THERMAL IMAGING EVALUATION FOR THE FIRE SERVICE

EXECUTIVE DEVELOPMENT

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ABSTRACT

The problem facing the Fire Department of North Providence, Rhode Island was that in an era of financial restraints, consideration was being made for the purchase of a thermal imaging camera. What prompted this attention was that several surrounding fire departments were in the process or had thermal imaging units in place. The fire department was then challenged to keep pace with the changes in technology, but had no systematic procedure to evaluate effectively thermal imaging technology.

The purpose of this applied research project was to provide a plan, checklist, and comparison charts to evaluate thermal imaging technology. The evaluative research method was used in the research project to answer the following questions:

1. What are the attributes of thermal imaging technology?
2. What are the recommendations, advantages, disadvantages, and limitations of each technology type?
3. What are the financial considerations involved with each technology?

A literature review was conducted to identify existing research on the subject of thermal imaging cameras or units for the fire service. The literature review conducted concentrated upon the four areas of focus for examination. Items examined included the historical background of thermal imaging technology, attributes of thermal imaging technology, system advantages and limitations, and lastly financial considerations. All of the authorities cited recommended that fire departments embrace the application of thermal imaging technology. Authorities stated that thermal imaging was advantageous for firefighting, hazardous materials, and emergency medical service operations, as well as an improvement in overall safety.

The procedure utilized to answer the three research questions included a survey mailed to 80 fire departments that comprise the fire service in the State of Rhode Island. The 83.75% (67) of the questionnaires were completed and returned. This survey indicated 26.8% (18) of departments in Rhode Island had thermal imaging in place. In addition, 13.4% (9) were currently planning to implement thermal imaging technology in the near future. The results of this research project indicated that 77.7% (14) thermal imaging equipped fire departments were using non-tax based revenue to finance to acquisition of this tool. Subsequently, 64.2% (43) of those surveyed stated that the financial restriction was an influencing factor delaying purchase.

This research paper has provided evidence to support a recommendation that the North Providence Fire Department make an effort to start the planning process with a stated goal to acquire thermal imaging technology. A proposal for a committee was recommended by this research. In addition, tools were provided for the committee to evaluate, funds, and consider the training necessary for the introduction of this advanced tool of safety.

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INTRODUCTION

In the summer of 1998, the Town of North Providence, Rhode Island faced a projected budget deficit between $5.2 - $5.8 million dollars (C.Bozzi, personal communication, December 7,1998). The fire department was challenged with several financial pressures being applied simultaneously. Personnel costs, especially overtime expenses were rising. Fire department equipment, both fire and EMS apparatus were declining because of normal aging and wear and tear. These aspects alone challenges all those involved in the acquisition of this equipment. Secondarily, the department’s morale and leadership were beginning to show the signs of the economic, financial strain placed upon the department (J. Lane, personal communication, December 5, 1998). Thirdly, several area fire departments were in the process of obtaining thermal imaging units or had acquired these units for their operations. The Town’s residents at various budgetary meetings demanded public service at a reduced cost, while maintaining the current level of services provided (B. Charello, personal communication, August 30, 1998). It was apparent that the people demanded a, “more with less” philosophy. As a public service, the fire service still has to respond to do the job, regardless of the financial restrictions imposed (D. Clark, personal communications, September 10 ,1998). A careful examination of planned capital expenditures and purchases became vital in this tight economic time when challenged with limited funding (D. Campbell, personal communication, September 11, 1998).

The problem that prompted this research project was that in era of tight economic budgetary restraints, the purchase of a thermal imaging device was being considered. Consequently, the North Providence Fire Department does not have a systemic procedure to evaluate effectively thermal imaging technology for purchase and acquisition consideration. An obstacle facing this consideration was that the fire service both nationally and locally is the majority of fire departments are not using these thermal imaging devices in their operations. A complete examination was needed of this emergent technology to adequately plan for the purchase or consideration of this thermal imaging camera.

The purpose of this applied research project was to provide a plan, checklist, and comparison charts to evaluate thermal imaging technology. The evaluative research method was chosen to answer the following questions:

1. What are the attributes of thermal imaging technology?
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BACKGROUND AND SIGNIFICANCE

North Providence Fire Department

The Town of North Providence borders the capital City of Providence, Rhode Island. In addition, the towns of Lincoln, Smithfield, and Johnston as well as the City of Pawtucket surround the town. As the smallest town in the State of Rhode Island, covering only 5.7 square miles in area, it ranks seventh in population out of 39 cities and towns that comprise the State of Rhode Island. The resident population of the community has increase 9.9% from 1980, to its present population of 32,090 (Rhode Island Department of Economic Development, 1995, citing 1990, U.S. Census Data). The 1980's brought forth a dramatic growth in building construction, especially homes, condominiums, and multiple family apartments, up 24.6% to its present figure of 14,134 residential housing units (RI Department of Economic Development,1995).

As per stated union /management contract, the North Providence Fire Department is comprised of 100 uniformed members and a staff of seven civilians. The operational division consists of four engine companies, one ladder-truck company, a special service vehicle, one on duty battalion chief, and two emergency medical service ambulances. The current distribution of staffing is 19 members plus the duty Chief per shift. The operational personnel are assigned on a four platoon/group rotation system of two ten hour day shifts, two 14 hour night shifts and followed by 96 hours off (J.Lane, personal communications, December 5, 1998).

The North Providence Fire Department organizational culture evolved from five volunteer fire companies, each protecting their village or section of town. In 1971, the Town of North Providence, assumed daytime protection of the community with the initial hiring of the first paid members to the fire department. A call and volunteer force continued to operate the fire and emergency medical service (EMS) division during the nights, weekends, and holidays. In the 1980's, the town grew due to the building boom of this period. Requests for service went from the approximately 1500 runs/requests for service to four to five thousands per year.

The EMS aspect in the 1980's also underwent dramatic changes due to the increased State mandated regulations (L. Carney, personal communication, August 30, 1998). In 1985, several factors led to the Town assuming the EMS Division on a full-time basis. These points enumerated by the Advanced Life Support implementation Committee in 1985. The first factor was the incorporation of advanced life support in the pre-hospital care provided by EMS units. This necessitated additional training and a dedicated staffing to operate per Rhode Island Health Department EMS Division Regulations. The second factor identified was that neighboring and surrounding communities had this service or were in the process of implementing or in the planning process for advanced emergency medical services by the fire department. The third factor was the North Providence Fire Department found itself with a decreasing number of trained members to support the department's call/volunteer force. This national trend had struck home as well as the surrounding communities. This hastened the next organizational change. The fire department started a gradual transition to a full-time fire department in 1988, yielding our current distribution of staffing and apparatus.

The fore mentioned action was brought about by the actions of a committee. A fire department advanced life support implementation committee obtained the necessary data, did the appropriate background research before the implementation of this service. This committee contained representatives from all members of the EMS community to identify options to consider in implementing fire department advanced life support operations (J. Gregson, personal communication, August 30,1998).

The summer of 1997 a similar challenge was poised to the department. The Town of Johnston began an aggressive public fundraiser for a thermal imaging camera. This drew much media attention regarding this technology. The North Providence Fire Department was caught unprepared to answer questions poised by the media, citizens, and by members of the department regarding this emergent technology (E. DiGiulio Jr., personal communication, September 9,1998).

The main objective of this applied research project was to provide insight into the area of thermal imagining devices. Areas that would be examined included the attributes of thermal imaging technology, advantages, disadvantages, and limitations of each technology for fireground operations. Financial consideration was then reviewed and evaluated in light of the current economic restrictions placed upon the fire department. The results of this study will aid the North Providence Fire Department in the selection and decision making process regarding the purchase of thermal imaging cameras. This review will aid others in the fire service in thermal imaging evaluations as well as students enrolled in the Executive Fire Officer Program at the National Fire Academy.

Thermal Imaging Cameras

Many changes have effected the fire service over the years. However, the inability to improve fireground visibility has hindered the basic operations of search and rescue (Woodworth, 1996, July). Thermal imaging technology allows the firefighter to “see” through the smoke. The translation or conversion of heat energy to a readable light image accomplishes image creations. This vital technological advantage appears to had been overlooked. A number of factors or a combination of factors, including funding, traditional resistance to new technology, inadequate pressure for change and a lack of awareness of the benefits of this technology (Patterson, 1997).

This project gained further importance based upon the fact that area fire departments were examining this technology or already had thermal imaging units in place. The failure to examine this new technology could hinder the safety and efficiency of our fireground operational personnel (J. Lane, personal communication, September 6, 1998). In addition, the public perception of not having a vital tool could effect the public’s idea of this department’s ability to do the job (J. Lane, personal communication, September 6, 1998). At the present time, economic constraints placed upon the fire department means it does not have the luxury of making expenditures based upon want only. The want must be justified by a need, substantiated by cost and benefit analysis (D. Campbell, personal communication, September 11, 1998). The delivery of innovative technology to the community that would improve the overall safety of firefighters and the public is the premise of this project.

This project specifically relates to the National Fire Academy's Executive Fire Officer Program entitled, Executive Development. The research project used the nine steps for effective research in unit three of the student manual. This paper was undertaken to satisfy the requirements of the National Fire Academy's Executive Fire Officer Program. This project and its results will be used by the North Providence Fire Department to make informed decisions on the purchase and operation of thermal imaging units

LITERATURE REVIEW

A literature review was performed to identify existing research on the subject of thermal imaging cameras or units for fire department operations. The literature review conducted concentrated upon four areas of focus for examination. Items examined included the historical background of thermal imaging technology, attributes of thermal imagining technology, system advantages and limitations, and lastly financial considerations. These essential issues would be compiled to form a comparison chart to aid in decision making process. The process of review included a search for authoritative sources that are experts in the field of thermal imaging for the fire service aided in this literature review. This literature review entailed a search of training manuals, fire service journals, magazines, and publications. Additional information was obtained through the collection of manufacturer's pamphlets and unit specific operational guides.

