath of data collection. This language would be important specifically for cases where underlying cardiac or medical conditions are revealed by سنسورهای پوششی that are not acute life threatening issues, but are issues that need to be addressed by a physician. In these cases, the proper wording in the contract would serve to protect the firefighters’ job, while also ensure that the firefighter is not permitted to continue working until they have been cleared to return to work by a physician.

**4. Start-up, Acquisition and Maintenance**

The start-up and acquisition costs of سنسورهای پوششی for use in the fire service will depend greatly on the style of garment selected and the number of different sensing capabilities within the system procured. Prices will be affected by system specific components, such as communication systems and capabilities, battery life, and system functionality. While the prices of سنسورهای پوششی are currently very expensive, that scenario may quickly change when production of these garments transitions into large-scale production. However, at this time, garments on the upper end of sensing capabilities are running $5,000–5,200 dollars per garment.[[154]](#footnote-154) While that cost includes all the necessary components for a single wearable sensor garment including battery, communication capabilities, and sensors, it does not include the hardware and software for the receiving side of the system. Those components will result in an additional expense that will increase costs another $4,000– 5,000 per receiving station.

For سنسورهای پوششی in the fire service, a support structure will need to be established that will result in costs associated with securing a contract with an information technology (IT) company or with a municipal entities IT department. The costs of such contracts will vary significantly based on the number of garments in use by the department, the number of receiving stations the department establishes, and any pre-existing contracts that may exist between the fire department and the IT service provider. Further system support will need to come in the form of garment maintenance to include making any necessary repairs in the event of rips or tears in the garment material and laundering services. Another component of start-up and acquisition would be the establishment of a repair and replacement schedule.[[155]](#footnote-155) Due to the costs of each garment, a budget would need to be created that would establish a replacement schedule for the garments themselves based on estimated life spans of the garments while accounting for the unexpected immediate replacement needs for “off-schedule” garment failures or replacement demands.

Cost consideration must extend beyond the start-up and acquisition costs and also consider the costs of maintaining the status quo and having to accept the costs associated with a firefighter’s LODD. Although this section focuses primarily on the financial aspects of a LODD, much more is at stake than the fiscal effects of a firefighter’s LODD. The death of a firefighter has been seen to result in a degree of loss of public confidence in the fire department, which can affect future budgeting, job security, and have political repercussions outside the fire department.[[156]](#footnote-156) The financial repercussions of a firefighter’s LODD can be extremely substantial. Very few fire departments have budgeted with consideration of being prepared to cover the expenses related to a firefighter on duty fatality. Another issue that must be considered is where the financial ripple effect of a LODD extends. In almost all cases, it goes well beyond the fire department and includes the community, the taxpayer, the insurance companies, the state, the federal government, and the family of the firefighter who died.

The financial costs of a firefighter’s LODD may be measured as either direct or indirect costs. Direct costs may include the replacement costs for lost or damaged equipment or apparatus, accrued sick leave expense and overtime expenses for relief, funeral expenses (typically several thousand dollars), the cost of reception and memorial services, and many others related to the incident and its investigation. The indirect costs can be built out to extremes, and at some point, become incalculable. However, indirect costs often include additional staffing sent to the fire ground as a support team for the incident and its responders, administrative costs for insurance, and union costs for planning and supporting the funeral activities. Table 2 has a layout of direct and indirect costs associated with a LODD.

Table 2. Layout of Direct and Indirect Costs Associated with a LODD

|  |  |
| --- | --- |
| **Type of Cost** | **Discussion** |
| **Direct** |  |
| **Workplace** |  |
| Backfilling | Cost of personnel to replace firefighter killed. |
| Lost Productivity | Cost required due to inability to perform required functions because replacement workers are not as skilled as deceased firefighter or because worker’s effectiveness was diminished following the firefighter fatality. |
| **Administration** |  |
| Legal Fees | Lawyer fees to defend personal injury and death lawsuits brought by firefighters or dependents and to prosecute against claims decisions to include legal fees, court costs, and settlements/judgments excluding punitive damages, and pain and suffering. |
| Paperwork and Data Collection | Cost of personnel time and systems used in filing reports of injury, claims for compensation, insurance forms, collecting information, etc. |
| Investigations | Time, expenses, and materials associated with investigating and documenting incidents and claims. |
| **Type of Cost** | **Discussion** |
| **Insurance** |  |
| Non-Medical Payouts | Wage differential payouts made by insurance coverage on death and disability coverage. |
| Premium Increases | Increase in insurance premiums. |
| **Medical Expenses** |  |
| In-patient Care | Costs directly related to any hospitalization for medical services, including emergent transport and care from the prehospital environment. |
| **Federal Payments** |  |
| Public Safety Officers Benefit Program | Cost of federal payments under the Public Safety Officers Benefit law. These are made for disabling injuries and fatalities. |
| **Lost Income** |  |
| Career | Difference between regular wages and those paid under death and disability status. |
| Second Jobs | Loss of wages from any additional source of income. |
| Caregiver | Loss of wages for any caregiver forced to reduce/terminate employment due to death of firefighter. |
| **Indirect** |  |
| **Insurance** |  |
| Administrative Costs | Costs related to the administration of insurance, which does not include indemnity or medical payouts. |
| **Prevention** |  |
| Personal Protective Equipment | Costs of equipment, including maintenance and upgrades. |
| **Other Direct Costs** |  |
| Pain and Suffering | Intangible costs and consequences of changes in the lives of the family or the deceased firefighter. |

It is not possible to put an absolute value on a firefighter’s life; thus, some allowances must be made for costs of a firefighter on duty death. However, based on a study of firefighter injuries, it was seen that a firefighter injury that does not result in death still may have a total cost of over $215,000.[[157]](#footnote-157) Those expenses, although substantial, do not include the many additional costs associated with a fatality. Following the LODD of a firefighter, the local government and fire department will need to be prepared to fund life insurance for the survivors of that family as mandated by the federal COBRA law for a period not to exceed 36 months.[[158]](#footnote-158) They will also have to pay for retirement, final paycheck, sick leave payout, vacation leave payout, and coverage of any hospital/emergency transport costs.[[159]](#footnote-159) State government must fund the state line-of-duty death benefits, workers compensation, funeral burial allowance, retirement/pension, health insurance in many states, and educational assistance for the surviving dependents of the firefighter, as well as the spouse.[[160]](#footnote-160)

The Public Safety Officers’ Education Assistance (PSOEA) Program provides financial assistance through the U.S. Department of Justice, Bureau of Justice Assistance. It provides a maximum of $881 a month to cover educational expenses.[[161]](#footnote-161) Beyond that amount, many states have passed laws that ensure that the dependents of a firefighter killed in the line-of-duty will be admitted to and receive free room, board, and education at any state college within that state.[[162]](#footnote-162) Another federal program that must pay following the death of a firefighter in the line-of-duty is The Public Safety Officers’ Benefit (PSOB) Act (42 U.S.C. 3796), which provides a one-time cash payout for eligible survivors. This payout as of October 2013 was $333,604.[[163]](#footnote-163)

While the immediate costs of implementing a سنسورهای پوششی system seem steep, they must be balanced against the costs of not implementing a program that can reduce the likelihood of needing to pay for the costs associated with a firefighter’s death.

**5. Training**

Training should be required for all department personnel who may use or otherwise be involved with the سنسورهای پوششی systems. This training should include all firefighters and fire officers, supervisors whose crews will be using the garments, and training staff members. Training should focus on practice and policies that involve the سنسورهای پوششی systems including how to document and report garment or system malfunctions or damage, procedures for operating the systems components safely and effectively, and include scenario-based exercises that replicate situations that will require the use of سنسورهای پوششی by firefighters.

Supervisors and those who will be exposed to the receiving end of the communications loop of this technology will need to receive training on procedures for responding to system alarms, policies for firefighter withdrawal if the system detects physiological abnormalities, and procedures for accessing and reviewing the data being received from the field worn سنسورهای پوششی garments. Training at the supervisors level will also need to address the legal considerations of who can delete the data received, when it can be deleted after an incident, and who shall have access to the data prior to its disposal.

This training will require a substantial investment of training hours that will detract from the available time to complete other mandated training. As a result, legally required training will have to be performed during other periods, which may result in fire departments needing to fund overtime (OT) expenses. Supervisors will have a particularly significant training demand placed upon them due to their need to understand and be able to operate both sides of the سنسورهای پوششی system. After the initial training cycle is complete, quarterly updates and annual refresher training will easily dovetail into existing training packages resulting in the original costs of the start-up training being a one-time expense.

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# CONCLUSIONS

The American firefighter is frequently referred to as “America’s bravest.” Firefighters’ willingness to go into harm’s way to save a human life, or put themselves in danger to protect another’s property has made that unofficial title well deserved. However, despite the bravery firefighters across the nation demonstrate each and every day, over 100 firefighters will die this year, just as they have for the last 30 years. The LODD death rate for the American firefighter remains unchanged despite the decrease in structure fires being fought, as well as the initiation of numerous programs that have targeted firefighter health and safety. Firefighters die in the line-of-duty for many reasons, which makes the possibility of a zero firefighter death a near impossibility. However, the leading cause of firefighter deaths has been well established to be heart attacks and/or cardiac arrest related to the exacerbation of underlying CHD.

