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Thermal Imaging Research Needs for First Responders: Workshop Proceedings

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ABSTRACT

This workshop provided a forum to discuss the strategies, technologies, procedures, best practices, research, and development that can significantly improve thermal imaging technology for the first responder community. The goal of the workshop was to identify barriers that impede advances in the application of thermal imaging technology to emergency response. The program included experts from the first responder community, thermal imaging camera and component manufacturers, fire fighter trainers, and those doing research on thermal imaging, speaking on today's safety challenges.

After hearing presentations, the workshop divided into three breakout sessions to discuss the following four questions:

What technological advances are needed?
What are the research needs for first responders?
What performance metrics are needed and how do they differ from current methods?
What standards are needed?

The results of each groups' deliberations were discussed when the full workshop reconvened. The responses from each group were coalesced and listed so that attendees could vote on the issues that they felt were most important. Attendees were grouped by their affiliation with industry or the first responder community. The combination of issues that relate to image quality (a collection of research, performance metrics, and standards needs) was voted to be the most important topic overall, and the most important subject for industry representatives. The development of camera durability (or ruggedness) metrics and standard testing methods was the second-most important subject overall, and the second-most important subject for industry representatives. Training and certification for personnel, and human factor/dynamics/ergonomic research were the first and second-most important topics for first responders.

Keywords: thermal imager, evaluation, performance metrics, heat detection, fire fighting, first responder, infrared camera, focal plane array

ACKNOWLEDGEMENTS

The success of any workshop is dependent on the hard work of the individual speakers, facilitators, and participants. These proceedings are an assimilation of the contributions from everyone involved in the workshop; copies of the presentations are included in Appendix 3. Thanks to all who made presentations and to those who participated in the workshop.

Special thanks go to Chief Brian Duggan of the Northampton Fire Department, Larry Konsin of the American Council for Thermal Imaging, and Chief Bruce Varner of the Santa Rosa Fire Department, who served as chairs of the breakout sessions and helped bring focus to the discussions. In addition, we wish to acknowledge the assistance of Ms. Ellen Altman of NIST, who helped with logistics.

TABLE OF CONTENTS page

THERMAL IMAGING RESEARCH NEEDS FOR FIRST RESPONDERS

INTRODUCTION

Historical overview

The inherent desire to see in the dark or in obscured conditions has been a part of humanity throughout history. Compelling reasons for acquiring this ability have evolved over the ages, ranging from the need to see predators or other dangers in the dark, to the need to identify victims or hot spots in burning structures. While a simple torch may have sufficed to address the former need, an infrared (IR) camera, or thermal imaging camera (TIC), may be necessary to fulfill the latter. Thermal imaging science has progressed significantly, especially over the past 80 years, and now thermal imagers are routinely used in a wide range of applications.

The concept of thermal imaging followed quickly on the heels of the development of visible imaging (television) in the 1920s. Military applications drove advancements in thermal imaging and low-light image intensifiers to the point that, in the mid-1940s, the first IR line scanner was produced that could create a two-dimensional thermal image. Improvements in detector materials and electronics continued, particularly in the 1960s, resulting in the development of Forward Looking InfraRed (FLIR) imaging cameras. These cameras produce high quality images, however, their detectors require cryogenic cooling to obtain acceptable sensitivity. In the 1970s and 1980s, military-funded commercial interests developed detectors that don't require cryogenic cooling, eventually leading to the production of uncooled solid-state imaging arrays [1]. Since the declassification of this work in 1992, new thermal imaging applications that exploit the lower-cost, smaller-format, uncooled imaging arrays have expanded into many areas, including preventive maintenance, process and quality control, non-destructive testing, driver/pilot vision enhancement, law enforcement, hazardous chemical detection, and fire fighting. The world market for commercial (including first responders) and dual-use military IR imaging is approximately $1 billion and is growing 10 % to 20 % annually [2]. Within this large commercial and military thermal imaging market, first responder TICs do not currently have enough market share to drive the development of specialized IR sensor technology.

The potential benefits of thermal imaging to fire fighters, essentially giving vision to the blind, became evident in the early to mid 1990s. Since then IR technology for first responder applications has matured to the point that most emergency response organizations either have purchased or are considering the purchase of TICs.

There is very little documented information available on performance evaluations of thermal imagers used in fire environments. One exception is a rigorous series of tests performed on commercially available thermal imagers by the U. S. Navy in 1998 [3]. The Navy tests were primarily designed to identify imagers that were robust enough to function in the harsh environment of a fire onboard a ship. The study considered 27 operational requirements and tested cameras provided by 7 manufacturers. Performance evaluations have been ongoing at NIST for the past two years, in which images from TICs having different detector types are compared in a variety of conditions. Preliminary results from these tests show that the image quality varies between detector types and between TICs for different conditions. An example of the differences found in image quality is given in Figure 1, in which three TICs are viewing an identical scene. While each TIC provides valuable information on the location of hot gases and fire, the amount of information available to an observer differs considerably between the three TICs. There are many factors other than image quality to consider when making a purchasing decision, such as size, weight, cost, ease of operation, etc…