The review started with contacting an authoritative source of information and standards regarding the fire service operations, namely the National Fire Protection Association, Quincy, Massachusetts. Contact was made in August 1998 and December 1998 requesting standards for thermal imaging cameras. In a conversation on December 9,1998, customer service stated to the author that currently no standards exists for this technology. Customer service referred me to standards administration division. Standard administration office advised me to send a committee proposal form that would suggest that the NFPA develop a committee for the purpose of standard development for thermal imaging. (Linda Cohen, personal conversation, December 10,1998). This influenced this research providing a limitation. It meant that there was not any objective based standard that could be applied for thermal image comparison purposes.

In 1973, the report *America Burning* identified our nation's fire problem. This report presented 90 recommendations for a fire safe America. A key item addressed was research and development. Even into the '80s, we did not have the ability to see effectively in a burning structure although we had the technology to put a man on the moon (Woodworth, citing America Burning, 1996, July).

Historical analysis indicated a military root in the establishment of this fire service technology. Thermal imaging was originally utilized by the military to provide the ability of night vision to ground forces and to pilots to see targets not visible to the eye. Thermal imaging units were used in the 1960's in the early days of the Vietnam Conflict, however it did not gain widespread benefit recognition until the Persian Gulf War. The first fire service to employ thermal imaging was the U.S. Forest Service in the 1970's. They used this technology to provide aerial surveillance of wildland fires. Jim Scott, a retired land surveyor for the forest service stated, "Today's thermal imaging systems are a boon to wildland firefighting efficiency and safety"(Wagner, 1998). The United States Military, especially the Coast Guard and Navy have thermal imaging aboard all vessels to aid in fire detection /suppression activities (Gallagher, 1991). After the Falkland War, the U.S. Navy and Coast Guard began an aggressive program in thermal imaging for fire suppression application. The lessons of this war and its devastating effects of fires at sea especially in the areas of hidden fires, lack of visibility and heavy toll upon life prompted this action (M. Scanllion, personal communication, December 10,1998).

Utilization of thermal imaging technology has not been limited to the United States alone. The European Community, especially the United Kingdom has been aggressively deploying units for their fire service. As reported by Lyons and Parmenter in *Fire Engineers Journal* of September 1995:

> Against a background of increasing demanding health and safety legislation, including European Community Directives, a more litigious environment and a general reduction in annual budgets, the Fire and Rescue Services will be required to radically assess their fireground operations to ensure the maximum safety of firefighters and greater efficiency in the deployment of resources and equipment…. Perhaps one major radical initiative would be the deployment of "Through Smoke Vision" as part of standard equipment…. (Lyons and Parmenter, 1995, p.7).

This article went on further to cite that the rational for the slow introduction of thermal imaging technology were a combination of similar issues that plagued the development of self contained breathing apparatus (SCBA). These reasons were a combination of funding, technology, and the pressure for change. In the case of SCBA's the need seemed apparent, without it firefighters cannot breath. In the case of thermal imaging, the case could be equally clear, without it firefighters cannot see. A forth reason was identified as a lack of awareness of the benefits of this technology, which in turn could limit widespread deployment of this technological advancement (Lyons and Parmenter, 1995).

Newman and Irving (1973) identified one of the first fire departments to uti1ize thermal imaging technology, this was the Reading Fire Department in Pennsylvania. In 1965 the HRB-Singer Corporation under contract with the Office of Civil Defense, Office of the Secretary of the Army, developed 20 units under one pound and was handheld. These units were able to detect infrared rays emanating from heat sources unaffected by the presence of thick smoke. The firefighter was alerted through an audible signal through an earphone. The Reading Fire Department found these units were quite useful. The Singer Corporation decided to discontinue production in 1966, believing that there was no market for these devices (Newman and Irving, 1973). These points influenced the research on documenting how early thermal imaging research was initiated and the results.

The literature review then examined the attributes of thermal imagining technology to understand the inner workings or principles of operations of the units. According to Woodworth (1996, July), numerous changes have occurred within the culture of the America's fire service. These changes included the introduction of SCBA's, lightweight large diameter hoses, and computers. The traditional fire department responsibilities have evolved to include the challenges of emergency medical service, hazardous materials, and technical rescue (J. McKenna, personal communication August 30,1998). Woodworth (1996, July) however, states even with these new changes and challenges, there remains a constant in structural firefighting operations that hinders all operations. This one factor identified by Woodworth (1996, July) is the lack of visibility caused by the products of combustion, namely smoke. Woodworth states that not being able to see slows the progression of search and rescue, advancement of handlines, makes ventilation difficult, and hides failing structural components. This lack of visibility causes a risk to firefighters. Firefighters can become disorientated and lost within the fire building which in turn affects their ability to exit the structure in an emergency situation (Woodworth, 1996, July). Woodworth's impact on this research identifies a key threat poised to firefighters is this lack of visibility.

This obscuring agent called smoke is composed of two elements; fire gases produced by the fuel's chemical breakdown, and soot. The breakdown of the fuel of the fire produces carbonaceous particles and creates toxicity of smoke. Soot obscures light in smoke filled environments, which in turn effects vision. The amount of obscuring soot depends upon the size of the fire, type of fuel, amount of oxygen present and structure of involvement. Heavy smoke causes all the light to be scattered or blocked where light waves cannot penetrate the particles. This zero visibility condition is what limits effective lights for firefighting operations (Woodworth,1996, July).

The human eye is limited in its ability to detect heat. Detection is relied upon the ability to see visible flame or a product of combustion such as smoke. Some types of fire produce a flame invisible to the human eye, such as hydrogen gas (Newman and Irving, 1973). These different forms travel in the spectrum called wavelengths, each are unique. In addition, heat waves are detectable through smoke, where as light cannot penetrate. Infrared energy is not visible to the human eye, the firefighter can feel the heat present, but are blind because the human eye cannot detect wavelengths greater than visible light (Newman and Irving, 1973). The firefighter using thermal imaging would be able to see a representation of this heat (Woodworth, 1996, August).

The thermometer is the simplest infrared heat detector readily known and recognized by many people. It measures the intensity of heat waves present, but does not produce a picture of what was being measured. The thermometer is limited in fireground operations. It cannot detect a person lying on the floor, locate the heat source, or penetrate smoke in burning structures (Newman, 1973).

As stated previously, smoke hinders fireground visibility for the firefighter. Woodworth (1996, July) found that until the advent of thermal imaging technology, the fire service had relied upon lights, which had little effect, and ventilation for visibility in structural fires. Basically stated, what thermal imagining performs is a thermal heat view of the world. The literature review conducted clarified the properties of heat energy and components of smoke by reviewing the combined writing of Woodworth and Newman.

Looking through the thermal imaging unit provides the firefighter with a black and white television view through the smoke and darkness. Woodworth (1997, February) identifies the process utilized in thermal imaging viewing as thermal contrast. This representation is displayed as follows; hot things appear white, hotter things brighter white, and colder things appear black to gray. The difference in this temperature or heat energy is what forms the picture viewed. A key is that everything viewed through the unit lens retains its shape, people look like people and rooms look like rooms (*Fire Rescue Magazine,* 1998, April).

Three sources emit infrared energy identified by Woodworth (1996, November). The knowledge of each is important to the operation of thermal imaging units. Importantly, how it would effect operation by the fire service. Again, thermal imaging is a representation of infrared energy sources. The three kinds of infrared energy sources are active emitters, passive emitters, and direct source emitters (Woodworth, 1996, November).

The active type emitters always emit infrared energy with limited variation, a constant. An example would be the human body. There is limited variation in the presentation of infrared energy distributed by the human body. Certain factors such as wet turnout gear and bulky clothing can mask portions of the image. These factors can insulate the energy available for detection (Woodworth, 1996, November).

Passive energy sources are objects that have great variations in infrared emissions. The example of steel at room temperature, the metal would appear darker than a person in the same room would. However, if steel were heated, the infrared energy emitted would appear white, indicating an increasing temperature compared to the surroundings (Woodworth, 1996, November).

McLaughlin (1992), in *Firehouse Magazine,* stated that thermal imaging technology has several misconceptions regarding its abilities. McLauglin states, “ It does not see through walls. If it could, every weirdo in the world would be buying one.”(p.37). Thermal imaging can be utilized to detect fires in hidden void spaces. However, this capability is limited or effected by several factors. The first of such is the minimum resolved temperature difference (MRTD) of the device. Some objects differ in temperature by less than one degree Fahrenheit. MRTD is determined by the sensitivity of temperature detection by the thermal imaging unit (Woodworth, 1996, November).

The density and mass of building material utilized in the construction can also effect energy emission affecting detection (Woodworth, 1996, August). The elements that compose the construction are examples of passive emitters. The detection of an impeding flashover condition may be revealed by the heating of the building and its contents detected by radiating infrared energy created by the fire (Woodworth, August 1996). However, a human being will not provide sufficient infrared energy to penetrate through most materials used in construction. When a building collapses, when a gypsum board or lightweight material is used, a human body against the material for an extended period could be detectable. The mass affects detection of infrared energy. A great amount of heat would need to detect heat through concrete. However, light weight concrete could be imaged. Renovation, multiple roofing layers, and remodeling of buildings can add mass and density to the building, thus affecting imaging abilities of the unit. The understanding of density and mass affect thermal imaging is a key in proper usage of thermal technology (Woodworth, 1996, November).