Firefighters share the same risk factors for CHD as does the general public, which includes poor diet, hypertension, lack of exercise, and stress. However, what is less known is that firefighters, as a result of their profession, are exposed to additional factors that substantially increase their risk of CHD and sudden cardiac arrest. Some of those additional factors are the strenuous physical nature of the work performed by firefighters, the heat stress that is ever presence on the fire ground, as well as dehydration that often accompanies the work of firefighting.

Prolonged episodes of sympathetic nervous system activation and numerous different psychological and sensory system assaults are also components that take a toll on firefighters who already suffer from underlying CHD. Programs, such as *NFPA 1500, Fire Department Occupational Safety and Health Program, NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, NFPA 1583, Standard on Health-related Fitness Programs for Fire Fighters* and the IAFF/IAFC’s *The Fire Service Joint Labor Management Wellness-Fitness Initiative*, have all failed to reduce the number of firefighters dying in the line-of-duty, despite their positive objectives.

The development of “smart clothing,” advancements in the miniaturization of technology, and improvements in the wireless communication fields have come together for the creation of a tool that could greatly reduce the number of firefighters who die from cardiac related events while operating on the fire ground. سنسورهای پوششی is the combining of a comfortable fabric with physiological sensing capabilities that allow for the continuous observation of the wearers’ vital signs from distant locations. Although the sensing capabilities of the garments differ from one design concept to another, all سنسورهای پوششی being marketed for the fire service allow for the monitoring of the wearers’ HR, RR, SpO2, and EKG/ECG. These four vital measurements of wearers’ physiological functioning are enough to allow an observer (generally the IC or respective aide) at the receiving end of the data stream being created by the سنسورهای پوششی to detect any changes in vital signs or EKG to initiate a timely medical intervention on the wearers’ behalf. As has been proven in numerous studies by the American Heart Association and the American College of Cardiology, the faster the recognition is made of a heart attack through a 12-lead EKG, the faster the treatment can begin and the better the survivability rates both in the shortterm and long-term.

Although the use of سنسورهای پوششی is not aimed at decreasing the number of heart attacks suffered by firefighters while operating at fire scenes, it has demonstrated a clear value in recognizing those who do suffer a cardiac event and may allow for a much more prompt response by medical professionals. Once in the care of the on-scene paramedics, rapid assessment including a 12-lead EKG will permit quicker initiation of pharmacological care that will exceed the national standards for ideal door-to-drug time. This rapid assessment, diagnosis, and initiation of cardiac treatment will result in less firefighters dying and allow for more firefighters who do suffer a cardiac event on duty to come back to their departments healthy and ready to serve their communities.

**A. FINAL ASSESSMENT AND DETERMINATION OF سنسورهای پوششی FOR THE FIRE**

**SERVICE**

After assessing and analyzing the four سنسورهای پوششی systems, a determination based on that research is that the ProeTEX system is currently the best system available for use in the fire service. As illustrated in Table 2, the ProeTEX system has been consciously designed to be exceptionally wearable, with minimal additional weight for the wearers, a comfortable design, easy to don and doff, easy to remove in the event of an emergency, while not limiting the wearers’ ROM. The durability of the ProeTEX system was an intentional design based on the knowledge that its technology was being made specifically for the fire service. As a result, the ProeTEX components have been made to resist rips and tears, moisture, and heat. In much the same way as ProeTEX was designed to be durable, it was also made to be easy to maintain through its easy of washing, easy of battery charging, and ease of software upgrading that will improve the long-term use of the system.

Perhaps the most critical component of the سنسورهای پوششی is its functionality. Like all the other systems, ProeTEX is able to deliver the wearers’ HR, RR, SpO2, and give a temperature reading, but it has many additional capabilities that make it stand out. ProeTEX’s ability to monitor external variables, such as hazardous gas levels and oxygen deficient environments, is a unique feature, shared only by the پوشاک هوشمند اورژانسی. However, unlike the پوشاک هوشمند اورژانسی the ProeTEX system measures a true respiratory rate based on thorax expansion rather than an estimated respiratory rate based on SpO2 readings, which do not reflect active breathing but rather estimates breathing rates. While the VTAMN and MagIC both also have true respiratory rate measurements, both systems fail to deliver in other areas, such as wearability or durability.

Additionally, ProeTEX is also able to detect falls and measure the absolute speed and position of the wearer, which has applications beyond the scope of this thesis. While ProeTEX is the most expensive of the systems whose prices are known, a great deal of the expense results from ProeTEX being an entire firefighting ensemble and not just a shirt worn under the firefighters’ current bunker gear. As fire departments are mandated to replace firefighters’ protective ensembles every 10 years, the additional cost of procuring the ProeTEX system with its complete bunker gear design negates a substantial portion of the cost difference.

1. **RECOMMENDATIONS AND EXPECTATIONS**

It is recommended that the American fire service explore the implementation of سنسورهای پوششی as a mandatory piece of safety equipment for all structural firefighters in the United States. Upon completion of testing and certification by organizations, such as OSHA, UL, and NFPA, fire departments should be given a mandate to provide سنسورهای پوششی garments to all firefighters regardless of career or volunteer status, as well as initial training, quarterly training, and annual recertification training. In addition, all fire departments should be mandated to ensure that IC and/or respective designee will monitor the سنسورهای پوششی receiving station for the duration of firefighting operations.

1. **UNKNOWNS AND LIMITATIONS**

Despite the significant amount of research that has gone into the development and refinement of سنسورهای پوششی , a few unknowns remain related to the acceptability and feasibility of its use within the fire service. The first unknown that remains is the willingness of the fire service to adopt such a change.

The culture of the fire service will offer significant resistance to the implementation of سنسورهای پوششی . This culture is one that has developed a resistance to change, and expects full involvement in the planning and researching of any potential change that may affect its routine or emergency operations. The NFFF has stated that “the culture of the fire service is a major contributor to the fatal trend in the fire service.”[[164]](#footnote-164) It is also recognized that “some type of cultural change is needed to change the perceptions of acceptable and unacceptable risks.”[[165]](#footnote-165) When asked about the dangerous behaviors they undertake, firefighters will often state that there are both organizational and public expectations require them to act as they do and to place their own lives and health second to that of those they serve. These beliefs and behaviors comply with the image that firefighters have earned and now try propagate as being the selfless American heroes who willingly puts their lives on the line “to save the life of a total stranger and who is lauded for doing so.”[[166]](#footnote-166)

The fire service takes great pride in its culture, and for many, their fire department is defined by its culture. This culture includes the use of “a uniform hierarchical command structure, promotion solely from within the existing ranks, and many longstanding traditions.”[[167]](#footnote-167) In some cases, these traditions are taught as solutions to problems that ignore the fact that they are incorrect practices. Despite the fact that these methods are recognized as being incorrect, their use continues as a department or fire service tradition.

The term “culture” in its most basic form simply describes how things are done within an organization.[[168]](#footnote-168) This definition may help to illuminate just how interwoven the fire services operational capabilities and delivery methodologies are with the culture within which the fire service operates. The culture of the fire services is driven by its “organizational history, policies, uniforming, facilities, vocabulary, leadership and management within the organization.”[[169]](#footnote-169) The culture that exists within the fire service has developed through years of passed down stories and shared experiences, as well as being acquired at training exercises, emergency incidents, and around the dinner table. It is through this process that the culture of the fire service has been formed, and it is through this process that the culture must change for the implementation of سنسورهای پوششی to be accepted.

As a “service-focused” organization, the fire service would be fine in having a well-defined identity and presence in the communities it serves, as well as being willing to take risks to carry out its calling. However, these traits are only acceptable when they exist in an environment in which safety is the constant driving force. Too often, however, the fire service culture is less focused on safety and more focused on retaining its “hero” image, prepared to risk the lives of its members while carrying out its duties. This emphasis on meeting the perceived cultural expectations of the community is reflected in LODDs, which are treated as heroic regardless of the nature and causes behind the death.[[170]](#footnote-170)

Recognizing that the culture of the fire service is a major contributor in the consistently high numbers of firefighter fatalities is not a recent development. The IAFC, IAFF, and the National Fallen Firefighters Foundation (NFFF) have identified culture as a crucial area that is impeding a revolution of thinking and acting with a safety first attitude within the fire service. Some of this cultural resistance comes from the strong unions that are a major component of the fire service culture. Changes that are mandated from department administration, such as the chief or assistant chief, are often meet with legal challenges and battled through contract negotiations regardless of the safety improvements that the change might have within the fire service. Related to the strong union presence within the fire service, close budgetary monitoring by firefighters of their departments leaders will create another challenge to the implementation of سنسورهای پوششی in the American fire service. Many firefighters or their union leaders will want to know what else could have been purchased, which has proven safety applications, and which do not risk invasion of personal privacy of the members.

While the current culture within the fire service does not seem ready for the introduction of سنسورهای پوششی , a change is taking place across the country. In March 2004 at the Firefighter Life Safety Summit in Tampa, Florida, the first of 16 firefighter life safety initiatives was written that reads, “Define and advocate the need for a cultural change with the fire service relating to safety, incorporating leadership, management, supervision, accountability and personal responsibility.” This initiative, although slow in its initiation, has begun to take root in many individual departments and specific regions.