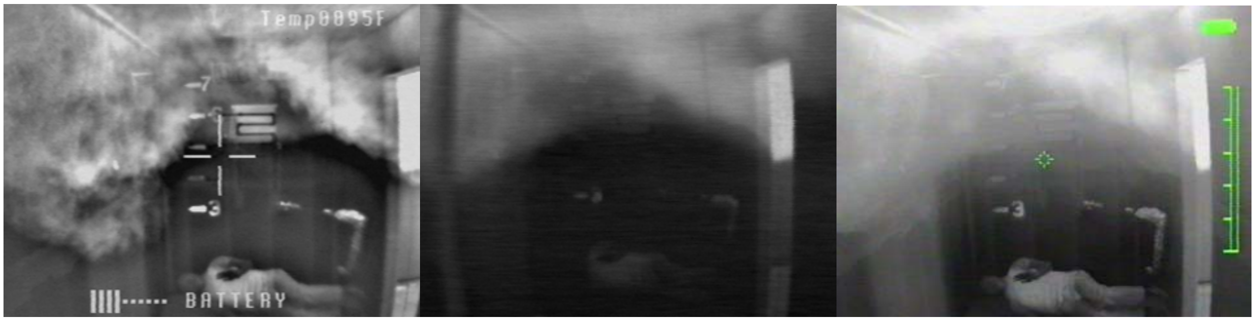

Figure 1. View of a corridor with a heated mannequin on the floor, and a temperature target and reflective strips on the back wall. Hot, smoke-laden gases are entering the corridor from an adjacent room on the right. The three TICs are viewing an identical scene at the same moment.

Thermal imagers are a significant tool for the fire service, enabling fire fighters to find their way out of burning structures, locate fires and victims, provide guidance to fire attack teams, and perform overhaul operations and fire investigations more effectively [4]. Beginning in fiscal year 2001, the United States government established the Assistance to Fire Fighters Grant Program (AFG) to provide assistance to fire fighters and enhance their ability to protect against fire and fire-related hazards. One-year grants have been awarded to help meet fire departments' fire fighting and emergency response needs. For the 2004 program year, Congress appropriated $750,000,000 and transferred the program's authority from the Federal Emergency Management Agency and the United States Fire Administration to the Office for Domestic Preparedness within the Department of Homeland Security (DHS) [5]. Under the AFG program, fire departments applying for equipment acquisition assistance in the "Operations and Fire Fighter Safety" focus area are allowed to purchase up to three TICs, depending on the population of the communities they serve.

Thermal imager characteristics for first responder applications

Certain characteristics are desirable for thermal imaging applications in which the user encounters harsh or visually obstructed environments. For example, fire fighters may need to utilize a thermal imager to maneuver within a burning structure. Therefore, a wide field of view is beneficial. Temperature measurements may provide useful information in a fire, such as permitting a fire fighter to decide whether or not it is safe to enter a room based on the temperature of the surfaces, the rate of change of the upper layer temperature, or the location of hot spots.

Most thermal imagers used by the fire service employ two sensitivity modes: a sensitive mode for viewing scenes in which the range of temperatures* is relatively small, and a less sensitive mode for scenes with large temperature ranges. The ability of the camera itself to withstand high temperatures is also an important design consideration. Given the severity of the physical conditions in which these cameras are used, they must be robust enough to resist damage from water, abrasion, and impact. The display refresh rate is important in applications in which the camera operator may be moving and/or constantly scanning the scene.

The stress of a fire event also dictates the need to keep the operation of the imager as simple as possible. Most imagers feature fully automated gain and focus settings, sometimes offering no more controls than a large on/off button that can easily be accessed by a fire fighter wearing heavy gloves. In some cases, the imager may have one or two added capabilities, such as a zoom button or a toggle between IR and visible viewing.

The camera's IR sensor (or detector) is a critical component. There are currently two well-established detector technologies and three sensing materials available in TICs designed for first responder applications: detectors made of a ferroelectric ceramic, usually a barium-strontium-titanate (BST) blend; and microbolometers utilizing thin films with either vanadium oxide (VOx) or amorphous silicon (ASi) as the sensing material. The optical system provides an interface between the signal processor and the recorded image, and is important to the overall performance of the instrument. Camera manufacturers may offer a single detector technology or may choose to offer a selection of thermal imager models using different technologies. A diagram of the principal imager components is shown in Figure 2.