In addition, it should be noted that some material does affect the delectability of infrared energy. Materials such as plastic, water, and glass present a solid barrier to infrared. The barrier must be heated in order for detection to occur. This ability is helpful to identify associated temperature difference of a drum, based upon fluid level (McLauglin, 1992).

The last source of detectable infrared energy is direct source emitters. These sources produce large amounts of energy. Examples are fires, chemical reactions, and the sun. The direct sources can affect the electronic portion of the camera, primarily the gain. Some units “white-out” when aimed at a direct source. This reading indicates a great amount of heat is present across the entire viewing area (Woodworth,1996, November).

Woodworth and McLaughlin’s writings affect this research by providing an assessment of capabilities and attributes associated with this technology.

The literature review then examined the types of devices currently available to the fire service. Several types were examined during the research process, the cooled IR detector, Pyro-Electric Videco (PEV), and Focal Plane Array (FPAC). This examination and review process would yield an understanding of the technological attributes of each type.

Using Maine’s Fire Training publication entitled, *Thermal Imaging for the Fire Service* (1997), several types of detectors were identified. Older, early designed thermal imaging units were known as “cooled IR detectors”. These units were sometimes bulky, large, heavy, and had limited fire service capability. In addition, these units required frequent part replacement. The recent changes in thermal imaging technology now have made this capability smaller, lighter in weight and less maintenance intense to be placed into fire department service. The viewing of a direct source emitter of infrared heat energy would cause a “white-out” condition if the unit were aimed at a very hot object (Woodworth, 1996, November). This condition could take several minutes to clear it causing the unit to be blind in the interim. Exposure to a “white-out” situation made this type of unit prone to sensor or tube damage. Frequently this situation would occur during the search for the fire itself. Thermal imaging units of this design type usually required a shut down period allowing the resetting and cooling of the unit (Nygren, 1997). This condition of “white-out” would influence the author in addition to others researching thermal imaging cameras for fire service evaluation.

The second type of technology reviewed by Nygren’s article, *Thermal Imaging for the Fire Service* (1997) was the Pyro Electric Videcon (PEV). This technological type is similar to the above mentioned cooled infrared detectors. This unit incorporates newer technological within its design. Several features include; decrease size and weight, improved sensitivity to temperature differences, and decrease sensitivity to “white-out” phenomenon. If the unit does encounter a “white-out” situation, it now would be cleared in seconds as opposed to minutes, usually by only directing the unit away from the direct emitter (Nygren, 1997).

The last type of unit examined by this publication was the Focal Plane Array (FPAC). This type of thermal imaging camera technology is considered to be leading edge in technology. The unit views without the tube construction of the PEV type of thermal imager (Woodworth,1996, November). The electronics of the instrument is solid state construction. Viewing is accomplished direct line of sight then is rendered into a simulated representation of it to the viewer. Direct source emitters of thermal energy can be observed for short periods without the "white-out" effect occurring. This type of thermal imager provides a detailed image without the need for significant thermal or temperature gradients to be present (Nygren, 1997).

The last type to be covered does not provide a visible detection capability. Instead this unit senses infrared heat sources and only provides the user an emitting audible tone. This unit at a higher temperature generates an increasing audible tone to the operator (Nygren, 1997).

The literature review focused on researching the advantages and limitations of thermal imaging cameras. *Fire Engineering Journal* (1995) reported the advantages using thermal imaging technology in describing the benefits derived from its use at three incidents. At the second incident described, five conclusions were reached on the advantages of the TIC. In addition, *Fire Engineering Journal* (1995) also noted a significant boundaries or limitations of this technology.

In the search for examples of applications of thermal imaging on the fireground, a limitation was noted during the research. In John Norman's book*, Fire Officer's Handbook of Tactics* (1991), no material was mentioned to aid in potential applications of this technology on the fireground for strategy and tactical purposes. Norman only provides a statement of the operation of the camera alone. This limited the author's search for documented examples tactical and strategic application of this technology on the fireground or rescue operations.

Maine's Fire Training and education publication entitled, *Thermal Imaging for the Fire Service* (1997), by Allen Nygren, reviews several advantages of thermal imaging in numerous areas of fireground operations. In addition, this training package also covers some disadvantages or limitations of implementing this thermal imaging technology. This publication itemizes cautions to be emphasized during the initial phase in period or training program before placing this system on the fireground.

Fire Rescue Magazine (1998,April) enumerated six advantages using thermal imaging for the fire service. Contained within this article was a handheld (PEV Technology) or helmet mount (FPAC) comparison chart (p.44). The impact of this chart influenced the research of this topic by displaying a simple comparative analysis of both of the commonly utilized thermal imaging technologies. This chart has been reproduced in this research paper and labeled, Table One on page 36 of this research paper. This article goes on further to provide a suggested method of selection between the two types of units. This article provided the research with the first written suggestion for the operation of thermal imaging technology. *Fire Rescue Magazine* (1998, April) also provides a way to demonstrate the need for the imager to others in the fire service or to others.

Woodworth (1995) provides insight into Atlanta, Georgia Fire Department's testing of thermal imaging. Through his writings, this provided a detailed account into several applications and advantages noted with the use of thermal imaging. These experiences documented the findings in the testing and actual incident application phase of thermal imaging technology by the Atlanta's Fire Department using the Cairnsiris system.

Fire Rescue Magazine (1998, May) continues the review of thermal imaging camera. Their article provided a list of nine precautions that should be undertaken with thermal imaging usage. The presentation further goes on to enumerates eleven fire service tasks that the application advantages were found in the usage of thermal imaging technology.

The writings of Wagner and West (1998) reviewed five of the current manufactured types of thermal imaging units. Their research produced a comparison chart of the respective units.

That information reviewed was taken in part, used, and labeled Table Two, located on page 42 of this research project. This chart developed identifies model, price, electronics, and styles of design, field of view, weight, thermal sensitivity, and special features of each thermal imaging type. Wagner and West (1998) further in their article go on to interview two fire department officers, each of whom uses thermal imaging. However, one department uses a handheld unit, and the other uses a helmet mount system. The interview process asks both objective and subjective questions to each of the officers. Some of Wagner and West's interview questions were incorporated for replication by this author during the survey aspect in this project. These interviews conducted by these authors provided this research with documented opinions of the two options of technology available. In addition, documentation of the advantages found with thermal imaging application on the fireground was provided.

Stevens (1991) reported some observations on the advantages of having thermal imaging capabilities. He also provides the accounting of an actual incident using thermal imaging camera. The additional capabilities of thermal imaging were given beyond the traditional fireground application. Stevens influenced this research by providing documented instances how new thermal imaging technology changed the fireground operation

Woodworth (1997, February) gives several additional features that a thermal imaging camera should possess to enhance safety and proper utilization. He mentions the importance of using technology in the fire service to improve firefighter safety and job performance. The author also provided an essential limitation that would influence this research.

Fire Rescue Magazine (1998,May) developed a list that influenced the research project in evaluating imager technology the most. It provided a listing of 17 factors to be considered in evaluating a thermal imager camera. A listing such as this provides the author of this research and perhaps others, a base of comparison beyond cost alone. This listing was influential in the author's development of a means of comparison for the final results of this paper.

The final area researched in this project was financing. An analysis of the cost involved in the obtaining thermal imaging technology varies with the unit chosen (*Fire Rescue Magazine,* 1998, May). Newman and Irving (1973) reached the conclusion that larger municipal fire departments could justify a costly, large purchase item such as thermal imaging based upon frequency of use. However, Newman and Irving (1973) concluded that smaller, rural fire department would be pressed for the justification of such an expense (p.42).

In the writings of Wagner and West (1998), manufacturers provided two reasons for the hefty price tags on these thermal imaging cameras. The rational provided was high production costs and low volume. Kerri Gordon, Cairnsiris product manger stated, " the pricing of these cameras is all driven by volume." (Wagner and West, 1998). Additional factors that had driven up the costs were identified as a limited market outside the fire service, very specific ceramic chip electronics, and rare metal utilization. Germanium, the rare metal used in the lens fabrication is not used for any other type of application (Wagner and West 1998).

Maine Fire Training and Education has developed an innovative approach for funding initiatives. The state division has assembled a newsletter, training programs, data collection, and fund distribution for thermal imaging. This operation had also established a coordinator for the endeavor (Dunbar, 1998).

An Examination of the use Thermal Imaging Cameras in the Fire and Rescue Services (Patterson, 1997), an EFO paper submitted by Assistant Fire Chief Thomas Patterson, Houston Fire Department, surveyed 40 departments utilizing thermal imaging cameras. This survey was replicated locally to check on the similarities of results. Influence of national statistics and local statistics would be compared.

Cairns and Brothers, a manufacturer of the Iris system has assembled a fundraising kit. This package contains fundraising ideas, form letters and planning agenda for the acquisition of thermal imaging for the fire department. A spokesperson at Cairns, Cathy Chakmakian, stated that 60% of orders received are the results of fundraisers (Wagner and West 1998). This measurement would be compared to local effort during this project's survey.

All of the major manufacturers, which were reviewed, state clearly the advantages of their respective systems. This point was evident in reviewing the literature and various videotapes provided by the following manufacturers: Cairns, International Safety Instruments, Bullard, and Mine Safety. This documentation provided the research process with technologies available, applications, and actual news reports of saves contributed to the use of thermal cameras.

Cairns (1998) in their product specifications also stated a limitation in the utilization of their system. Woodworth (1997, March) also reports limitations in using this tool. Render (1997), reported on the fund raising activities of the Signal Hill Fire Department, but in addition provided a word of caution in this technology. These points would be influential in the research project, as potential disadvantages or system limits, especially if implementation of thermal imaging was recommended by this research project.