Changes in the values of the fire service have legitimized and encouraged further variance in behavior. The changes in behavior then must be reinforced and rewarded by a continuous dedication to the development and advancement of a safety minded organization that can only be achieved, as it always has been, through training, emergency responses, proper use of downtime around the station, and during informal activities. A change of culture “can only be accomplished by convincing the firefighters at every level that change is both desirable and necessary, and that adjustments may be accommodated without compromising any of the highly valued aspects of the fire service culture.”[[171]](#footnote-171) Through this process, the “hero” culture of the fire service can slowly be replaced by a culture of intelligent strategy and strategic actions based on on-going risk and reward assessments of the situation.

The second unknown that remains for the implementation of سنسورهای پوششی in the fire service is the system limitations for data reception. While studies of systems like ProeTEX have performed well with individual or small group data streams, trials have not been performed where large numbers of firefighters were simultaneously transmitting their data to a single receiving station. To ensure that the system selected for fire service use is able to handle large amounts of data, trials will need to be performed where receiving stations are required to receive large amounts of data simultaneously. Receiving stations should be taxed to the point of failure to see what the results of such a collapse would be, as well as to assist in designing emergency actions to take by the receiving station attendant in the event of such a failure.

A significant limitation to سنسورهای پوششی capabilities is the lack of a consistent and reliable GPS capability for structural firefighters. Due to the nature of structural firefighting, most operations take place within the confines of walled and covered structures. As a result, the GPS signals from most سنسورهای پوششی systems are not able to transmit to the satellites needed to pinpoint the wearers’ exact location. This capability, although not a critical component of the system, is a potentially significant benefit to the firefighters wearing the garment, as well as the citizenry who are relying on the firefighters to perform their job with peak efficiency. As technology continues to improve, the author is hopeful that a resolution to this current limitation can be resolved to allow for the full potential of سنسورهای پوششی to be achieved.

**D. FUTURE RESEARCH**

This thesis and its expectations are based on estimations, correlations, and best evidence. Should سنسورهای پوششی be adopted, a performance matrix will need be established based on reporting and incident data collection. System successes and failures will need to be collected by the fire service and not just the manufacturers of the garments. Data collection, to be accurate, will need to be performed at a national level from departments of all sizes, composition, and locations. The data will need to assess the accuracy and reliable of the system and its individual components, as well as any unintended consequences of its usage.

Additional research into سنسورهای پوششی should explore the use of this technology in the fire service beyond the fire ground to include the value it may have in training and during response times when firefighters are driving to and returning from emergency incidents. Research should also explore beyond the fire service to find applications for this technology in other fields. This research may focus on سنسورهای پوششی for monitoring of astronauts during their missions, as well as for deep sea divers who spend long durations submerged breathing gases in concentrations different than those found in the atmosphere.

The potential uses for سنسورهای پوششی are numerous, and research into its many applications is limited only by the imagination of the designers and academics who choose to explore its potential.

# LIST OF REFERENCES

Abowd, Gregory, Barry Brumitt, Marc Langheinrich, and Steven Shafer. *Privacy by Design—Principles of Privacy-Aware Ubiquitous Systems*. Berlin: Springer Berlin Heidelberg, 2001.

Ades, P. A, M. L. Waldmann, W. J. McCann, and S. O. Weaver. “Predictors of Cardiac Rehabilitation Participation in Older Cardiac Patients.” *Journal of*

*Cardiopulmonary Rehabilitation* 13, no. 3 (1993): 212–213. doi:10.1097/000084 83-199305000-00012.

Administrator. “Revolutionary GPS Could Save Firefighters Lives.” Getreading, 2008.

http://www.getreading.co.uk/news/local-news/revolutionary-gps-could-savefirefighters-4255616.

Adnane, Mourad, Zhongwei Jiang, Samjin Choi, and Hoyoung Jang. “Detecting Specific

Health-Related Events Using an Integrated Sensor System for Vital Sign Monitoring.” *Sensors* 9, no. 9 (2009): 6897–6912. doi:10.3390/s90906897.

Ahsan, Arif, Brahmbhatt Ashish, Dermot Cantwell, Ashot Melik-Martirosian, and JerriAnn Meyer. “Wearable Sensor for Cardiac Rehabilitation.” *Insights in Engineering Leadership White Paper* 6, no. 2 (2014): 3–18.

Al Ameen, Moshaddique, Jingwei Liu, and Kyungsup Kwak. “Security and Privacy Issues in Wireless Sensor Networks for Healthcare Applications.” *J Med Syst* 36, no. 1 (2010): 93–101. doi:10.1007/s10916-010-9449-4.

Armijo, Kenneth, C. R. Baker, M. Benhabib, S. Belka, V. Bhargava, N. Burkhart, A. Der Minassians, G. Dervisoglu, and M. B. Hack. “Wireless Sensor Networks for Home Health Care.” In 21st International Conference on Advanced Information Networking and Applications Workshops, 2007.

Axisa, Fabrice, Georges Delhomme, Andre Dittmar, Claudine Gehin, Eric McAdams, and P. M. Schmitt. “Flexible Technologies and Smart Clothing for Citizen Medicine, Home Healthcare, and Disease Prevention.” *IEEE Transactions on Information Technology in Biomedicine* 9, no. 3 (2005): 325–336. doi:10.1109/ titb.2005.854505.

Aylor, James, Adam Barth, Benton Calhoun, Mark Hanson, John Lach, Harry Powell, and Kyle Ringgenberg. “Body Area Sensor Networks: Challenges and Opportunities.” *Computer* 42, no. 1 (2009): 58–65.

Baghai, R., D. Blanc, A. Blinovska, B. Comet, C. Corroy, A. Dittmar, F. Klefstat, S. Vaysse, and J. L. Weber. “VTAMN—A Smart Clothe for Ambulatory Remote Monitoring of Physiological Parameters and Activity.” In *26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Boston, 2004.

Baghai, R., D. Blanc, A., Blinowska, B. Comet, C. Corroy, A. Dittmar, N. Noury, and J.

L. Weber. “VTAMN—A New “Biocloth” for Ambulatory Telemonitoring.” In *4th International IEEE EMBS Special Topic Conference on Information Technology Applications in Biomedicine*. Boston, 2003.

Bajcsy, Ruzena, Dennis Chang, Dennis Chen, Karric Kwong, and Jerry Luk. “Wearable Sensors for Reliable Fall Detection.” In *27th Annual International Conference of the Engineering in Medicine and Biology Society*. Boston, 2005.

Baldwin, T., T. Hales, and S. Jackson. *NIOSH Alert: Preventing Fire Fighter Fatalities Due to Heart Attacks and Other Sudden Cardiovascular Events*. Washington, DC: National Institute for Occupational Safety and Health, 2007.

Barr, David, Stefanos Kales, and Dennis Smith. “*Extreme Sacrifice: Sudden Cardiac Death in the U.S. Fire Service.” Extreme Physiology and Medicine* 2, no. 6 (2013): 105–133.

Berthold, Oliver, and Hannes Federrath. “Identitaetsmanagement.” (2000): 189–204.

Blumenthal, David. “Launching HIteCH.” *New England Journal of Medicine* 362, no. 5 (2010): 382–385.

Bonato, Paolo. “Advances in Wearable Technology and Applications in Physical Medicine and Rehabilitation.” *Journal of Nureoengineering and Rehabilitation* 2, no. 1 (2005): 2–19.

———. “Advances in Wearable Technology for Rehabilitation.” *Harvard-MIT Division of Health Science and Technology*, 2009.

———. “Clinical Applications of Wearable Technology.” In *Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. Boston: Harvard University, 2009.

Bonato, Paolo, Leighton Chan, Hyung Park, Shyamal Patel, and Mary Rodgers. “A Review of Wearable Sensors and Systems with Application in Rehabilitation.” *Journal of NeuroEngineering and Rehabilitation* 9, no. 21 (2012): 1–16.

Bonfiglio, Annalisa, Davide Curone, Gabriela Dudnik, Giacomina Loriga, Jean Luprano, Giovanni Magenes, Rita Paradiso, and Alessandro Tognetti. “Smart Garments for

Safety Improvement of Emergency/Disaster Operators.” In *29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 2007.

Bonfiglio, Annalisa, Nicola Carbonaro, Cyril Chuzel, Davide Curone, Gabriela Dudnik, Fabio Germagnoli, David Hatherall, Jean Mark Koller, and Thierry Lanier. *Managing Catastrophic Events by Wearable Mobile Systems*. Berlin: Springer, 2007.

Borodoni, Bruno, Gabriella Brambilla, Paolo Catiglioni, Marco Di Rienzo, Maurizio Ferratini, Paolo Mazzoleni, Paolo Meriggi, and Gianfranco Parati. “MagIC System.” *IEEE Engineering in Medicine and Biology Magazine* 28, no. 6 (2009): 35–40.

Brainard, Andrew Han, William Raynovich, Dan Tandberg, and Edward J. Bedrick. “The

Prehospital 12-Lead Electrocardiogram’s Effect on Time to Initiation of

Reperfusion Therapy: A Systematic Review and Meta-Analysis of Existing Literature.” *The American Journal of Emergency Medicine* 23, no. 3 (2005): 351– 356. doi:10.1016/j.ajem.2005.02.004.

Cai, Ying, Thomas Magedanz, Minglu Li, Jinchun Xia, and Carlo Giannelli. *Mobile Wireless Middleware, Operating Systems, and Applications*. New York: Springer Publishing, 2010.

Caldani, Laura, Davide Curone, Giovanni Magenes, and Emanuele Lindo Secco.