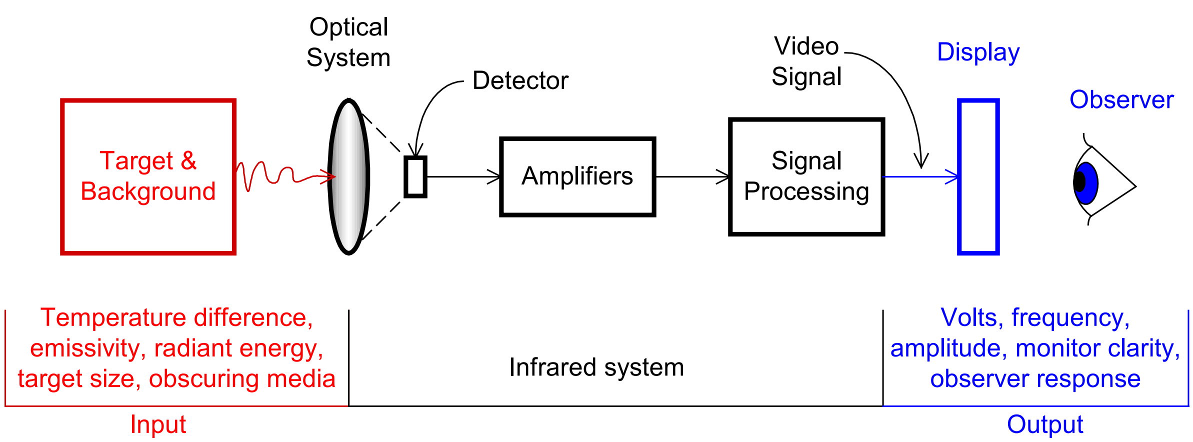

Figure 2. Principle TIC components. An image is projected into the optical system and focused on the detector. The detector converts the image into an electrical signal and conditions the signal for output to the display.

* The detectors in thermal imagers actually respond to differences in radiated energy, which is related to the temperature of an object's surface.

First responder thermal imaging uses

TICs represent a significant investment, typically on the order of \$10,000 per camera. Most consumers, however, have little guidance on instrument performance beyond manufacturer literature and recommendations from other users [6]. This issue is further complicated because the demands placed on thermal imagers are application dependent. First responders may use thermal imagers for search, rescue, target identification, helicopter pilot or vehicle driver vision enhancement, as a tactical decision aid, wildland size up, hot ballast and hidden fire identification, code compliance, as a diagnostic tool for emergency medical personnel, or as a command and control tool for incident commanders. With the variety of uses, the end users may have very different ideas about which imaging properties are most important; sharp image contrast may be sufficient for fire fighting applications but advanced fire detection systems may require collection of quantitative data from IR imagers. Currently, there are no performance guidelines available to aid end users in making purchasing decisions.

Thermal imaging standards

The National Fire Protection Association (NFPA)[†] is currently drafting an umbrella standard on electronic safety equipment for emergency services, which includes the electronics embedded in TICs. Due to the relatively complex nature of thermal imagers, it is anticipated that a future NFPA standard will be published specifically to address TICs. The American Society for Testing and Materials (ASTM) has published several testing standards that apply to thermal imaging performance and may be useful, if modified, for first responder applications [7-10]. For example, ASTM Standard E 1543-00, "Standard Test Method for Noise Equivalent Temperature Difference of Thermal Imaging Systems," might be modified to include a test series in which the target temperature ranges from ambient to 400 ºC and the temperature of the camera itself is increased from ambient to 50 ºC. The NFPA Technical Committee is free to consider inclusion of existing test standards that bear on thermal imager performance for incorporation into a new thermal imager standard.

The establishment of comprehensive, understandable, consistent performance evaluation methods and reporting practices will benefit the first responder community by enabling users to identify thermal imaging equipment that best suits their needs. Several categories of standards exist. Design standards ensure that thermal imagers employ particular types of signals, electronics, power isolation, intrinsic safety considerations, etc. In line with the AFG program, which states "Equipment that promotes interoperability with neighboring jurisdictions may receive additional consideration in the cost-benefit assessment…", standards that require consistency in user interfaces, such as button types and color, display icons, and switches stand to benefit first responders in situations in which several agencies or departments respond to an event. Performance standards prescribe the actual testing criteria used to evaluate the performance of the instrument. The harsh environment in which TICs are used in first responder applications must be considered in the development of performance standards, particularly with respect to such issues as temperature stress, impact resistance, heat and flame resistance, and immersion/leakage, among others. Standardized test methods state specifically how each test is to be performed. Non-binding information, such as best practice suggestions for selection, care, and maintenance may be included in the text or appendices of a standard as well.

[†] NFPA Technical Committee for Electronic Safety Equipment (FAE/ELS)

WORKSHOP ORGANIZATION AND OBJECTIVES

This workshop provided a forum to discuss the strategies, technologies, procedures, best practices, research, and development that can significantly improve fire protection and first responder safety and effectiveness through the sensible development of thermal imaging technology. The participants included experts from the first responder community, TIC and component manufacturers, fire fighter trainers, and those doing research on thermal imaging. Many of the participants were involved in thermal imaging in multiple ways, enabling them to discuss thermal imaging needs from a variety of perspectives. The workshop agenda and a list of attendees are provided in Appendices 1 and 2, respectively. The viewgraphs and abstracts for each presentation are provided in Appendix 3.