McLauglin, Patterson, Newman, Irving, Stevens, Woodworth, Wagner, West, the writings from *Fire Rescue Magazine*, and training material from Maine Fire Training and Education, influenced this research by examining the role of thermal imaging technology on the fire service. All the authors and organizations provided information regarding operations and technological aspects of thermal imaging cameras for comparison purposes. They all provided a solid, rational arguments in favor of implementing this technology on the fireground. In addition, documentation of instances of how new technology can influence firefighter safety and impact fireground operations in a positive manner.

PROCEDURES

The research procedures in preparing this paper started with a literature review at the Learning Resource Center at the National Fire Academy in September 1998. Additional literature reviews were conducted at the North Providence Union Free Library in North Providence, Rhode Island, the Providence Public Library in Providence, Rhode Island, the Providence College Library in Providence, Rhode Island, and the author's personal library between September 1998 and December 1998. The purpose was to obtain material relative to thermal imaging technology for the fire/rescue service.

The literature review focused on four areas for review. The first area researched upon was the historical origins of thermal imaging. This was initiated to understand the background of this technology and learn about early applications of this unit. The next area examined was the attributes associated with the technology of thermal imaging cameras. This was done to gain a perspective of the workings of this tool. A review of material was conducted thirdly, to examine the reporting of system advantages and limitations of fire departments using this technology. Lastly, a review of the financial aspect of purchasing thermal imaging cameras was conducted.

Interviews were conducted with Ms. Cheryl Bozzi, North Providence mayoral aide, on December 7, 1998; Jack D. Lane Jr., Battalion Chief, North Providence Fire Department, and Department's command officer with technical rescue background, on December 5, 1998 and December 6, 1998; Bernard Charello, retired Chief of Department, on August 30, 1998; Donald Clark, Acting Chief of Department, on September 10, 1998: Donald Campbell, Chief of

Department, Hope Jackson Fire Company, Scituate, Rhode Island, and current President of Rhode Islands Chiefs Association, on December 11, 1998; Leone Carney, Emergency Medical Coordinator, Smithfield, Rhode lsland Fire Department, on August 30,1998; John Gregson, Captain with the North Providence Fire Department, and former advanced life support committee member, on August 30, 1998; Michael Scanllion, Captain/EMS Coordinator Hope Jackson Fire Department, and retired Chief Petty Officer United States Coast Guard; Linda Cohen, NFPA standards division, on December 10, 1998; and Edward DiGuilio Jr., Lieutenant with the North Providence Fire Department, and union Health and Safety Officer, on September 9,1998.

A survey instrument, which was titled " Thermal Imaging for the Fire Service Survey" was developed to gather information about the utilization and consideration of thermal imaging cameras in Rhode Island (see Appendix A). The results of this survey are referenced in Appendix C of this research project. Each letter included a cover letter describing the purpose of the study. The survey was divided into three sections. Departments considering or had units answered the first section. The second section was completed by departments that had units on order or in place. The last section asked departments whom had units in place to complete based upon their experience. The information sought included whether the department owned or had considered the purchase of thermal imaging cameras. Any obstacles faced in the purchase of the unit. How the department arrived at the decision to purchase the unit. The factors involved, that influenced the departments purchase. How the unit was funded. Thermal imaging types of unit under consideration by the fire department. Any system advantages found using this technology. In addition, any problems experienced with the thermal imaging technology. How the thermal imaging assisted the fire department. Including any reports on specific incident utilization of thermal imaging.

The survey instrument was mailed out and delivered to all 80 fire departments listed by the Rhode Island State Fire Marshal's Office. This represented a survey of the entire 39 cities and towns comprising the State of Rhode Island, including two federal installations. In addition, a random mailing and telephone survey to ten fire departments using thermal imaging cameras inside of Rhode Island were contacted. This listing was provided by the various manufactures of thermal imagers, five of which that were contacted used of hand held types and five utilized helmet mounted units. A total of 80 surveys were handed or mailed out. Sixty seven surveys (83.75% percent) were completed and returned.

The results of the survey were entered into a database (Microsoft Excel for Windows 98) and analyzed. The results were tabulated and used to assist in answering the research questions.

Limitations

This research was limited by a number of factors; not the least of, which was the fact that the core subject matter (i.e., utilizing thermal imaging cameras) is not widespread in the State of Rhode Island. The subjective nature of handheld units and helmet-mounted thermal imaging camera units resists being quantified.

The author was limited in his research by the lack of information and documentation about thermal imaging cameras. Very few articles and no books were found that specifically addressed the role of thermal imagers in the fire / rescue scene. There was no national standard or National Fire Protection Association publication regarding minimum standards for thermal imagers. A search at the Learning Resource Center at the National Fire Academy located only one research paper on the topic of thermal imaging.

The survey instrument was flawed. It was limited in scope and failed to examine the utilization of thermal imaging throughout the Untied States fire service. The survey audience should have been broader in scope. The results, therefore appear to limit the research to the State of Rhode Island only, and thereby should not be construed as being statistically representative of the fire service of the United States.

Definitions

Active Emitters - infrared energy emitted with little variation of energy. An example is the human body.

Direct Source Emitters - infrared energy sources that produce great amounts of heat. Examples are fires, chemical reactions, and the sun.

Field of View- is the area of the thermal imaging camera through which the firefighter looks.

Focal Plan Array Chip (FPAC) – this type of thermal imager provides a virtual reality image as opposed to of pictorial representation. Possess the ability to view direct sources without "whiting out".

Infrared Energy- is a region of the electromagnetic spectrum. The human eye cannot view this energy type, only the heat can be felt.

Minimum Resolvable Temperature Difference (MRTD) - describes the capability of the thermal imaging camera to detect differences in temperature. The MRTD is the sensitivity of the unit, or how little a temperature differences the unit can detect.

Passive Emitters- are objects or materials that have infrared emissions with significant variability. An example is steel at room temperature, steel appears cold or darker than a person in the same area. If steel is heated, it appears white, indicating an increase in temperature.

Pyro Electric Vidicon (PEV)- a thermal image camera type, usually handheld. This type of unit can be affected by pointing at direct source emitters causing the "white-out" phenomenon.

Thermal Contrast - the difference in the temperatures of the object being viewed. This contrasting makes it possible for thermal imaging camera to create a viewable image. The contrast is displayed as follows: Black indicates cooler or absences of heat in areas, white indicates heated objects, and shades of gray are detected in between the range.

Thermal Inversion- are changes noted with images viewed due to changes in ambient temperature. Firefighters viewed by a thermal imaging camera outside a structure would appear white or hotter then the surrounding area. When viewed inside the burning structure this image displayed would change or invert. The firefighters would appear darker, indicating the temperature of the surroundings have changed.

Thermal Imaging Camera (TIC)- a tool capable of converting infrared heat energy to a viewable real time image.

Thermal Resistance- the maximum temperature the thermal imaging camera can be subjected to without damage. Duration usually stated in terms of minutes.

Virtual Reality- the temperature differences of detected concerted into a visible image.

White Out or Whiting out Effect- refers to what happens to the thermal imaging camera when it is pointed at a very hot object (direct source emitter). This causes the sensor to be overloaded and generates a completely white screen on the view screen. The unit must be cleared to resume operation

RESULTS

1. What are the attributes of thermal imaging technology?

The literature review found that there were no National Fire Protection Association guidelines or standards that addressed thermal imaging cameras for the fire service. During the research review, a search for authoritative sources on thermal imaging technology was undertaken.

Thermal imaging cameras are the most exciting new technologies to emerge for the fire service as stated by Wagner and West (1998, p.32). Wagner and West provided an understanding into the operation of thermal imaging technology. The attribute in which the authors go on to describe was that thermal imagers read infrared radiation or heat energy. Wagner and West stated that some units are capable of detection of heat in fractions of a degree Fahrenheit.

Steven Woodworth, a firefighter with the City of Atlanta, Georgia and instructor with the Georgia Fire Academy, has written numerous articles regarding the use of thermal imaging, provides additional information. Woodworth (1996, July) in his writings states that thermal imaging is the fastest growing tool in the fire service. Thermal imaging cameras provide the firefighter the ability to see through smoke. Traditional firefighting activities have relied on the utilization of lights and ventilation for this visibility inside burning buildings (Woodworth,1996, July).

Woodworth's writings provided this research with information regarding the operational attributes of thermal imaging technology. Thermal imaging translates infrared heat energy into a visual image that can be viewed by a firefighter (Woodworth, 1996, July). Woodworth provided an information into the principle of energy transmission. Infrared energy, unlike light energy, can penetrate the obscuring effects of smoke. Woodworth then introduces the concept of thermal contrast, the difference in the temperatures of the objects being viewed, makes it possible for the imager to create an image which can be viewed (Woodworth, 1997, February). The images are displayed in a black and white representation of heat transmission. Black indicates a lack of heat, white indicates the presence of heat, and shades of gray are in between this scale. The whiter the representation displayed, the more heat is present in that object, conversely, the colder the object is, the darker the representation displayed (Woodworth, 1997, February).

2. What are the recommendations, advantages, disadvantages, and limitations of each technology type?

The literature review then focused upon researching the advantages, disadvantages, and limitations of thermal imaging cameras. Lyons and Parmenter article in *Fire Engineering Journal* (1995) provided the author with detailed information regarding the advantages and limitations regarding the utilization of thermal imaging at three cited incidents. These reports were complied by John Lyons and Graeme Parmenter, thermal camera sales, EEV Ltd. for the Argus thermal imaging camera in the United Kingdom. Derek Thacker of the Cleveland County Fire Brigade provided the information based upon his operational crew's incident reports.