“Firefighters and Rescuers Monitoring through Wearable Sensors: The Proetex Project.” In *2010 Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*,Boston, 2010.

Cao, Q., T. Doan, L. Fang, Z. He, R. Kiran, S. Lin, S. Son, J.A. Stankovic, R. Stoleru, and A. Wood. “Wireless Sensor Networks for In-Home Healthcare: Potential and Challenges.” In *High Confidence Medical Device Software and Systems Workshop*. Charlottesville, VA: University of Virginia, 2005.

Castiglioni, Paolo, Marco Di Rienzo, M. Ferrarin, Maurizio Ferratini, Paolo Mazzoleni,

Paolo Meriggi, and Francesco Rizzo. “MagIC: A Textile System for Vital Signs

Monitoring. Advancement in Design and Embedded Intelligence for Daily Life Applications.” In *29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 2007.

Celli, Bartolome R., William MacNee, Alvar Agusti, Antonio Anzueto, B. Berg, A. Sonia Buist, and Peter M. A. Calverley et al. “Standards for the Diagnosis and

Treatment of Patients with COPD: A Summary of the ATS/ERS Position Paper.” *European Respiratory Journal* 23, no. 6 (2004): 932–946. doi:10.1183/09031936.

04.00014304.

Chaudhuri, K. Ray, and Anthony H. V. Schapira. “Non-Motor Symptoms of Parkinson’s Disease: Dopaminergic Pathophysiology and Treatment.” *The Lancet Neurology* 8, no. 5 (2009): 464–474. doi:10.1016/s1474-4422(09)70068-7.

Chetan, S., A. Ranganathan, and R. Campbell. “Towards Fault Tolerant Pervasive Computing.” *IEEE Technol. Soc. Mag.* 24, no. 1 (2005): 38–44.

Chi, Charlie, Darryl Gurganious, and Mareca Hatler. “Health & Wellness Wireless Sensor Networks.” *ON World* 1, no. 1 (2013): 1–81.

Choi, Young B., Kathleen E. Capitan, Joshua S. Krause, and Meredith M. Streeper. “Challenges Associated With Privacy in Health Care Industry: Implementation of HIPAA and the Security Rules.” *J Med Syst* 30, no. 1 (2006): 57–64.

Christiani, David, Costas Christophi, Stefanos Kales, and Elpidoforos Soteriades.

“Emergency Duties and Deaths from Heart Disease among Firefighters in the United States.” *New England Journal of Medicine* 356, no. 12 (2007): 1207– 1215.

Christiani, David, Stavros Christoudias, Stefanos Kales, and Elpidoforos Soteriades. “Firefighters and On duty Deaths from Coronary Heart Disease: A Case Control Study.” *Environmental Health* 2, no. 1 (2003): 1–14.

Client.prod.iaff.org. “Welcome to the IAFF website.” Accessed May 22, 2015. http:// client.prod.iaff.org/#page=AboutUs.

Cooper, Simon, Abdennour El Rhalibi, Paul Fergus, Kifayat Kifayat, and Madjid Merabti. “A Framework for Physical Health Improvement Using Wireless Sensor

Networks And Gaming.” In *3rd International Conference on Pervasive Computing Technologies for Healthcare*, 2009.

Curone, Davide, Emanuele Lindo Secco, Alessandro Tognetti, Giannicola Loriga, Gabriela Dudnik, Michele Risatti, Rhys Whyte, Annalisa Bonfiglio, and Giovanni Magenes. “Smart Garments for Emergency Operators: The Proetex Project.” *IEEE Transactions on Information Technology in Biomedicine* 14, no. 3 (2010): 694–701.

Curone, Davide, Matteo Lanati, Giovanni Magenes, and Emanuele Lindo Secco. “LongDistance Monitoring of Physiological and Environmental Parameters for Emergency Operators.” In *Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 2009.

D. Compton. “Leadership for Today and Tomorrow.” In *The Fire Chief’s Handbook* (2003): 205–228.

DeNoon, Daniel. “Firefighter Killer: Heart Disease.” *Webmd*, March 21, 2007. http:// www.webmd.com/heart-disease/news/20070321/firefighter-killer-heart-disease?

DeRossi, Danilo, Angelo Gemignani, Rita Paradiso, and Enzo P. Scilingo. “Knitted Bioclothes for Cardiopulmonary Monitoring.” In *25th Annual International Conference of the IEEE Engineering in Medicine And Biology Society*. Boston:

Harvard, 2003.

DeRossi, Danilo, T. Faetti, Antonio Lanata, Elena Nardini, and Enzo P. Scilingo. *A Comparative Evaluation of Different Techniques for Ambulatory Monitoring of Respiratory Rates*. Pisa: University of Pisa, 2008.

Devine, E. B., K. So, and Leslie Wilson. “Direct Medical Costs of Chronic Obstructive Pulmonary Disease; Chronic Bronchitis and Emphysema.” *Respiratory Medicine* 94, no. 3 (2000): 204–213.

Di Rienzo, Marco, Francesco Rizzo, Paolo Meriggi, Paolo Castiglioni, Paolo Mazzoleni, Gianfranco Parati, Bruce Bordoni, Gabriella Brambilla, and Maurizio Ferratini. “Magic System.” *IEEE Eng. Med. Biol. Mag.* 28, no. 6 (2009): 35–40. doi:10. 1109/memb.2009.934627.

———. “MagIC System: A New Textile-based Wearable Device for Biological Signal

Monitoring. Applicability in Daily Life and Clinical Setting.” *2005 IEEE Engineering in Medicine and Biology 27th Annual Conference*, 2005.

———. “MagIC System.” *IEEE Engineering in Medicine and Biology Magazine* 6, no.

28 (2009): 35–40.

Dyer, Robert F. “Polyvinyl Chloride Toxicity in Fires.” *JAMA* 235, no. 4 (1976): 393. doi:10.1001/jama.1976.03260300019022.

Egidio, Astesiano, Nikolay Dokovsky, Nicolas Guelfi, Aart van Halteren, Gianna Reggio, and Ing Widya. *Banip: Enabling Remote Healthcare Monitoring with Body Area Networks*. Berlin: Springer Berlin Heidelberg, 2004.

Fallon, James, Joan Fallon, Matthew Heil, and Stephen Weiss. “Systems and Methods

Employing Remote Data Gathering and Monitoring for Diagnosing, Staging, and Treatment of Parkinson’s Disease, Movement and Neurological Disorders and Chronic Pain.” *United States Patent and Trademark Office* (2009): 32–67.

Firoozakhsh, Babak, Nikil Jayant, Sundaresan Jayaraman, and Sungmee Park. “Wireless Communications of Vital Signs Using the Georgia Tech Wearable Motherboard.” In *2000 IEEE International Conference on Multimedia and Expo*, 2000. Fisher, Elise, Sue McDonald, Lori Moore-Merrell, Jonathon Moore, and Ainong Zhou.

*Contributing Factors to Firefighter Line-of-Duty Death in the United States*.

Washington, DC: International Association of Firefighters, 2006.

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Fisher, Elise, Sue McDonald, Lori Moore-Merrell, Jonathon Moore, and Ainong Zhou.

*Contributing Factors to Firefighter Line-of-Duty Death in the United States*. Washington, DC: International Association of Firefighters, 2006.

Fitzgerald, Todd. “The HIPAA Final Rule: What’s Changed?.” *Information Systems Security* 12, no. 2 (2003): 50–59. doi:10.1201/1086/43326.12.2.20030501/425 87.9.

Fleet, Bernard, and Hari Gunasingham. “Electrochemical Sensors For Monitoring Environmental Pollutants.” *Talanta* 39, no. 11 (1992): 1449–1457.

GCR, NIST. *The Economic Consequences of Firefighter Injuries and Their Prevention*. Final Report. Arlington, VA: National Institute of Standards and Technology, 2005.

Georgia Institute of Technology. “Georgia Tech Wearable Motherboard™: The Intelligent Garment for the 21st Century.” Accessed April 12, 2015. http:// www.پوشاک هوشمند اورژانسی.gatech.edu/.

González-Alonso, José, Craig G. Crandall, and John M. Johnson. “The Cardiovascular Challenge of Exercising in the Heat.” *The Journal of Physiology* 586, no. 1 (2008): 45–53. doi:10.1113/jphysiol.2007.142158.

Gopalsamy, Chandramohan, Sungmee Park, Rangaswamy Rajamanickam, and Sundaresan Jayaraman.”The Wearable Motherboard?: The First Generation of Adaptive and Responsive Textile Structures (ARTS) for Medical Applications.” *Virtual Reality* 4, no. 3 (1999): 152–168.

Hash, Joan. “An Introductory Resource Guide for Implementing the Health Insurance Portability and Accountability Act (HIPAA) Security Rule.” PhD diss., National Institute of Standards and Technology, 2005.

HHS.gov. “Combined Regulation Text of All Rules.” 2015. http://www.hhs.gov/ocr/ privacy/hipaa/administrative/combined/index.html.

Himayat, N., K. D Johnson, K. Johnsson, S. Talwar, and G. Wu. “M2M: From Mobile to Embedded Internet.” *IEEE Communications Magazine* 49, no. 4 (2011): 36–43.

Jayaraman, Sundaresan, and Sungmee Park. “Enhancing the Quality of Life through Wearable Technology.” *IEEE Engineering in Medicine and Biology Magazine* 22, no. 3 (2003): 41–48. doi:10.1109/memb.2003.1213625.