The goals of the workshop, outlined in the workshop agenda in Appendix 3A, were to identify barriers that impede advances in the application of thermal imaging technology to emergency response. In this regard, the workshop explored:

- Recent Developments in Thermal Imaging Technology
- Uses of Thermal Imaging during Emergency Operations
- Special needs for Fire Service Applications
- End-User Performance Priorities
- Characterization of Thermal Imaging Performance
- The Role of Standards Developing Organizations
- Federal Agency Activity
- Opportunities for Collaboration

After the workshop goals were reviewed, the first technical session of presentations was devoted to end users. These presentations are found in Appendices 3B-3D. Presenters were asked to address the way they currently use and make purchasing decisions for TICs, which technical and physical qualities they find important, and the value of features such as colorized images, zoom, and toggles for image appearance. The end users indicated a need for low cost, ease of use, reliability, and consistency in user interfaces.

In the second session, camera and detector manufacturers discussed the technological trade-offs that manufacturers face in the development of TICs, the difficulties, value, and methods of conducting performance testing on thermal imagers, their vision of the future with regard to technological advances, and critical issues related to developing industry-wide performance standards. These presentations are found in Appendices 3E-3F. TIC manufacturers reported that they must consider the relatively small fire service/first responder market and the harsh environment in which the cameras are used when making design decisions. The development of operational performance standards was something that both the end users and camera manufacturers agreed is important. Detector manufacturers predicted that imagers will decrease in size, weight, power requirements, and cost, and increase in resolution, thermal sensitivity, and the range of conditions at which the detectors can operate effectively.

The third session was comprised of presentations on government agency involvement and the way consensus standards are developed. These presentations are found in Appendices 3G-3H.

Involvement in funding of thermal imaging standards for first responders and related work by the Department of Homeland Security and Office of Law Enforcement Standards was presented[‡]. The U. S. Navy has done research using thermal imaging technology for damage control and situational awareness [3]. The ASTM approach to forming consensus standards and the value of such standards was explained.

The last session of presentations focused on thermal imaging science and research. These presentations are found in Appendices 3I-3K. There are several projects underway at NIST that support fire fighter technologies: the development of a heat transfer model and new materials for protective clothing, a structural collapse prediction tool, tactical decision aids, and virtual fire fighter training software. In addition to these projects, NIST is investigating the effectiveness of various optical performance metrics applicable to TICs used in first responder applications. Advanced experimental methods, such as testing of detector spectral responsivity, are being studied in the Physics Laboratory at NIST. Research is also being conducted at the Night Vision Laboratory, a research laboratory associated with the U. S. Army[§].

After the presentations, the workshop participants were divided into three groups. Each group was composed of representatives from industry, the first responder community, and the scientific community. The groups were asked to respond to these four questions:

- What technological advances are needed?
- What are the research needs for first responders?
- What performance metrics are needed and how do they differ from current methods?
- What standards are needed?

A chairperson (Chief Brian Duggan, Larry Konsin, and Chief Bruce Varner) moderated each group. The results of each group's discussion were combined and discussed when the workshop reconvened, and a vote was taken to prioritize the responses to the questions. An analysis of the results is presented in the following section.

[§] This presentation is not included in Appendix 3 at the request of the speaker.

BREAKOUT GROUP RESULTS

The unanalyzed results of the breakout group discussions are located in Appendix 4A. These results reflect more than simple answers to the discussion questions; in some cases the items listed are important points or questions raised through discussion within the breakout groups and, as such, may not be a direct answer to the question at hand. As the discussions proceeded, it became clear that some items were relevant in multiple categories. A logical order to the questions was revealed as the sessions continued. A wish list of technology advancements set the stage for the discussion of technological research needs, as well as the research needed to allow adequate measurement of the performance of thermal imagers. These topics dovetailed with the identification of performance metrics that evolved from discussion of needed standards. In deference to this logic, the results will be discussed following this order. Discussion question responses were prioritized when the groups reconvened at the end of the workshop.

Commonalities among the results of the three groups were apparent when the breakout groups reconvened. The same response wasn't always listed in exactly the same manner among all groups, but there was significant overlap among the groups. Conversely, identically listed responses may have had different meanings when taken within the context of the group discussion. Therefore, commonalities between groups are presented in general categories, with related issues listed in the 'scope' column of Tables 1 - 4. The number of working groups that contributed to the items listed in a category is indicated in the 'groups' column. A complete listing of breakout group notes is presented in Appendix 4A.

Table 1. Responses to "What technological advancements for IR imagers are needed?"

Category	**Scope**	**Groups**
Battery & Charger	Remaining time indicator in minutes, smart and durable charger technology, static vs. show time, longer battery life with no maintenance	3
Image & Display	Coatings or automatic shutter for lens & display. Is better display necessary? Does sensor or display limit image quality? Heads-up display, info on the screen, display self-test, more informative icons, broader temperature displays, automated pattern recognition and/or image interpretation, image fusion (visible and IR)	3
Imager	low-cost with water bottle (sized) packaging and/or hands-free operation, self-test, reliability, less mass, testing instrumentation, housing ruggedness, immediate needs addressed, stay ON button (no sleep mode), manual Electronic Iris (EI) switch, depth perception/range finder	3
Sensor	Solid state technology improvements, AC and DC coupled sensors, application specific technology	2
Training	Advanced training technology	3
Comment: There should be no ceiling on technological advances		

Table 2. Responses to “What are the thermal imaging research needs for first responders?”