1. The first fire incident described occurred in a two story building used for automobile repairs and body shop on June 16,1994. A TIC was used to locate cylinders of oxygen and acetylene. The fire scene was extremely hot and visibility was zero. These cylinders were at the rear of the complex and would not have been reached for some time without the TIC. Once located, the cylinders were cooled, and firefighting suppression could be carried out with confidence without fear of exploding cylinders. Without the TIC, these

cylinders would have not been located as quickly, thus increasing the risk of an explosion (Lyons and Parmenter, 1995).

The second incident described a fire incident, which took place at a cable factory on April 16,1994. The factory lay out was described as a maze of cages, wires, racks, and machines. The thick black smoke causing visibility to be reduced to zero further hampered movement. Locating the fire location proved difficult to the reporting officer since smoke was emanating from all exterior openings. Using thermal imaging, a crew was able to “see” the full extend of the fire and position of interior obstacles, and forwarded a report to the command officer for analysis (Lyons and Parmenter, 1995).

This incident reached five conclusions based upon thermal camera utilization as reported in *Fire Engineering Journal* (1995);

1. Although vision in the factory was zero, the TIC restored vision to almost normal.
2. It was invaluable in locating the fire.
3. Enabled a faster more effective attack.
4. Improved safety for firefighters.
5. Enables the officer in charge to accurately assess the situation (p. 8).

The third reported incident was a fire at an office with a large secured workshop attached. A large volume of smoke was coming from the workshop roof. The workshop itself was secured with metal roll up windows and doors. A TIC was used to scan the exterior, which proved negative. The building was entered after assess was gained and scanned again with a TIC. This scan revealed that a party wall was not penetrated, thereby releasing firefighters to suppress the office fire. The speed with which the crews were able to check the workshop was the main advantage reported (Lyons and Parmenter, 1995).

Lyons and Parmenter (1995) further provided some essential limitations found in thermal imaging camera implementation. Limitations expressed by these authors include the lack of awareness of the benefits of the technology, funding limitations, and resistances to change by the fire service. An additional concern was expressed in the writings. Based upon an interview conducted by these authors with Deputy County Fire Officer Peter Shead, Lead Officer on equipment at the National level, expressed the following, "The most efficient and safe use will be dependent on the development of procedures for the use of TIC inside structures."(p. 7)

Maine's Fire Training and Education publication, *Thermal Imaging for the Fire Service,* (1997) provided several application advantages of thermal imaging in specific areas of fireground operations. This state agency has a stated goal of 300 cameras with Maine fire services within three years(p.5). The firefighting activity of search and rescue was stated as the primary advantage found with TIC utilization. Unique applications stated included the following. The detection of water flow to the sprinkler heads in a system determines if the system is reaching the seat of the fire. Thermal imaging assists the officer in size up. A survey of the structure's exterior may provide the location of the fire by area, room, or floor. Additional, information regarding fire spread or hidden fires could be determined through the use of TIC. Overheated electrical fluorescent ballasts, overheated motors, and heated containers could be detectable by thermal imaging cameras. This information would assist in ventilation, salvage and overhaul, and fire suppression operations. Fire suppression would be assisted by TIC in determining the shortest route to the fire, holes in the floor, and obstacles in the structure. Finding the exit out of the structure would be possible because hose lines would be cooler, thereby easily detectable (Nygren, 1997).

The survey instrument given during this research paper found that several local fire departments had similar results. Those fire departments using TIC, area departments reported success in locating hidden fires, overheated motors, faulty electrical fixtures and ballasts, and search and rescue, both interior and exterior activities.

Nygren (1997) also provided this author with some important limitations. "Never forget your training", was stated as a key. Firefighters could enter the structure too deeply too fast. Thermal imaging devices must be used with the thought that the unit might fail. The battery could fail or be lost, or misjudgments in the life remaining are limits noted by the author. The author states a limit of counting on 20 minutes of operation, less in the cold (Nygren, 1997).

Traditional firefighting operations must not be forgotten. The author stated several disadvantages included failure to recognize building collapse indicators, failure to recognize victims, failure to note flashover conditions, and moving too quickly (Nygren, 1997). Firefighters and occupants, who are wet from hoselines, could be masked during the search. The article goes on to state certain material will cause imaging problems. Materials such as glass, water, or mirrors will cause imaging problems. The effects of "Tunnel Vision" can place the operator in peril or danger according to the author of this publication. Holes can be misjudged to be farther away, or masked. In addition, the author goes on to state that the operator can often overlook the structural integrity of the building by depending upon TIC alone. Render (1997) goes on further to state that, " Thermal imaging is not a substitute for good fire prevention behavior habits"(p.1).

The importance of utilizing TIC along with the traditional approach of search and rescue, complete with necessary hand tools, lights, and tag lines was stressed (Nygren,1997). The thermal imaging training of all team members in the utilization of the camera was stated by the author as a vital safety link, thereby allowing passing of the unit from one member to another. Training with the unit was identified as a key in safety. The information communicated to search and rescue members, such as obstacles and hazards, was stated by the author as imperative in proper and safe TIC usage by a team.

Fire Rescue Magazine (1998, April) enumerated six advantages using thermal imaging for the fire service. The advantages listed are:

1. Search and rescue.
2. Night time wildland fires.
3. The ability to accurately check smell of smoke in the area calls.
4. Hazardous material use.
5. Fire extension checks.
6. Most importantly, improved vision that results in reduced firefighter and civilian injuries and deaths (p.40).

This article further provided a checklist comparison between handheld units and helmet mounted thermal imaging cameras. This chart has been reproduced in this research paper, and is provided on page 36, labeled as Table One. In addition, this article provides a recommendation for decision-making purposes between the two technologies. The article stated that the decision between a handheld and helmet mounted is up to the end user. It clearly stated that both units had saved lives in smoke filled areas (*Fire Rescue Magazine,* 1998, April).

Table One

Handheld Thermal Imager Versus Helmet-Mounted Thermal Imager

Handheld Thermal Imager		Helmet-Mounted Thermal Imager	
Pro	**Con**	**Pro**	**Con**
Do not have to adjust eyepiece.	Some units don't focus within 12 ft.	System allows for hands free operation.	What you see in the eyepiece may not be in front of the wearer. Image can be a few feet or inches off.
No helmet to adjust.	Potential to drop or strike an object.	Certain units offer video and thermal images.	The wearer must remember to move their head up & down, left & right to expand the field of view.
No wires to snag.	Inability to use both hands.	Unit can be connected to a data link for live broadcast.	They are heavy to wear.
Cost approx. 25% less than helmet mounted.	View may be better with helmet mounts due to inferior optics in some handhelds.	With the imager attached to the helmet, it goes in whether it's needed or not. Someone must be designated to wear it or it will not be there when you need it.	Helmet must be adjusted during the transfer process.
Easily transferable from one firefighter to another.	Optics easily damaged by heat in some older models.	Helmet view may be superior to handheld units.	Battery pack must also be transferred to new user.
Batteries easily replaced longer duration.	Other than easily damaged vidicon tubes on older analog systems, heldhelds are tough.		Quick disconnect on battery wire and eyepiece easily damaged.
Can secure around user's neck, allowing hands free operations.			Increase need for spare batteries.
What you see in the viewfinder is what is actually in front of you because the viewfinder and imager are in line.			
They can be held above the head or through a hole to get an image.			

Battery pack to helmet cable	equipped with a breakaway feature	difficult to connect in smoke.

Replicated from *Fire Rescue Magazine* (1998, May, p.44).

The article recommends that a fire department possess both units. The articles proposed that the helmet-mounted unit would be utilized for attack, but once knock down is achieved, use a handheld unit. Command and first in company officers should use a handheld unit to scan the building before entry (*Fire Rescue Magazine*, 1998, April). In this article, a method of presentation or demonstration to others regarding the need for this thermal imaging technology was provided. The publication suggests using an abandoned multiple story house, school, warehouse, hanger, or gym after hours. Then use a smoke generator to create a zero visibility condition. Place two victims in the structure and send in ten firefighters wearing breathing apparatus to find them. In most situations, these crews will run out of air in 15-30 minutes later, with no victims. Then send in two new firefighters with an imager and they will be out with the victims. It had been suggested that local elected officials be invited to this demonstration (*Fire Rescue Magazine*, 1998, April).

In the survey instrument distributed in this research, a similar demonstration was conducted by a fire department. The Warren, Rhode Island Fire Department conducted a mock search in a room with victims, first without and with TIC. This comparison demonstration was provided for firefighters and others that showed the abilities of TIC, which included better visibility, faster searches, and recoveries, and improved firefighter safety.

An advantage also presented by this article presents the following scenario. In the past, fighters have gone into buildings and have gone down. Even with portable radios and PASS units have not requested assistance. Imagers would allow command too see what is going on with the interior crew by direct broadcast capabilities of a TIC. Command would now have a view of the fire building roof top, rooms, and exterior conditions.

Woodworth (1995) provided insight into Atlanta, Georgia Fire Department's testing of thermal imaging. Through his writing, this provided a detailed account into several applications and advantages noted with TIC. These reported incidents summarize the experience with the Cairnsiris helmet mounted system. After receiving initial training at the departments division of training, along with burn building application the Iris was placed on two companies. The Cairnsiris was used at numerous fires, predominately for search and rescue in two story frame dwellings according to Woodworth. Woodworth further stated that the time for search and rescue was cut in half because of thermal imaging.

Woodworth described some unique advantages of thermal imaging application. The first account described was an industrial fire at a detergent silo. Using a thermal imager, the firefighters were able to view through the silo that a sprinkler valve was closed. This was determined by viewing the exterior of the silo, areas cool indicated sprinkler operation, and white areas indicating heat, indicated non functioning heads. The valves were opened thus controlling the fire. Woodworth detailed building construction in Atlanta as balloon frame in construction, were hidden fire can lead to rapid expansion. Thermal imaging allowed firefighters to check for extension while doing less damage and monitor the condition of the structure itself according to Woodworth. The last incident advantage found by Woodworth was using TIC in hazardous materials response. The fire department using thermal imaging was able to monitor fume location and spread, in addition to monitoring chemical reactions. These two aspects were detected by noting a difference in temperature accomplished through monitoring with TIC according to the author.