Jayaraman, Sundaresan, Kenneth Mackenzie and Sungmee Park. “The Wearable Motherboard: A Framework for Personalized Mobile Information Processing (PMIP).” In *39th Annual Design Automation Conference*. New York: ACM, 2002.

Jovanov, Emil, Aleksandar Milenkovic, and Chris Otto. “Wireless Sensor Networks for

Personal Health Monitoring: Issues and Implementation.” *Computer Communications* 29, no. 13–14 (2006): 2521–2533.

Judith, Mackay, George A. Mensah, Shanthi Mendis, and Kurt Greenlund. *The Atlas of Heart Disease and Stroke*. Geneva: World Health Organization, 2004.

Kales, Stefanos N., Elpidoforos S. Soteriades, Costas A. Christophi, and David C. Christiani. “Emergency Duties and Deaths from Heart Disease among Firefighters in the United States.” *New England Journal of Medicine* 356, no. 12 (2007): 1207–1215. doi:10.1056/nejmoa060357.

Kargl, Frank, Elaine Lawrence, Martin Fischer, and Yen Yang Lim. “Security, Privacy and Legal Issues in pervasive ehealth Monitoring Systems.” In *Mobile Business, 2008. ICMB’08. 7th International Conference on*, IEEE, 2008.

Kenney, Larry, Narihiko Kondo, and Nigel Taylor. *Faculty of the Physiology of Acute Heat Exposure, with Implications for Human Performance in the Heat Health and Behavioral Sciences*. Wollongong, New South Wales, Australia: University of Wollongong, 2008.

Korhonen, Illka, Juha Parkka, and Mark Van Gils. “Health Monitoring in the Home of the Future.” *IEEE Eng. Med. Biol. Mag.* 22, no. 3 (2003): 66–73. doi:10.1109/ memb.2003.1213628.

Kunadharaju, Kumar, Todd D. Smith, and David M. DeJoy. “Line-of-Duty Deaths among U.S. Firefighters: An Analysis of Fatality Investigations.” *Sciencedirect* 43, no. 3 (May 2011): 1171–1180. http://www.sciencedirect.com/science/article/ pii/S0001457510004070.

Langheinrich, Marc. “Privacy by Design—Principles of Privacy-aware Ubiquitous Systems.” In *Ubicomp 2001: Ubiquitous Computing*., Berlin Heidelberg: Springer 2001.

LaTourrette, Tom, D. J. Peterson, James T. Bartis, Brian A. Jackson, and Ari Houser.

*Protecting Emergency Responders, Vol. 2: Community Views of Safety and Health Risks and Personal Protection Needs*. Santa Barbara, CA: RAND Corporation, 2003.

Lawson, J. Randall. *Fire Fighter’s Protective Clothing and Thermal Environments of*

*Structural Fire Fighting*. Gaithersburg, MD: U.S. Dept. of Commerce, Technology Administration, National Institute of Standards and Technology, 1996.

Lymberis, Andreas, and Andre Dittmar. “Advanced Wearable Health Systems and Applications—Research and Development Efforts in the European Union.” *IEEE Eng. Med. Biol. Mag.* 26, no. 3 (2007): 29–33. doi:10.1109/memb.2007.364926.

Lymberis, Andreas, and Silas Olsson. “Intelligent Biomedical Clothing for Personal

Health and Disease Management: State of the Art and Future Vision.” *Telemedicine Journal and E-Health* 9, no. 4 (2003): 379–386.

Maddigan, S. L., K. B. Farris, N. Keating, C. A. Wiens, and J. A. Johnson. “Predictors of Older Adults.” Capacity for Medication Management in a Self-Medication Program: A Retrospective Chart Review.” *Journal of Aging and Health* 15, no. 2 (2003): 332–352. doi:10.1177/0898264303251893.

Marculescu, Diana, Radu Marculescu, Nicholas H. Zamora, Phillip Stanley-Marbell, Pradeep K. Khosla, Sungmee Park, Sundaresan Jayaraman, Stefan Jung, and Christl Lauterbach, Werner Weber et al. “Electronic Textiles: A Platform for Pervasive Computing.” *Proceedings of the IEEE* 91, no. 12 (2003): 1993–1994.

doi:10.1109/jproc.2003.819607.

McCann, Jane, and David Bryson, *Smart Clothes and Wearable Technology*. Cambridge: Woodhead Publishing, 2009.

Meingast, Marci, Tanya Roosta, and Shankar Sastry. “Security and Privacy Issues with Health Care Information Technology.” *2006 International Conference of the IEEE Engineering in Medicine and Biology Society*, 2006. doi:10.1109/iembs. 2006.260060.

MEDES. “VTAMN PROJECT (RNTS 2000): “Medical Teleassistance Suit.” 2005. http://george.medes.fr/home\_en/telemedicine/assistance\_to\_patients/vtamn.html.

Miller, Robert, and Ida Smith. “Physicians.” Use of Electronic Medical Records: Barriers and Solutions.” *Health Affairs* 23, no. 2 (2004): 116–126.

Millman, Jason. “Here’s Exactly How the United States Spends $29 Trillion on Health Care.” *The Washington Post*, 2014.

Myhre, Loren G., Donald M. Tucker, Daniel H. Bauer, Josheph R. Fisher, and Wade H.

Grimm. *Relationship between Selected Measures of Physical Fitness and Performance of a Simulated Fire Fighting Emergency Task*. Ft. Belvoir, VA: Defense Technical Information Center, 1997.

National Fallen Firefighters Foundation. *Line-of-Duty Death Benefits Guide*. Emmitsburg, MD: National Fallen Firefighters Foundation, 2013.

———. *Line-of-Duty Death Benefits Guide—A Handbook for Survivors of Fallen Firefighters*. Emmitsburg, MD: National Fallen Firefighters Foundation, 2008.

Olsen, Jorn, and Linda Rosenstock. “Firefighting and Death from Cardiovascular

Causes.” *New England Journal of Medicine* 356, no. 12 (2007): 1261–1263.

Pantelopoulos, Alexandros, and Nikolaos G. Bourbakis. “A Survey on Wearable Sensorbased Systems for Health Monitoring and Prognosis.” *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)* 40, no. 1 (2010): 1–12. doi:10.1109/tsmcc.2009.2032660.

Park, Sungmee, and Sundaresan Jayaraman. “Enhancing the Quality of Life through Wearable Technology.” *IEEE Eng. Med. Biol. Mag.* 22, no. 3 (2003): 41–48. doi:10.1109/memb.2003.1213625.

———. “Smart Textiles: A Platform for Sensing and Personalized Mobile InformationProcessing.” *Journal of the Textile Institute* 94, no. 3–4 (2003): 87–98.

Patel, Maulin, and Jianfeng Wang. “Applications, Challenges, and Prospective in Emerging Body Area Networking Technologies.” *IEEE Wireless Communications* 17, no. 1 (2010): 80–88.

Patel, Shyamal, Hyung Park, Paolo Bonato, Leighton Chan, and Mary Rodgers. “A Review of Wearable Sensors and Systems with Application in Rehabilitation.” *Journal of Neuroengineering and Rehabilitation* 9, no. 1 (2012): 21. doi:10.1186/ 1743-0003-9-21.

Poon, Carmen C. Y., Yuan-Ting Zhang and Shu-Di Bao. “A Novel Biometrics Method to

Secure Wireless Body Area Sensor Networks for Telemedicine and M-Health.” *IEEE Commun. Mag.* 44, no. 4 (2006): 73–81.

Post, David G. “What Larry Doesn’t Get: Code, Law, and Liberty in Cyberspace.” *Stanford Law Review* (2000): 1439–1459.

Quiros, Kimberly. “Firefighter Obesity: A Public Safety Risk.”Healthy-Firefighter.Org, 2015. http://www.healthy-firefighter.org/media-room/524-firefighter-obesity-apublic-safety-risk.

Reidenberg, Joel. “Setting Standards for Fair Information Practice in the U.S. Private Sector.” *Iowa Law Review*, 1995.

Ridenour, Marilyn. *NIOSH Fire Fighter Fatality Investigation and Prevention Program*. Cincinnati, OH: Dept. of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, 2008.

Rosenstock, Linda, and Jorn Olsen. “Firefighting and Death From Cardiovascular Causes.” *New England Journal Of Medicine* 356, no. 12 (2007): 1261–1263. doi:10.1056/nejme078008.

State of Texas Legislative Budget Board. *Review of Replacement Schedules for Information Technology Equipment*. Austin, TX: Department of Information Resources, 2013.

Taguchi, Genʼichi. *Introduction to Quality Engineering*. Tokyo: The Organization, 1986.

Tate, David L., Linda Sibert and Tony King. “Virtual Environments for Shipboard

Firefighting Training.” *Proceedings of IEEE 1997 Annual International Symposium on Virtual Reality*, 1997. doi:10.1109/vrais.1997.583045.

Terrill, James B., Ruth R. Montgomery, and Charles F. Reinhardt. “Toxic Gases from

Fires.” *Science* 200, no. 4348 (1978): 1343–1347. doi:10.1126/science.208143.

Tucker, Patrick. *The Naked Future*. New York: Penguin Group, 2014.

U.S. Fire Administration. *National Safety Culture Change Initiative* (FA-342).