Category	Scope	Groups
Battery & Charger	User feedback, discharge curve, effect of fire on battery life, flammability, duration needs.	2
Image & Display	Degradation with exposure to environment and when viewing through soot and weather, compensation for ambient light, coatings for condensation & deposition, importance of image quality, appropriate field of view, refresh rate, contrast. Is display or sensor limiting? Scientific evaluations of image quality.	3
Imager	Emissivity settings, pattern recognition and object tracking, intrinsic safety, integration with other equipment, ergonomics and human factors, self-diagnostic testing, feasibility of injury evaluation, temperature display & accuracy/calibration.	3
Sensor	Better sensor material & circuitry for first responder application, lower cost, lower power requirement.	2
Testing Environment	Establish fire environment and operational conditions, live fire field tests, find failure points and limitations.	2

Table 3. Responses to “What performance metrics are needed for thermal imagers and how do they differ from current methods?”

Category	Scope	Groups
Battery & Charger	Battery heat test profile, Battery self test (minutes), Battery life (1.5 h to 2 h fire)	2
Image & Display	Scene dynamic range, image quality: test and quantify, display quality over temperature range, how the image is displayed (contrast), temperature accuracy, focal length, pixel saturation, sensitivity figure of merit, Noise Equivalent Temperature Difference (NETD), frame rate, quick & dirty target, field of view.	3
Imager	Reliability (mean time between failures), environmental limits of use, stability, subsystem metrics, ease of use, manual assembly lines.	3
Comment: Draw on existing metrics whenever possible.		

Table 4. Responses to "What standards are needed for thermal imagers?"

Category	Scope	Groups
Battery & Charger	Battery service guidelines, self-test, minimum life, types, and number.	3
Image & Display	Simple, quick field test/calibration. Image degradation due to smoke and dust. Standard test target. Image quality standards: contrast?	3
Imager	Accelerated life testing. Immersion, flame, corrosion, and impact resistance, temperature tolerance. Lens & display abrasion, condensation, and deposition. Housing inspection procedure, intrinsic safety testing, reliability, shall not cause or be affected by EMF/RF interference, limit transmission range to 90 m (300 ft.), out of range indicator, functionality across range of operation conditions, minimum operating criteria, require gloves-on operation, consideration of equipment integration, default settings.	3
Training	Dissect teaching requirement and set the standard. Training- a big step to see IR without fully understanding it.	2
User Interface	Consistent icons, switches, buttons. Default icons. Human factors: color scale, palette, gradients. Alarm if unit isn't working properly, maximum weight. American Council for Thermal Imaging (ACTI) group to lead follow-on study of user interface.	3
Comments: Draw on existing standards whenever possible. Standards need to be minimum to assure consistency and safety. Standards should not be design limiting; they should be a living document.		

A number of items appeared several times in response to multiple questions. For example, the need for better batteries, battery chargers, and battery life indicators crossed the boundaries between *technology advances*, battery and charger *research needs*, battery *performance metrics*, as well as *standards needs* for battery service guidelines, self-tests and minimum battery life. Several other items also appeared in several categories, including equipment integration (technological advances and research needs), reliability (technological advances, performance metrics and standards), and establishment of environmental limits of use (research, performance metrics, and standards).

Prioritization

The last activity on the agenda was to prioritize the topics that the attendees felt were most critical to address at this time. The responses from each group were coalesced and listed so that attendees could vote on the issues they felt were most important. Attendees were grouped by their closest affiliation, either with industry or with the first responder community. The complete results of the voting, normalized to the total number of votes per discussion question, are shown in Appendices 4B-4E. Items that received no votes are omitted from the discussion. The response to the individual discussion questions is discussed the following section and the overall voting results are discussed in the last section of this part of the proceedings.

Response to discussion questions

The votes cast for topics related to advancements in technology, which are listed in Table 1 and charted in Appendix 4B indicate that reducing the cost and size of thermal imagers through technological improvements was considered most important, especially among the first responders. Other technological advancements that received attention dealt largely with improvements in user interfaces and battery/charger technology.

Guidance for research in support of thermal imaging for first responders shows, in Table 2 and Appendix 4C, that the establishment of a typical operational environment is needed. Research in this area would lay the groundwork for developing meaningful metrics and standards on imager performance under conditions resembling those experienced by end users. Human factor research may include many aspects of the user interface, from the color and placement of buttons and display icons to novel methods of hands-free operation to reduction of imager size and weight. Research to find an appropriate means by which to measure imaging quality for first responder applications, and on developing a distinctive emissivity-based target for fire fighter turn-out gear was also found to be important.

Each of the performance metrics listed in Table 3 and Appendix 4D rely to some degree on the environment in which the imager is used. The sensitivity metric received twice the number of votes as its nearest competitor, and is particularly dependent on the imager's operating conditions because the detectors tend to become less sensitive when viewing a wide range of temperatures.