Fire Rescue Magazine (1998, May), continues the review of thermal imaging units. This writing provided this research with a listing of nine precautions or limitations that should be undertaken with TIC application. In addition, a list of eleven fire service tasks that TIC application can provide significant advantages when utilized properly.

Nine precautions for imager use described by *Fire Rescue Magazine* (1998, May,) are as follows:

1. Exercise extreme caution when using delicate and expensive thermal imaging cameras.
2. When the cameras off, do not point it at the sun or any other heat source.
3. Do not look directly at the fire with older imagers because it damages imaging tube.
4. Always check the imager battery level before walking away with it, and replace batteries with every use.
5. Operators should carry a rag to wipe the imager's tube or eyepiece because of the build up of the products of combustion, namely, steam, fog, or high carbon smoke.
6. With vehicle mounted systems leave the unit on white-hot and scan during response.
7. Be aware that with some helmet-mounted systems, the lens is offset from the natural line of sight, making things seem two feet to three feet to the left of the image. This makes it difficult to judge distance, stairs, doorknobs, and other obstacles.
8. Know that on occasion, the entire viewer will "white-out" because everything is hot. Practice staying oriented when traveling through a structure.
9. Peel off thermally transparent plastic covers to protect heat seeking optics from smoke and tar in fire conditions, and protect the optics from scratching when cleaning. (p.77)

In the survey instrument utilized in this research, the Central Falls Fire Department, Rhode Island reported some of the same problems listed as precautions by this article. This department has been using the Cairnsiris system the longest in the state and reported that the lens had become foul in smoke created from burning plastics. This was resolved by cleaning with a rag.

Eleven areas of fire suppression activities that would benefit from thermal imagining utilization were identified by *Fire Rescue Magazine* (1998, May) as advantages. Several of the applications found a local connection. These results were expressed in the survey instrument used in this paper. The listing in this article was then crossed checked with survey results received.

1. Response: Command vehicles would be able to see through smoke and properly positioned. The Rhode Island Airport Corporation subsequently reported this benefit. In the survey instrument returned this was listed as an advantage on their truck mounted system.
2. Size-up: Size up of the structure by TIC utilization to indicate fire floor, involvement, and extension.
3. Attack: The article suggests the officer is equipped with a helmet mounted system for the attack crew. The crew compartment carried a handheld unit for rescue crew or second attacks line. All crew members have head sets to report operations.
4. Search: The article states that thermal imaging would greatly speed up the search in fire buildings. The article reports each floor on a single family building should take three minutes to search.
5. Command Eye in the Sky: The article stated imager at large incidents could display multiple sides of a building and monitor attack and rescue operations.

6. Rapid Intervention Teams: These units should be equipped with an imager when possible, A RIT should be led by the deputy incident commander who has viewed thermal images of the incident up to that point according to this article.
7. Hazardous Materials: A benefit that was stated by this publication was the ability of TIC to determine heat intensity and levels of fluid within vessels. The Central Falls Fire Department in their response to the survey echoed this ability. This department has worked with the Drug Enforcement Agency (DEA) in clandestine drug lab raids. The DEA used the fire department's Cairnsiris to monitor clean up operations with the fire department's assistance. DEA was so impressed with the application; they ordered one for their operations.
8. Water Rescue: The article reported the use of TIC to find individuals in swift water rescue situations. This was conditional on the person being alive and on the surface of the water.
9. Wildfires: This use echoes the U.S. Forest Service early use of thermal imaging as reported in the literature review of this paper.
10. Overhaul: Viewing all fires completely to ensure the fire is out was an advantage stated by the author. The author then went on to remind the reader that the third largest fires in the United States, Oakland California Fire in 1991 was a rekindle, which cost 24 lives and destroyed 5,000 structures.
11. Mutual Aid: This series recommends informing non imager departments about imagers and the technological advantage they provide. In the survey instrument used in this report, seven, (7) of the departments reported they considered purchasing thermal imagers, but did not since one existed in a neighboring community (pp. 68-75).

The writings of Wagner and West (1998) identified the advantages and disadvantages of the two types of technology available for thermal imaging cameras. Their article stated that tube technology carries a less expensive price and presents a higher resolute picture than most chip based units. A disadvantage presented was that tubes do not last as long as chip or microchip sensor technology. The article goes further to state the life span of a tube is between 700 and 5,000 hours or more of operation. Chip technology may require less maintenance and have 3,500 plus hours of operation life. The pricing of chip technology based units is higher, and improvement in picture quality can be expected with the expected development according to this article. Wagner and West's article provided information that was reviewed and taken in part and presented as Table Two, cited below page 42. This chart compares technological facets of several thermal-imaging types.

Table Two
Thermal Imaging Comparison of Facets

Legend: **1.**Helmet Mount Configuration. **2.** Handheld Type of Thermal Camera

As of 27 December 1998

Model	***Price***	***Tech Type***	***Style***	***Operation Time***	***Field of View***	***Wt.***	***Thermal Sensitivity***	***Thermal Resistance***	
Cairns	25k.	chip	1	30 Minutes.	36 degrees	7.5l bs.	.5 Degree F.	1,200 Degrees F. (10 seconds.)	
Argus	18k.	tube	2	1 hour.	55 degrees	6 lbs.	.10 Degree F.	482 Degrees F. (5 min.)	
Vision 3	18k.	chip	2	3 plus Hours.	59 degrees	4 lbs.	.05 Degree C.	700 + Degrees F. (2 min.)	
Palm IR-250	13k.	chip	2	4 Hours.	12 degrees	2.6 lbs.	.10 Degree F.	120 Degrees F. (MAX Op.)	
Bullard	18.5k	chip	2	1 – 1.5 Hours.	45 degrees	5 lbs.	.05 Degree C.	500 Degrees F. (5 min.)	

Stevens (1991) reported observations on the advantages of using thermal imaging cameras. An actual incident that was reported where a fire company searched a 5,000 square foot balloon framed building in less than two minutes utilizing a TIC. In addition, when the two man crew exited the building, they reported to the incident commander that three people were trapped on the second level of the building above the fire. An added feature allowed the incident commander to develop a strategy based upon a video recording made by the search crew, which added in the rescue of the trapped civilians. Stevens, in this article presented additional advantages when thermal imaging technology is utilized. Motor vehicle collisions provided another way TIC could be applied. The area around the scene could be scanned for victims thrown from the crash. In structural fires, using thermal imaging would reduce the time consuming activity of firefighters checking for hidden fires in walls and ceiling.

Woodworth (1997, February) presented some information regarding safety and limitations of thermal imaging. Woodworth notes that thermal imaging can make the job of a firefighter safer and faster. In addition, he stated that the fire service should take advantage of this technology. However, a single fact remains, that the firefighter must be properly trained to operate this equipment. Woodworth (1997, August) quoted Lieutenant Michael Cogan, Fire Department City of New York (FDNY) Rescue 3, comments at FDIC 97: “If Joe Montana threw the football only once a year, he would not make it to the Super Bowl”. Woodworth’s (1997, March) article, the author mentions that the firefighter must be trained in the classroom and be provided with practical session in order to effectively use the camera.

One manufacturer, Cairns (1993) cites a limit in their product specification. The only problem with TIC included this system as well as other TIC systems are the increase risk of failure resulting in blindness of the operator. The operator of a thermal imager can become accustom to using these units and dependent on it for navigation. Failure then would create disorientation and confusion, which then could cause harmful or fatal results.

A similar limitation was also mentioned by Woodworth (1997, February), regards TIC as a reliable tool, however these are mechanical devices that can fail. He stressed the importance of carrying flashlights, contact with the wall, and maintaining communication with command. Woodworth (1997, February) goes on to provide some features TIC should possess in order to maintain safety. A TIC should provide warning icons for low battery, high temperature warning, and operating time available. He notes a good rule of thumb of changing the battery with each air bottle change to provide for safety of the operator.

Fire Rescue Magazine (1998, May) developed a list that influenced the research project in thermal imaging evaluation. This listing considered 17 factors to be considered in this assessment of thermal imaging technology. This listing was influential in the author's development of a method of comparison for the results of paper. Presented as Table Three on page 45 of this applied research paper, a set of evaluation questions was developed by this author using the writings of Woodworth (1997, February), and Nygren (1997) to develop this evaluation. The evaluation questions would assist in listing advantages and disadvantages of each system.

Table Three

Evaluation Questions for Thermal Imaging Consideration

1. Do not buy an imager that you cannot point directly at flames without damaging the optics or the electronic components of the thermal imager.
2. Image quality is extremely important for the user to distinguish between objects and people.
3. Thermal imagers should have good thermal sensitivity; they should be able to see the heat signature of a person's footprints on carpet after they have walked by with shoes on.
4. Two-three bottles of air per battery change is a good goal. However, it is recommended rule of thumb to change battery with each air bottle change
5. The image should not "white-out" in high heat, if so, the unit should be able to reset itself if pointed away from the direct emitter.
6. Imagers with dual battery system (run off AA's or rechargeable). Batteries should indicate a full charge, battery low condition, or operational time remaining in the viewfinder.
7. Imagers should have a wireless data link to broadcast images outside the fireground.
8. Take into account the overall size. A large, bulky unit will be difficult to handle.
9. Viewfinder size should be a consideration the bigger the better.
10. Temperature readout in the monitor and a warning icon if unit is overheating is valuable.
11. Units should have shoulder and hand straps, or capability to clip on to an air pack harness.
12. Shielding for on/off controls so the unit cannot be accidentally activated.
13. Thermal Camera's controls should remain simple, the simpler the better.
14. Consider the ability to change the battery in the smoke / limited visibility with gloved hands.