Emmitsburg, MD: Federal Emergency Management Administration, 2015.

———. *Special Report: The Aftermath of Firefighter Fatality Incidents—Preparing for the Worst*. Emmitsburg, MD: Department of Homeland Security, 1998.

United States Fire Administration. *Firefighter Fatalities in the United States in 2013*. Emmitsburg, MD: FEMA, 2014.

Varshney, Upkar. “Pervasive Healthcare And Wireless Health Monitoring.” *Mobile Networks And Applications* 12, no. 2–3 (2007): 113–127. doi:10.1007/s11036007-0017-1.

Weiss, Deric C., and Jeff T. Miller. *A Study on Chemicals found in the Overhaul Phase of Structure Fires using Advanced Portable Air Monitoring available for Chemical Speciation*. Salem, OR: State of Oregon Fire Service Policy Council, 2011.

Williams, W. Jon, Aitor Coca, Raymond Roberge, Angie Shepherd, Jeffrey Powell, and Ronald E. Shaffer. “Physiological Responses to Wearing a Prototype Firefighter Ensemble Compared with a Standard Ensemble.” *Journal of Occupational and Environmental Hygiene* 8, no. 1 (2011): 49–57. doi:10.1080/15459624.2011.538 358.

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1. Sungmee Park and Sundaresan Jayaraman, “Enhancing the Quality of Life through Wearable Technology,” *IEEE Eng. Med. Biol. Mag.* 22, no. 3 (2003): 41–48, doi:10.1109/memb.2003.1213625. [↑](#footnote-ref-1)
2. Axisa et al., “Flexible Technologies and Smart Clothing for Citizen Medicine, Home Healthcare, and Disease Prevention,” 325–336. [↑](#footnote-ref-2)
3. Lymberis and Olsson, “Intelligent Biomedical Clothing for Personal Health and Disease Management: State of the Art and Future Vision,” 379–386. [↑](#footnote-ref-3)
4. Lymberis and Dittmar, “Advanced Wearable Health Systems and Applications—Research and Development Efforts in the European Union,” 29–33. [↑](#footnote-ref-4)
5. Shyamal et al., “A Review of Wearable Sensors and Systems with Application in Rehabilitation,” 15–21. [↑](#footnote-ref-5)
6. Axisa et al., “Flexible Technologies and Smart Clothing for Citizen Medicine, Home Healthcare, and Disease Prevention,” 325–336. [↑](#footnote-ref-6)
7. Curoni et al., “Smart Garments for Emergency Operators: The ProeTEX Project,” 694–701. [↑](#footnote-ref-7)
8. Curoni et al., “Smart Garments for Emergency Operators: The ProeTEX Project,” 694–701. [↑](#footnote-ref-8)
9. Jayaraman and Park, “Enhancing the Quality of Life through Wearable Technology,” 41–48. [↑](#footnote-ref-9)
10. Chandramohan Gopalsamy et al., “The Wearable Motherboard?: The First Generation Of Adaptive And Responsive Textile Structures (ARTS) For Medical Applications,” *Virtual Reality* 4, no. 3 (1999): [↑](#footnote-ref-10)
11. –168. [↑](#footnote-ref-11)
12. Gopalsamy et al., “The Wearable Motherboard?: The First Generation Of Adaptive And Responsive Textile Structures (ARTS) For Medical Applications,” 152–168. [↑](#footnote-ref-12)
13. Diana Marculescu et al., “Electronic Textiles: A Platform for Pervasive Computing,” *Proceedings of the IEEE* 91, no. 12 (2003): 1993–1994, doi:10.1109/jproc.2003.819607. [↑](#footnote-ref-13)
14. Curone et al., “Smart Garments for Emergency Operators: The ProeTEX Project,” 694–701. [↑](#footnote-ref-14)
15. Gopalsamy et al., “The Wearable Motherboard?: The First Generation Of Adaptive And Responsive Textile Structures (ARTS) For Medical Applications,” 152–168. [↑](#footnote-ref-15)
16. Sungmee Park and Sundaresan Jayaraman, “Smart Textiles: A Platform for Sensing and Personalized Mobile Information-Processing,” *Journal of the Textile Institute* 94, no. 3–4 (2003): 87–98. [↑](#footnote-ref-16)
17. Ibid. [↑](#footnote-ref-17)
18. Marculescu et al., “Electronic Textiles,” 1993–1994. [↑](#footnote-ref-18)
19. Babak Firoozakhsh et al., “Wireless Communications of Vital Signs Using the Georgia Tech Wearable Motherboard,” in *2000 IEEE International Conference on Multimedia and Expo*, 2000, 1253– 1256. [↑](#footnote-ref-19)
20. Marculescu et al., “Electronic Textiles,” 1993–1994. [↑](#footnote-ref-20)
21. Marculescu et al., “Electronic Textiles,” 1993–1994. [↑](#footnote-ref-21)
22. Ibid. [↑](#footnote-ref-22)
23. Sundaresan Jayaraman, Kenneth Mackenzie, and Sungmee Park, “The Wearable Motherboard: A Framework for Personalized Mobile Information Processing (PMIP),” in *39th Annual Design Automation Conference* (New York: ACM, 2002), 170–174. [↑](#footnote-ref-23)
24. Ibid. [↑](#footnote-ref-24)
25. Firoozakhsh et al., “Wireless Communications of Vital Signs Using the Georgia Tech Wearable Motherboard,” 1253–1256. [↑](#footnote-ref-25)
26. Jayaraman et al., “The Wearable Motherboard: A Framework for Personalized Mobile Information,” 170–174. [↑](#footnote-ref-26)
27. Curone et al., “Smart Garments for Emergency Operators: The ProeTEX Project,” 694–701 178 Ibid. [↑](#footnote-ref-27)
28. Annalisa Bonfiglio et al., *Managing Catastrophic Events by Wearable Mobile Systems* (Berlin:

    Springer, 2007). [↑](#footnote-ref-28)
29. Curone et al., “Smart Garments for Emergency Operators: The ProeTEX Project,” 694–701. [↑](#footnote-ref-29)
30. Curone et al., “Smart Garments for Emergency Operators: The ProeTEX Project,” 694–701. 182 Laura Caldani et al., “Firefighters and Rescuers Monitoring through Wearable Sensors: The Proetex Project,” in *2010 Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* (Boston, 2010), 3594–3597. [↑](#footnote-ref-30)
31. Bonfiglio et al., “*Managing Catastrophic Events,” 95–10.* [↑](#footnote-ref-31)
32. Caldani et al., “Firefighters And Rescuers Monitoring through Wearable Sensors: The Proetex Project,” 3594–3597. [↑](#footnote-ref-32)
33. Curone et al., “Smart Garments for Emergency Operators: The ProeTEX Project,” 694–701. [↑](#footnote-ref-33)
34. Ibid. [↑](#footnote-ref-34)
35. Caldani et al., “Firefighters and Rescuers Monitoring through Wearable Sensors: The Proetex Project.” [↑](#footnote-ref-35)
36. Ibid., 3594–3597. [↑](#footnote-ref-36)
37. Curone et al., “Smart Garments for Emergency Operators: The ProeTEX Project,” 694–701. 190 Ibid. [↑](#footnote-ref-37)
38. Ibid. [↑](#footnote-ref-38)
39. Ibid. [↑](#footnote-ref-39)
40. Ibid. [↑](#footnote-ref-40)
41. Curone et al., “Smart Garments for Emergency Operators: The ProeTEX Project,” 694–701. [↑](#footnote-ref-41)
42. Caldani,” Firefighters and Rescuers Monitoring,” 3594–3597. [↑](#footnote-ref-42)
43. Ibid. [↑](#footnote-ref-43)
44. Curone et al., “Smart Garments for Emergency Operators: The ProeTEX Project,” 694–701. [↑](#footnote-ref-44)
45. Bonfiglio et al., “Smart Garments for Emergency/Disaster Operators,” 3962–3965. 199 Ibid. [↑](#footnote-ref-45)
46. Curone et al., “Smart Garments for Emergency Operators: The ProeTEX Project,” 694–701. [↑](#footnote-ref-46)
47. Ibid. [↑](#footnote-ref-47)
48. Axisa et al., “Flexible Technologies and Smart Clothing for Citizen Medicine, Home Healthcare, and Disease Prevention,” 325–336. [↑](#footnote-ref-48)
49. R. Baghai et al., “VTAMN—A Smart Clothe for Ambulatory Remote Monitoring of Physiological Parameters and Activity,” in *26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society* (Boston, 2004), 3266–3269. [↑](#footnote-ref-49)
50. Axisa et al., “Flexible Technologies and Smart Clothing for Citizen Medicine, Home Healthcare, and Disease Prevention,” 325–336. [↑](#footnote-ref-50)
51. Baghai et al., “VTAMN—A Smart Clothe for Ambulatory Remote Monitoring of Physiological Parameters and Activity,” 3266–3269. [↑](#footnote-ref-51)
52. Ibid. [↑](#footnote-ref-52)
53. Ibid. 208 Ibid. [↑](#footnote-ref-53)
54. Curone et al., “Smart Garments for Emergency Operators: The ProeTEX Project,” 694–701. [↑](#footnote-ref-54)
55. R. Baghai et al., “VTAMN—A New “Biocloth” for Ambulatory Telemonitoring,” in *4th International IEEE EMBS Special Topic Conference on Information Technology Applications in Biomedicine* (Boston, 2003), 299–301. [↑](#footnote-ref-55)
56. Rossi et al., *A Comparative Evaluation of Different Techniques for Ambulatory Monitoring of Respiratory Rate*. [↑](#footnote-ref-56)
57. Baghai et al., “VTAMN—A Smart Clothe for Ambulatory Remote Monitoring of Physiological Parameters and Activity,” 3266–3269. [↑](#footnote-ref-57)
58. Ibid. [↑](#footnote-ref-58)
59. Baghai et al., “VTAMN—A New “Biocloth” for Ambulatory Telemonitoring,” 299–301. [↑](#footnote-ref-59)
60. Rossi et al., *A Comparative Evaluation of Different Techniques for Ambulatory Monitoring of Respiratory Rate*. [↑](#footnote-ref-60)
61. Rossi et al., *A Comparative Evaluation of Different Techniques for Ambulatory Monitoring of Respiratory Rate*. [↑](#footnote-ref-61)
62. Ibid. [↑](#footnote-ref-62)
63. Baghai et al., “VTAMN—A New “Biocloth” for Ambulatory Telemonitoring,” 299–301. [↑](#footnote-ref-63)
64. Marco Di Rienzo et al., “Magic System,” *IEEE Eng. Med. Biol. Mag.* 28, no. 6 (2009): 35–40, doi:10.1109/memb.2009.934627. [↑](#footnote-ref-64)
65. Marco Di Rienzo et al., “MagIC System: A New Textile-based Wearable Device for Biological Signal Monitoring. Applicability in Daily Life and Clinical Setting,” *2005 IEEE Engineering in Medicine and Biology 27th Annual Conference*, 2005, 7167–7169. [↑](#footnote-ref-65)
66. Bruno Borodoni et al., “MagIC System,” *IEEE Engineering in Medicine and Biology Magazine* 28, no. 6 (2009): 35–40. [↑](#footnote-ref-66)
67. Paolo Castiglioni et al., “MagIC: A Textile System For Vital Signs Monitoring. Advancement In Design And Embedded Intelligence For Daily Life Applications,” in *29th Annual International Conference of the IEEE Engineering in Medicine And Biology Society*, 2007, 3958–3961. [↑](#footnote-ref-67)
68. Di Rienzo et al., “MagIC System: A New Textile-based Wearable,” 7167–7169. [↑](#footnote-ref-68)
69. Ibid. 224 Ibid. [↑](#footnote-ref-69)
70. Marco Di Rienzo et al., “MagIC System,” *IEEE Engineering in Medicine and Biology Magazine* 6, no. 28 (2009): 35–40. [↑](#footnote-ref-70)
71. Di Rienzo et al., “MagIC System: A New Textile-based Wearable,” 7167–7169. [↑](#footnote-ref-71)
72. Di Rienzo et al., “MagIC System,” 35–40. [↑](#footnote-ref-72)
73. Ibid. [↑](#footnote-ref-73)
74. Di Rienzo et al.,” MagIC System: A New Textile-based Wearable,” 7167–7169.230 Ibid. [↑](#footnote-ref-74)
75. Ibid. [↑](#footnote-ref-75)
76. Linda Rosenstock and Jorn Olsen, “Firefighting and Death From Cardiovascular Causes,” *New England Journal Of Medicine* 356, no. 12 (2007): 1261–1263, doi:10.1056/nejme078008. [↑](#footnote-ref-76)
77. De Rossi et al., “*A Comparative Evaluation of Different Techniques for Ambulatory Monitoring of Respiratory Rate*. [↑](#footnote-ref-77)
78. Kales et al., “Emergency Duties and Deaths from Heart Disease among Firefighters in the United States,” 1207–1215. [↑](#footnote-ref-78)
79. Kumar Kunadharaju, Todd D. Smith, and David M. DeJoy, “Line-of-Duty Deaths among U.S. Firefighters: An Analysis of Fatality Investigations,” *Sciencedirect* 43, no. 3 (May 2011): 1171–1180, http://www.sciencedirect.com/science/article/pii/S0001457510004070. [↑](#footnote-ref-79)
80. Kales et al., “Emergency Duties and Deaths from Heart Disease among Firefighters in the United States,” 1207–1215. [↑](#footnote-ref-80)
81. W. Jon Williams et al., “Physiological Responses to Wearing a Prototype Firefighter Ensemble Compared with a Standard Ensemble,” *Journal of Occupational and Environmental Hygiene* 8, no. 1 (2011): 49–57, doi:10.1080/15459624.2011.538358. [↑](#footnote-ref-81)
82. Andrew Han Brainard et al., “The Prehospital 12-Lead Electrocardiogram’s Effect on Time to

    Initiation of Reperfusion Therapy: A Systematic Review and Meta-Analysis of Existing Literature,” *The American Journal of Emergency Medicine* 23, no. 3 (2005): 351–356, doi:10.1016/j.ajem.2005.02.004. [↑](#footnote-ref-82)
83. Ibid. [↑](#footnote-ref-83)
84. Williams et al., “Physiological Responses to Wearing a Prototype Firefighter Ensemble Compared with a Standard Ensemble,” 49–57. [↑](#footnote-ref-84)
85. Loren G. Myhre et al., *Relationship between Selected Measures of Physical Fitness and Performance of a Simulated Fire Fighting Emergency Task* (Ft. Belvoir, VA: Defense Technical Information Center, 1997). [↑](#footnote-ref-85)
86. Larry Kenney, Narihiko Kondo, and Nigel Taylor, *Faculty of the Physiology of Acute Heat Exposure, with Implications for Human Performance in the Heat Health and Behavioral Sciences* (Wollongong, New South Wales, Australia: University of Wollongong, 2008), 341–358. [↑](#footnote-ref-86)
87. Williams et al., “Physiological Responses to Wearing a Prototype Firefighter Ensemble Compared with a Standard Ensemble,” 49–57. [↑](#footnote-ref-87)
88. Ibid. 245 Ibid. [↑](#footnote-ref-88)
89. J. Randall Lawson, *Fire Fighter’s Protective Clothing and Thermal Environments of Structural Fire Fighting* (Gaithersburg, MD: U.S. Dept. of Commerce, Technology Administration, National Institute of Standards and Technology, 1996). [↑](#footnote-ref-89)
90. Ibid. [↑](#footnote-ref-90)
91. Ibid. [↑](#footnote-ref-91)
92. José González-Alonso, Craig G. Crandall and John M. Johnson, “The Cardiovascular Challenge of Exercising in the Heat,” *The Journal of Physiology* 586, no. 1 (2008): 45–53, doi:10.1113/jphysiol.2007. 142158. [↑](#footnote-ref-92)
93. Williams et al., “Physiological Responses to Wearing a Prototype Firefighter Ensemble,” 49–57. [↑](#footnote-ref-93)
94. Tom LaTourrette et al., *Protecting Emergency Responders, Vol. 2: Community Views of Safety and Health Risks and Personal Protection Needs* (Santa Monica, CA: RAND Corporation, 2003): 39–47. [↑](#footnote-ref-94)
95. Kunadharaju, Smith, and DeJoy, “Line-of-Duty Deaths among U.S. Firefighters: An Analysis of

    Fatality Investigations.” [↑](#footnote-ref-95)
96. Robert F. Dyer, “Polyvinyl Chloride Toxicity in Fires,” *JAMA* 235, no. 4 (1976): 393, doi:10.1001/ jama.1976.03260300019022. [↑](#footnote-ref-96)
97. Dyer, “Polyvinyl Chloride Toxicity in Fires,” 393. [↑](#footnote-ref-97)
98. Deric C. Weiss and Jeff T. Miller, *A Study on Chemicals found in the Overhaul Phase of Structure Fires using Advanced Portable Air Monitoring available for Chemical Speciation* (Salem, OR: State of Oregon Fire Service Policy Council, 2011). [↑](#footnote-ref-98)
99. James B. Terrill, Ruth R. Montgomery and Charles F. Reinhardt, “Toxic Gases from Fires,” *Science* 200, no. 4348 (1978): 1343–1347, doi:10.1126/science.208143. [↑](#footnote-ref-99)
100. LaTourrette et al., *Protecting Emergency Responders, Vol. 2: Community Views of Safety and Health Risks and Personal Protection Needs*, 39–47. [↑](#footnote-ref-100)
101. Ibid. [↑](#footnote-ref-101)
102. Weiss and Miller, *A Study on Chemicals found in the Overhaul Phase of Structure Fires using Advanced Portable Air Monitoring available for Chemical Speciation*. [↑](#footnote-ref-102)
103. Weiss and Miller, *A Study on Chemicals found in the Overhaul Phase of Structure Fires using Advanced Portable Air Monitoring available for Chemical Speciation*. [↑](#footnote-ref-103)
104. Bernard Fleet and Hari Gunasingham, “Electrochemical Sensors For Monitoring Environmental Pollutants,” *Talanta* 39, no. 11 (1992): 1449–1457. [↑](#footnote-ref-104)
105. Ibid. [↑](#footnote-ref-105)
106. Baghai et al., “VTAMN—A Smart Clothe for Ambulatory Remote Monitoring of Physiological Parameters and Activity,” 3266–3269. [↑](#footnote-ref-106)
107. David L. Tate, Linba Sibert and Tony King, “Virtual Environments for Shipboard Firefighting Training,” *Proceedings of IEEE 1997 Annual International Symposium on Virtual Reality*, 1997, doi:10.1109/vrais.1997.583045. [↑](#footnote-ref-107)
108. Administrator, “Revolutionary GPS Could Save Firefighters Lives,” Getreading, 2008, http://www.getreading.co.uk/news/local-news/revolutionary-gps-could-save-firefighters-4255616. 266 Ibid. [↑](#footnote-ref-108)
109. Moshaddique Al Ameen, Jingwei Liu, and Kyungsup Kwak, “Security and Privacy Issues in Wireless Sensor Networks for Healthcare Applications,” *J Med Syst* 36, no. 1 (2010): 93–101, doi:10.1007/s10916-010-9449-4. [↑](#footnote-ref-109)
110. Frank Kargl et al., “Security, Privacy and Legal Issues in pervasive ehealth Monitoring Systems,” in *Mobile Business, 2008. ICMB’08. 7th International Conference on*, IEEE, 2008, 296–304. [↑](#footnote-ref-110)
111. Ibid. [↑](#footnote-ref-111)
112. Marc Langheinrich, “Privacy by Design—Principles of Privacy-aware Ubiquitous Systems,” in *Ubicomp 2001: Ubiquitous Computing* (Berlin Heidelberg: Springer 2001), 273–291. [↑](#footnote-ref-112)
113. Kargl et al., “Security, Privacy and Legal Issues in pervasive ehealth Monitoring Systems,” 296– 304. [↑](#footnote-ref-113)
114. Ibid. [↑](#footnote-ref-114)
115. Oliver Berthold and Hannes Federrath, “Identitaetsmanagement,” (2000): 189–204. [↑](#footnote-ref-115)
116. Langheinrich, “Privacy by Design—Principles of Privacy-aware Ubiquitous Systems,” 273–291. [↑](#footnote-ref-116)
117. Kargl et al., “Security, Privacy and Legal Issues in pervasive ehealth Monitoring Systems,” 296– 304. [↑](#footnote-ref-117)
118. Ying Cai et al., *Mobile Wireless Middleware, Operating Systems, and Applications* (New York:

     Springer Publishing, 2010.) [↑](#footnote-ref-118)
119. Al Ameen, Liu, and Kwak, “Security and Privacy Issues in Wireless Sensor Networks for Healthcare Applications,” 93–101. [↑](#footnote-ref-119)
120. Ibid. 280 Ibid. [↑](#footnote-ref-120)
121. Gregory Abowd et al., *Privacy by Design—Principles of Privacy-Aware Ubiquitous Systems* (Berlin: Springer Berlin Heidelberg, 2001), 273–291. [↑](#footnote-ref-121)
122. Langheinrich, “Privacy by Design—Principles of Privacy-aware Ubiquitous Systems.” [↑](#footnote-ref-122)
123. Ibid. [↑](#footnote-ref-123)
124. Ibid. [↑](#footnote-ref-124)
125. Joel Reidenberg, “Setting Standards for Fair Information Practice in the U.S. Private Sector,” *Iowa Law Review*, 1995, 497. [↑](#footnote-ref-125)
126. Reidenberg, “Setting Standards for Fair Information Practice in the U.S. Private Sector,” 497. [↑](#footnote-ref-126)
127. Ibid. [↑](#footnote-ref-127)
128. David G. Post, “What Larry Doesn’t Get: Code, Law, and Liberty in Cyberspace,” *Stanford Law Review* (2000): 1439–1459. [↑](#footnote-ref-128)
129. Ibid. [↑](#footnote-ref-129)
130. Ibid. [↑](#footnote-ref-130)
131. Ibid. [↑](#footnote-ref-131)
132. Kargl et al., “Security, Privacy and Legal Issues in Pervasive ehealth,” 296–304. 296 Ibid. 297 Ibid. [↑](#footnote-ref-132)
133. Langheinrich, “Privacy by Design—Principles of Privacy-aware Ubiquitous Systems,” 273–291. [↑](#footnote-ref-133)
134. Marci Meingast, Tanya Roosta, and Shankar Sastry, “Security And Privacy Issues with Health Care Information Technology,” *2006 International Conference of the IEEE Engineering in Medicine and Biology Society*, 2006, doi:10.1109/iembs.2006.260060. [↑](#footnote-ref-134)
135. Langheinrich, “Privacy by Design—Principles of Privacy-aware Ubiquitous Systems,” 273–291. [↑](#footnote-ref-135)
136. “Combined Regulation Text of All Rules.” 302 “Combined Regulation Text of All Rules.” 303 Ibid. [↑](#footnote-ref-136)
137. Ibid. [↑](#footnote-ref-137)
138. Ibid. [↑](#footnote-ref-138)
139. Todd Fitzgerald, “The HIPAA Final Rule: What’s Changed?,” *Information Systems Security* 12, no. 2 (2003): 50–59, doi:10.1201/1086/43326.12.2.20030501/42587.9. [↑](#footnote-ref-139)
140. David Blumenthal, “Launching HIteCH,” *New England Journal of Medicine* 362, no. 5 (2010): 382–385. [↑](#footnote-ref-140)
141. Ibid. [↑](#footnote-ref-141)
142. Ibid. [↑](#footnote-ref-142)
143. “Combined Regulation Text of All Rules.” [↑](#footnote-ref-143)
144. Ibid. [↑](#footnote-ref-144)
145. Young B. Choi et al., “Challenges Associated With Privacy in Health Care Industry: Implementation of HIPAA and the Security Rules,” *J Med Syst* 30, no. 1 (2006): 57–64. [↑](#footnote-ref-145)
146. “Combined Regulation Text of All Rules.” [↑](#footnote-ref-146)
147. Joan Hash, “An Introductory Resource Guide for Implementing the Health Insurance Portability and Accountability Act (HIPAA) Security Rule” (PhD diss., National Institute of Standards and Technology, 2005). [↑](#footnote-ref-147)
148. Ibid. [↑](#footnote-ref-148)
149. “Combined Regulation Text of All Rules.” [↑](#footnote-ref-149)
150. “Welcome to the IAFF website,” accessed May 22, 2015, http://client.prod.iaff.org/#page= AboutUs. [↑](#footnote-ref-150)
151. Ibid. [↑](#footnote-ref-151)
152. Ibid. [↑](#footnote-ref-152)
153. Marilyn Ridenour, *NIOSH Fire Fighter Fatality Investigation and Prevention Program* (Cincinnati, OH: Dept. of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, 2008). [↑](#footnote-ref-153)
154. ProeTEX and the European Commission, *D1.1 Report of Requirements*, *Protection E-Textiles: Micronanostructured Fibre Systems for Emergency-Disaster Wear* (Pavia, Italy: Eucentre, 2006). Not available for public access. Permission to use this document was granted by author to this researcher. [↑](#footnote-ref-154)
155. State of Texas Legislative Budget Board, *Review of Replacement Schedules for Information Technology Equipment* (Austin, TX: Department of Information Resources, 2013). [↑](#footnote-ref-155)
156. U.S. Fire Administration, *Special Report: The Aftermath of Firefighter Fatality Incidents— Preparing for the Worst* (Emmitsburg, MD: Department of Homeland Security, 1998). [↑](#footnote-ref-156)
157. GCR, NIST, *The Economic Consequences of Firefighter Injuries and Their Prevention*, Final Report (Arlington, VA: National Institute of Standards and Technology), 2005. [↑](#footnote-ref-157)
158. National Fallen Firefighters Foundation, *Line-of-Duty Death Benefits Guide—A Handbook for Survivors of Fallen Firefighters* (Emmitsburg, MD: National Fallen Firefighters Foundation, 2008). [↑](#footnote-ref-158)
159. National Fallen Firefighters Foundation, *Line-of-Duty Death Benefits Guide—A Handbook for Survivors of Fallen Firefighters*. [↑](#footnote-ref-159)
160. Ibid. [↑](#footnote-ref-160)
161. U.S. Fire Administration, *Special Report: The Aftermath of Firefighter Fatality Incidents— Preparing for the Worst*. [↑](#footnote-ref-161)
162. National Fallen Firefighters Foundation, *Line-of-Duty Death Benefits Guide—A Handbook for Survivors of Fallen Firefighters*. [↑](#footnote-ref-162)
163. National Fallen Firefighters Foundation, *Line-of-Duty Death Benefits Guide* (Emmitsburg, MD:

     National Fallen Firefighters Foundation, 2013), 16–32. [↑](#footnote-ref-163)
164. U.S. Fire Administration, *National Safety Culture Change Initiative* (FA-342) (Emmitsburg, MD: Federal Emergency Management Administration, 2015). [↑](#footnote-ref-164)
165. Ibid. [↑](#footnote-ref-165)
166. U.S. Fire Administration, *National Safety Culture Change Initiative*. [↑](#footnote-ref-166)
167. Ibid. [↑](#footnote-ref-167)
168. D. Compton, “Leadership for Today and Tomorrow,” in *The Fire Chief’s Handbook* (2003): 205– 228. [↑](#footnote-ref-168)
169. Ibid. [↑](#footnote-ref-169)
170. U.S. Fire Administration, *National Safety Culture Change Initiative*. [↑](#footnote-ref-170)
171. Compton, “Leadership for Today and Tomorrow,” 205–228. [↑](#footnote-ref-171)