As seen in Table 4 and Appendix 4E, the most pressing need for standards is for training and certification of personnel. After that, image quality and imager durability standards, respectively, are desired. Once again, established operational conditions are needed to facilitate the development of these standards.

Overall thermal imaging priorities

In order to present the overall voting results in a manner in which reasonable conclusions can be made, some of the individual listings found in Appendices 4B-4E were combined into more general categories. For example, items related to image quality, such as image quality research, sensitivity metric, scene dynamic range metric, and image quality performance metric standard were lumped into a single bin labeled "image quality". Similarly, all entries that referred to batteries and chargers were lumped together into a single bin labeled "battery and charger". The information presented in Figure 1 is a result of combining the individual listings into naturally occurring categories. The reader is encouraged to peruse Appendix 4 to examine the voting results in their entirety. The key to the combination of voting results used to produce Figure 1 is found in Appendix 4F.

The overall voting results indicate that the combination of issues relating to image quality (research, performance metrics, and standards) was the most important topic overall, as well as the most important subject for industry representatives. Discussion during the workshop indicated that improving image quality makes TICs into more valuable and versatile tools. The development of camera durability (or ruggedness) metrics and standard testing methods was the second-most important subject overall, and the second-most important subject for industry representatives. Training and certification for personnel and human factor/dynamics/ergonomic research were the first and second-most important topics for first responders.

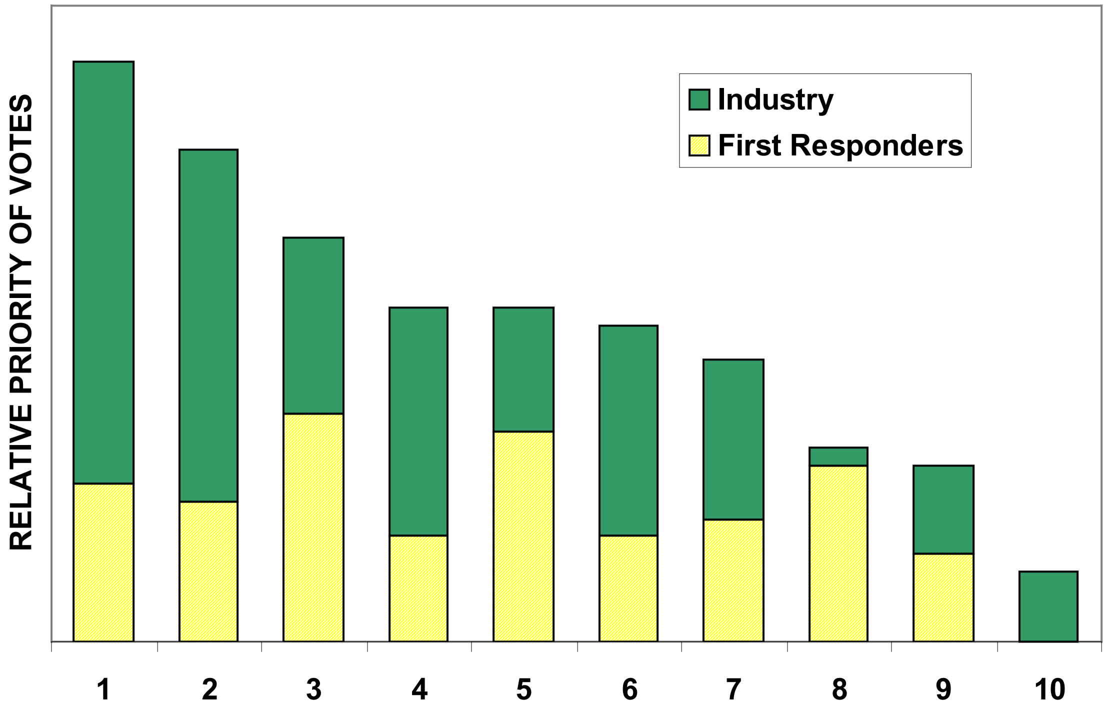

Figure 1. Total consolidated voting results (first responders and industry representatives). Votes are shown relative to the total number of votes.

Voting key for item numbers in abscissa of Figure 5.

1. Image quality (research, metrics, standards, contrast, sensitivity)
2. Durability (metric, MTBF, standard test methods for ruggedness)
3. Training and certification for personnel
4. Establish minimum/typical test environments
5. Human factor/ergonomic and human dynamics research
6. Image display (technology, viewability, metrics)
7. Battery and charger (life/maintenance, icons, and self-test improvements)
8. Reduction in imager cost ("water bottle" sized package priced at $2K)
9. Standard target (for field test/calibration and emissivity target for turnout gear)
10. Imager self-test procedure and warning system

CONCLUSIONS

The cost of thermal imagers was the leading topic with regard to technological advancements, and was an especially important issue for first responder organizations.

Establishing a typical set of testing conditions that adequately represent the operational environment was acknowledged as the most important research topic. Research in this area would lay the groundwork for developing meaningful metrics and standards for imager performance under conditions resembling those encountered by first responders.