Chart derived from the following sources, Woodworth (1998, February, p.18), *Thermal Imaging for the Fire Service* (1997), and *Fire Rescue Magazine* (1998, May, p.75).

3. What are the financial considerations involved with each technology?

The final area researched was the financial aspect of thermal imaging acquisition. Newman and Irving (1973) reached the conclusion that larger municipal fire departments could justify a costly, large purchase item such as thermal imaging based upon frequency of use. However, Newman stated that smaller, rural fire departments would be pressed for the justification of such an expense. In the survey instrument used, 67 fire departments responded, of this 26.8% (18) possess or are acquiring thermal imaging. Municipal, paid city fire departments only accounted for three (3) departments in the Rhode Island or 16.6%. The remaining 83.3% (15) departments are classified as small municipal paid, combination or volunteer based. This appears that in Rhode Island the converse is true of Newman's justification statement of 1973.

McLaughlin (1992) also noted that a major disadvantage to acquisition of thermal imaging is the cost. In the survey of fire departments in Rhode Island, 64.1% (43) of respondents reported cost as the primary obstacle in the purchase of thermal imaging.

In the writings of Wagner and West (1998), manufacturers provided two reasons for the high price tag on these units. The first was the high production costs, associated low volumes, and limited outside additional market. Kerri Gordon, Cairnsiris product manger stated, " the pricing of these cameras is all driven by volume" (Wagner and West, 1998). The second cost factor identified by these authors was the cost of the ceramic chip technology and the rare element germanium used in lens construction for high costs.

Stevens (1996) made a thought provoking statement in *Firefighter News.* Many of people had marveled at the thermal imaging technology utilized in the Persian Gulf Conflict, but only a limited number of fire departments have placed in the hands of the firefighters. The author asks the question, " Does command care?"(p.6) He goes on to state that maybe a firefighter's life is not important to the people controlling the purse strings within the fire department. Stevens compares the price of a command rig or a commercial versus custom chassis as the difference between seeing a down firefighter or not.

Cairns and Brothers, the manufacturer of the Iris system has assembled a fundraiser kit. Cairns reported that 60% of all orders received are a result of fundraisers (Wagner and West, 1998). Thomas E. Patterson, Assistant Chief of the Houston, Texas Fire Department, EFO paper (1997), reported that 61% of the 22 departments responding to the survey raised funds through alternately budgetary methods. Only 27% used a budget method to finance the purchase. In Rhode Island, the survey results indicated that of the 18 units in service, 22.2% (4) were acquired through budgetary process. The remaining 14 (77.8%) units were obtained by grants, donations, or fundraising activities. The locally received survey results received replicated Patterson's Executive Fire Officer survey of 1997, which had surveyed fire departments throughout the Untied States.

Maine Fire Training and Education Division newsletter, *Thermal Imaging for the Fire Service* (1997, September) has a stated goal to place 300 thermal imaging cameras with Maine's fire departments within three years (p.5). The expressed purpose of this operation is to identify sources of grants, and donations to assist fire departments acquisition of thermal imaging cameras. This newsletter reports that 80% of departments are using fundraisers as a method to purchase thermal imagers. Methods of fundraising listed include: bottle drives, private grants, private donations, raffles, fill the boot, dances, club donations, car washes, phone solicitation, dinners, and letters writing campaigns.

The completed surveys received indicated that 77.8% of the Rhode Island Fire Departments had indicated funding by the utilization of several of these methods. Fire Departments reported the methods used included a receipt of a Champlin Grant; a local charitable source, Rotary and Lions Club donations, individual private donations, and public fundraising activities.

DISCUSSION

The literature review conducted in this research paper was in agreement with the TIC survey tool used in this paper. The survey instrument indicated that 77.7% of those who have thermal imagers in place used alternate methods of purchase beyond traditional tax supported measures. This was in direct agreement with Cairns (1993) statement that 60% of their purchases are through fundraising activities. In addition, the survey conducted by this author replicates Patterson EFO paper (1997) results of 61% of 40 departments used fundraising method to acquire thermal imagers. This non-traditional way of funding is new to the North Providence Fire Department. However, new does mean impossible for the organization to perform with proper planning and coordination.

Cogan (1992) stated several applications of thermal imaging cameras including locating overheated motors, duct fires, defective florescent fixtures and hidden fires. All these stated applications collaborated by respondents in the survey conducted of actual cases where thermal imaging was used by local fire departments. This provided an application advantage that can be interpreted as a universal application of thermal imaging.

In Woodworth (1997, February) article, a comparison of technology was made. This author further went on to state additional features that thermal imagers should posses. In the survey instrument used, departments that had imagers in service had all considered these features in the acquisition process. Any decision by the North Providence Fire Department should be based upon the experiences of others so lessons learned can be repeated with success.

Fire Rescue Magazine (1998,May), provided the research with eleven applications of thermal imaging by the fire service. Again, the survey indicated that local departments were using their TIC in many of the areas suggested by the author. This article provided factors to consider in when purchasing an imager, and can be found on page 45 in this paper labeled as Table Three. The information contained in Table Two in this paper on page 42, would allow the proposed committee to compare facets of each thermal imager technology. *Fire Rescue Magazine* (1998, April) also provided a chart that would further assist the organization in comparing the types of technology, and was influential in creating Table One, on page 36 of this paper.

The lack of technology can be traced to the element of change. Woodworth (1995), stated, thermal imaging is not new, but it has not been applied to the fire service. *Fire Rescue Magazine* (1998, April) stated that perhaps a lack of awareness of the potential benefits of TIC. All departments surveyed indicated that they had considered TIC. The survey indicated only 22.2% (18) have imagers in place, with a 64% placing funding as an obstacle to purchase. The fire department organizations must question this rational. Lyons and Parmenter (1995) stated the similarities of breathing apparatus introduction. Air packs, regarded as necessary for safety, are in place by a majority of today's fire departments. However, cost delayed their implementation in the early days. An organization must question the lack of thermal imaging application delayed by awareness and cost alone.

The North Providence Fire Department and the fire service in general, must recognize the benefits of changes in technology. These changes can improve the overall operational efficiency of the fire department and improve safety. The organization should view change as a force to be dealt with, not hidden by the excuses of funding or lack of awareness. Remaining current, organizations must expect the resistance, anticipate, and forecast the implications change. Organizations must recognize this need for innovation in technology called thermal imaging, and apply its advantages.

RECOMMENDATIONS

The Town of North Providence should begin the process of evaluating thermal imaging cameras for the fire department. The leadership must continue to advance the department's capability with advancements in technology. The fire department should take full advantage of the well documented opportunities that a thermal imaging camera would offer the service. The benefits associated with thermal imaging are often overlooked because of the resistance to change, or even hidden by the excuse of cost. These barriers to implementation must be broken down.

The importance thermal imaging would be communicated to all department members to bring forth universal acceptance of this technological change. The purchase of this technology must be presented to the taxpayers as a cost efficient move as well as, an opportunity to improve the safety of the community and the firefighters.

The department should establish a committee to evaluate thermal imaging technology. As demonstrated by other successful fire departments, 100% of those fire departments surveyed who have a thermal imager utilized a committee format for the decision making process. A committee process was previously used by the department with the advance life support implementation program in the1980's with great success. The committee had a membership which was representative of the entire EMS/Fire section and the community .The actions of this group were well received by the department's members because of a shared well communicated purpose.

This committee should have a three-fold purpose. The first purpose is to evaluate the needs of the department and match these needs to various types of imagers. The committee can use Table One to compare hand held units and helmet mounted units, and Table Two to compare the technological facets of each type of unit. In addition, the members can apply the evaluation questions on Table Three to compare each unit. Using Table Four, cited below, committee members can contact the manufacturer's representatives for further demonstrations and information.

Table Four

Manufacturer's Information ***As 29 December 1998***			
Manufacturer	**Model(s)**	**Phone**	Misc.
Cairns & Brother Inc.	Iris	800-422-4767	Helmet system
Mine Safety Appliances	Argus	800-672-2222	Handheld
International Safety Instruments	Vision 3	888-474-7233	Handheld (Vision 3)
E.D. Bullard	Bullard	800-827-0423	Handheld
Texas Instruments	Palm IR	888-474-7233	Handheld
Scott	Eagle	704-282-8400	No Data Received as of 01-01-99
Texas Instruments	Night Sight	972-243-3307	Truck Mounted Crash Fire Rescue Vehicle Mount System.

Actual field tests of the units would be conducted using acquired structures to field test all models considered. As the survey conducted in this paper, indicated 100% of the responding departments with thermal imaging cameras had the manufacturer's representatives present the various units to committee. A field demonstration would be arranged, to test the units before purchase was made. Input from members would be sought and evaluated before final purchase decision was reached.

The second purpose of the committee would be consideration of the funding for this unit. Render (1997) in his writings reported that volunteer firefighters, with the assistance of a committee raised enough funds for the purchase of a thermal imager. The committee can use Table Two to compare costs associated with each technology. In addition, contact the various manufacturer's for current pricing of each unit. This could be accomplished through a variety of means, budgetary, grants, fundraising, and donations. The committee would contact neighboring departments to compare methods used and success of each. The committee would set goals and bench marks for obtaining this technology, again communicating this to all members. The committee would actively campaign through various media and community groups the importance of this thermal imaging camera to the town. Input would be sought from manufacturers on their ideas for funding, publicity, and media available from them.