Both the first responders and the industry representatives identified the need for a thermal sensitivity metric as being most critical with regard to thermal imager performance metrics.

The voting results showed that training and certification was the most important standards need. This topic was also the most important overall issue for first responders, although industry representatives also felt that this topic is critical.

Workshop participants also found that all aspects of batteries and battery chargers (technology, research, metrics, and standards) were important to the advancement of thermal imaging.

The overall voting results indicate that the combination of issues related to image quality (research, performance metrics, and standards) was the most important topic overall, as well as the most important subject for industry representatives. The development of camera durability (or ruggedness) metrics and standard testing methods was the second-most important subject overall, and the second-most important subject for industry representatives.

Training and certification for personnel, and human factor/dynamics/ergonomic research were the first and second-most important topics for first responders. These two topics are linked in the sense that uniformity in the user interface and ease of camera operation facilitates training and, ultimately, acceptance of thermal imagers by the end users. Human factor research also underlies the development of standards and performance metrics for user interfaces and drives the advancement of certain types of technology, such as display and hands-free technology.

FUTURE WORK

This workshop was a first attempt to gather representatives from many sectors of the thermal imaging first responder community and industry with the goal of identifying barriers that impede advances in the application of thermal imaging technology for first responders. Participants included representatives from the first responder community, TIC and component manufacturers, fire fighter trainers, and those doing thermal imaging research. The Workshop provided an opportunity for participants to learn from each other and to work together to guide future developments in thermal imaging. Where go we go from here?

At this time the first responder community does not have a market share of sufficient size to drive the development of major TIC components (e.g., detector and display) specifically suited to this application. However, as advances are made in IR technology, better technology will likely be available for the same cost.

The need for standardization of the TIC user interfaces, such as button type and color, display icons, battery life indicators, etc… has motivated interested parties to form a discussion group in order to lay the foundation for future design standards.

This workshop provided a strong foundation for follow-on efforts among government agencies, the first responder community, industry, and academia to:

- Further identify and refine research needs of the user community
- Develop performance standards that consider interoperability and integration
- Demonstrate performance metrics
- Create standards that will improve the usability and effectiveness of thermal imagers

Work is ongoing in each of these areas through NFPA and ASTM committees, industry and user groups, and at government laboratories including NVL, NRL and NIST. Through the efforts of these stakeholders to advance thermal imager use and technology, the safety of first responders and the general public can be improved, leading to reductions in losses due to catastrophic events. As these efforts gather momentum, new stakeholders and a wider scope of TIC usefulness may be identified, promoting further advancements in the application of thermal imaging technology for first responders.

REFERENCES

[1] R. G. Buser and M. F. Tompsett, Uncooled Infrared Imaging Arrays and Systems, Semiconductors and Semimetals **47**, Academic Press, Massachusetts (1997) p. 1-16.

[2] The World Market for Commercial & Dual-Use Military Infrared Imaging and Infrared Thermometry Equipment, Market Research Report IRW-C, Maxtech International, Inc., Fairfield, CT, 2004, 400 pp.

[3] F. Crowson, B. Gagnon, and S. Cockerham, Evaluation of Commercially Available Thermal Imaging Cameras for Navy Shipboard Fire Fighting, Report No. SS99-001, Department of the Navy, Office of the Assistant Secretary (Installations and Environment), Washington, DC, February 1999, 60 pp.

[4] R. D. Lucier, Hot enough for you? Applications of IR thermal imaging equipment in the fire service, FLIR Systems [web page], http://www.flirthermography.com/media/026lucier.pdf [last updated 09/09/00].

[5] 2004 Program Guidance for the Assistance to Fire Fighters Grant Program, U. S. Dept. of Homeland Security [web page], http://www.usfa.fema.gov/grants/afgp/ [last updated 05/02/05].

[6] S. P. Woodworth, Choosing a Thermal Imaging Unit, Fire Engineering, **153** (1), 83-84 (2000).

[7] ASTM Standard E 1213-97 Standard Test Method for Minimum Resolvable Temperature Difference for Thermal Imaging Systems, ASTM International, West Conshohoken, PA, 2002, 3 pp.

[8] ASTM Standard E 1256-95 Standard Test Method for Radiation Thermometers (Single Waveband Type), ASTM International, West Conshohoken, PA, 2001, 7 pp.

[9] ASTM Standard E 1311-89 Standard Test Method for Minimum Detectable Temperature Difference for Thermal Imaging Systems, ASTM International, West Conshohoken, PA, 2004, 3 pp.

[10] ASTM Standard E 1543-00 Standard Test Method for Noise Equivalent Temperature Difference for Thermal Imaging Systems, ASTM International, West Conshohoken, PA, 2000, 4 pp.