The last action of the committee would be to implement a training program for the thermal imager before placement on apparatus. As previously discussed by Woodworth, this is a tool, and the successful operation of thermal imaging is dependent upon the training of the operator. Additional research should be conducted to determine the training aspect of thermal imaging cameras and technology in the fire service. Contact would be made with Maine's Fire, Training and Education division to obtain their training program. Training packages obtained from the various manufacturers could assist in the development of training resources. Cairns and Brothers is known to offer a special school for their system. The NFPA should possibly consider appropriate standards for this tool similar to the standards for SCBA, PASS and turnout protection.

This research paper has provided evidence to support a recommendation for thermal imaging for the North Providence Fire Department. In addition, tools have been given to a committee to evaluate, fund, and consider the training necessary for the introduction of this technological advanced tool of safety.

Appendix A

Chief of Department / Training Director
0000 Street
City/Town, State 00000-0000

Chief of Department/ Training Director:

I am conducting a survey of Fire Departments surrounding the Town of North Providence, and the State of Rhode Island. The survey is regarding the use or consideration of *Thermal Imaging Cameras in the Fire Service.* The survey has also been given to departments that are in the process of obtaining or have units already in service. The purpose of this survey is to examine the opinions of experts in the Rhode Island Fire Service such as you. In particular, I am examining factors, which led to the purchasing of this type of technology. In addition, I have requested information on how your department secured funding for this purchase. Your answers will assist the North Providence Fire Department on making informed decisions on the purchase and use of Thermal Imaging.

Please take a few minutes to fill out the enclosed questionnaire and return it in the self-addressed reply envelope at your earliest convenience. If you are interested in receiving a copy of the National Fire Academy's Executive Fire Officer Project, please indicate this on the last page of the questionnaire with a mailing address

Thank you In Advance,

John N. Carnegis, Captain
North Providence Fire Department

<u>APPENDIX B</u>

NATIONAL FIRE ACADEMY
EXECUTIVE FIRE OFFICER PROGRAM
APPLIED RESEARCH PROJECT

Course: Executive Development

Subject Matter: Thermal Imaging For the Fire Service

Survey Questions: Fire Chiefs/ Training Officers

The purpose of this survey is to obtain opinions and perspectives on the subject of thermal imaging units for the fire service. These surveys are to be collected from individual fire departments that surround the Town of North Providence Fire Department that have made a recent purchase or are considering the purchase of a thermal imaging camera (TIC). The results of this survey will be included in an applied research project for the National Fire Academy's Executive Fire Officer Program. Please answer the following questions:

<u>Part One</u> *All Departments Please answer:*

<u>Department Responding:</u> ____________________________ *Type: Paid ___ Call Volunteer __*
Combination_____

1. Does your department currently own a Thermal Imager Camera? Yes____ No ____

2. If not, does your department plan to purchase one? Yes____ No ____

3. If no purchase is planned, check the primary factor: Cost_____

   Lack of Need____

   Other ______

<u>Part Two</u> *Only Departments with Thermal Units on board or on order please answer:*

1. How did your department arrive at the decision to purchase a thermal imaging camera?

   Committee_____

   Chief _____

   Officers _____

   Other _____

2. What led you to consider the purchase of a TIC?

____

____

____

2. What factors were considered in purchasing the unit?

   ____

   ____

   ____

3. What type of unit do you have or are considering to purchase? _______________________

4. How did your department fund the purchase? Budget Item_____ Capital Financed ____

   Fund Raiser______ Other ________

   Grants, or Donations ________

Part Three Only for fire departments with Thermal Imaging Cameras in use.

1. How long has the unit been in service? ______

2. Have you had any technical trouble with the TIC? ___________________________

3. Do you carry spare batteries? Yes ______ No _______

4. What are the advantages of the Thermal Imaging to your department?

____

____

5. Have any of the following occurred?

White Out ________ Extensive Maintenance ______ Tube or Screen Repair______

Other Disadvantages noted: ____

____

6. How does your department use the TIC? (In what role(s))

____

____

7. Finally, do you have any reports on how the Thermal Imaging has helped you on the scene.

____

____

8. Copy of Final Report Requested: Mailing Address _______________________________

____

Thank you for your assistance.

APPENDIX C

Thermal Imaging Survey
Rhode Island December 1988

Department	Type Of Department			TIC	Planned	Limiting Factor	
	Paid	*Volunteer*	*Combination*			*Cost*	*Other*
Barrington	1			1			
Bristol		1		0	0	1	
Burrilville- Harrisville		1		0	0	1	
Burrilville- Nasonville		1		0	0		1
Burrilville-Oakland-Mapleville		1		0	0	1	1
Burrilville- Pascoag		1		0	0	1	
Central Falls	1			1			
Coventry- Anthony			1	0	1	1	
Coventry- Central			1	0	0	1	
Coventry- Harris			1	0	0	1	
Coventry- Hopkins Hill			1	1			
Coventry- Tiogue			1	0	0		1
Coventry- Washington			1	0	0	1	
Coventry- Western Coventry		1		0	0	1	
Cranston	1			0	0	1	
Cumberland- Fire District			1	1			
Cumberland-Cumberland Hill			1	1			
Cumberland- N. Cumberland			1	0	0		1
Cumberland- Valley Falls			1	0	0	1	
East Greenwich			1	0	1	1	
East Providence	1			0			
Foster-South		1		0	0	1	
Glocester- Chepachet		1		0	0	1	
Glocester-Harmony		1		0	0	1	
Glocester- West		1		0	0	1	
Hopkinton- HVFD		1		0	0	1	
Hopkinton-Ashaway		1		0	1	1	
Jamestown		1		0	0	1	
Johnston	1			1			
Kingston		1		0	1	1	
Lincoln- Albion			1	0	0	1	
Lincoln- Limerock			1	0	0	1	
Lincoln-Lonsdale			1	0	0	1	
Lincoln- Manville		1		0	0	1	
Lincoln- Saylesville			1	0	0	1	
Little Compton		1		0	0	1	
Middletown	1			0	1		1
Narragansett	1			0	0	1	
Newport	1			1	0		
New Shoreham		1		1	0	1	
North Kingstown	1			0	0	1	
North Providence	1			0	1	1	
North Smithfield			1	0	0		1
North Smithfield-Primrose			1	1			

Department	Paid	Volunteer	Combination	TIC	Planned	Cost	Other
Pawtucket	1			1			
Portsmouth	1			1			
Providence	1			1			
Richmond		1		0	0	1	
Scituate- North		1		1			
Scituate- Hope- Jackson		1		1			
Scituate- Potterville		1		0	0	1	1
Scituate-Chopmist Hill		1		0	0	1	1
Smithfield	1			0	1		
South Kingston		1		0	1		
Tiverton			1	0	1		
Warren		1		1			
Warwick	1			0	0	1	
Westerly- Bradford		1		0	0	1	
Westerly- Dunn's		1		0	0	1	
Westerly- Misquamicut		1		0	0	1	
Westerly-Watch Hill		1		0	0	1	
West Warwick	1			0	0	1	
Westerly		1		0	0	1	
Woonsocket	1			0	0	1	
RI Air Guard	1			1	0	1	
RI Airport Corp.	1			1	0		
U.S. Navy	1			1	0	1	
Totals	20	29	18	18	9	43	8

Department	**Type of TIC**	**Type TIC**	**Type TIC**		**Decision Method**	**Funding Method**			
	Helmet	*Hand*	*Truck*	*Unsure*		*Fundraiser*	*Budget*	*Grants*	*Capital*
Barrington	1				1	1			
Bristol									
Burrilville- Harrisville									
Burrilville- Nasonville									
Burrilville-Oakland-Mapleville									
Burrilville- Pascoag									
Central Falls	1				1	1			
Coventry- Anthony									
Coventry- Central									
Coventry- Harris									
Coventry- Hopkins Hill	1				1	1			
Coventry- Tiogue									
Coventry- Washington									
Coventry- Western Coventry									
Cranston									
Cumberland- Fire District									
Cumberland-Cumberland Hill	1				1	1			
Cumberland- N. Cumberland									
Cumberland- Valley Falls									
East Greenwich									
East Providence		1			1			1	

Department	Helmet	Hand	Truck	Unsure	Decision	Fundraiser	Budget	Grants	Capital
Foster-South									
Glocester- Chepachet									
Glocester-Harmony									
Glocester- West									
Hopkinton- HVFD	1				1	1			
Hopkinton-Ashaway	1				1		1		
Jamestown									
Johnston									
Kingston									
Lincoln- Albion									
Lincoln- Limerock									
Lincoln-Lonsdale									
Lincoln- Manville									
Lincoln- Saylesville									
Little Compton									
Middletown									
Narragansett									
Newport		1			1	1			
New Shoreham				1					
North Kingstown									
North Providence									
North Smithfield									
Nortrh Smithfield-Primrose									
Pawtucket									
Portsmouth									
Providence					1	1			
Richmond									
Scituate- North	1				1	1			
Scituate- Hope- Jackson	1				1	1			
Scituate- Potterville									
Scituate-Chopmist Hill									
Smithfield									1
South Kingston		1			1		1		1
Tiverton	1				1		1		
Warren	1				1	1			
Warwick		1			1	1	1		
Westerly- Bradford									
Westerly- Dunn's		1			1			1	
Westerly- Misquamicut		1			1			1	
Westerly-Watch Hill									
West Warwick									
Westerly					1				
Woonsocket					1				
RI Air Guard					1	1			
RI Airport Corp.		1			1	1			
U.S. Navy									
Totals	**8**	**8**	**1**	**1**	**19**	**11**	**4**	**3**	**2**

Based upon information received
As of December 1998

Thermal Imaging Survey

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