APPENDIX 1- WORKSHOP AGENDA

Agenda: Workshop on Thermal Imaging Research Needs for First Responders

Day One – December 9th, 2004

8:00 Coffee & Refreshments (Building 224, Room B245)

8:30 Welcome *(Dr. James Hill, Director, Building & Fire Research Laboratory (BFRL), NIST)*

8:45 Opening Remarks – Workshop Goals and Logistics *(Dr. Anthony Hamins, Leader, Analysis and Predictions Group, NIST)*

8:55 Self Introductions

9:00 Visionary Presentations - End User's Response to these Questions:

How do you currently use thermal imagers?
How important are technical qualities?
How important are physical qualities?
What is the value of features (bells & whistles)?
What info do you currently use to make purchasing decisions?

9:00 The Ideal Thermal Imager for the Fire Service *(Bruce Varner, Fire Chief, City of Santa Rosa Fire Department, CA)*

9:20 The Ideal Thermal Imager for Fire Fighting *(Brian Duggan, Fire Chief, City of Northampton Fire Department, MA)*

9:40 The Wide-Angle View from a First Responder Trainer *(Bob Athanas, President, SAFE-IR, Inc.)*

10:00 Break

10:10 The Industrial Point of View

10:10 Perspectives from TI Camera Manufacturers *(Larry Konsin, P. E., American Council for Thermal Imaging)*

10:30 Perspectives from a Detector Manufacturer *(Tim McCaffrey, Raytheon)*

10:50 Standards Development and Government Agency Involvement

The performance standards creation process.
Government agency contributions to thermal imaging technology development for first responder applications.

10:50 DOJ/NIJ *(Chris Tillery, Deputy Chief, Research and Technology Development Div., NIJ)*

11:10 DHS/OLES *(Phil Mattson, Office of Law Enforcement Standards (OLES), NIST)*

11:30 NRL *(John Farley, Navy Safety & Survivability, Naval Research Laboratory)*

11:50 Standards Development Procedures *(Terry Clausing, P. E., Chairman, ASTM E-7 Committee on Non-Destructive Testing)*

12:10 Lunch

1:20 Thermal Imaging Science and Research Activities

1:20 Overview of NIST Efforts to Support Fire Fighter Technologies *(Nelson Bryner, Leader, Fire Fighting Technology Group, NIST)*

1:35 Overview of NIST Thermal Imager Project *(Dr. Francine Amon, Analysis and Prediction Group, NIST)*

1:50 Testing Spectral Responsivity of IR Cameras *(Dr. Joseph Rice, Optical Technology Division, NIST)*

2:05 Perspectives from the Night Vision Lab *(John O'Neill, Lead Electronics Engineer, Prototype IRFPA and IR Camera Characterization Laboratory, Night Vision Laboratory)*

2:25 Break

2:40 Purpose and Guidelines for the Working Sessions *(Anthony Hamins)*

- What are the prioritized research needs for thermal imaging for first responders?
- What performance metrics are needed? How do they differ from current methods?
- What standards are needed?
- What technological advances are needed?

2:55 Working Sessions

Session 1: (Bldg 224/Rm B245) Coordinator: Nelson Bryner
Session 2: (Bldg 224/Rm A369) Coordinator: Francine Amon
Session 3: (Bldg 224/Rm A312) Coordinator: Anthony Hamins

4:00 Tour of NIST Large Fire Laboratory, AML, and Thermal Imaging Facility *(Bldg 205, AML Bldg. 216/Rm C106 & Bldg 224/Rm B347)*

5:00 Adjourn for the Day

Agenda: Workshop on Thermal Imaging Research Needs for First Responders

Day Two – December 10th, 2004

8:00 Coffee and Refreshments (Building 224, Room B245)

8:30 Reconvene Working Groups (Rooms B245, A312, A369)
Review working session purpose, progress, questions and issues

10:00 Break

10:10 Reconvene Workshop *(All Participants)*
Sessions provide summary of their discussions

10:40 Group Discussion *(Nelson Bryner, moderator)*
Deliberation on working session topics:

- What are the prioritized research needs for thermal imaging for first responders?
- What performance metrics are needed? How do they differ from current methods?
- What standards are needed?
- What technological advances are needed?

12:15 Wrap-Up *(Nelson Bryner)*

12:30 Adjournment

APPENDIX 2- WORKSHOP ATTENDEES

Meet the workshop participants, shown here in the long wavelength infrared (above) and visible (below) spectra.

Workshop on Thermal Imaging Research Needs for First Responders				
	Name	Affiliation	Address	Email/Phone
1.	Francine Amon	Building and Fire Research Laboratory, NIST	100 Bureau Drive, MS8663 Bldg. 224, Rm. A269 Gaithersburg, MD 20899	francine.amon@nist.gov 301-975-4913
2.	Bob Athanas	SAFE-IR	P.O. Box 297 Montgomery, NY 12549	boba@SAFE.IR.com 845-457-2421
3.	William Grady Baker	Int'l Association of Chiefs of Police	515 N. Washington Alexandria, VA 22314	baker@theiacp.org 703-836-6767 x811
4.	Amir Beeri	CTO Camero	9 Homanut Street Netanza ISRAEL	abeeri@camero-tech.com +972-54-4892157
5.	Garry Briese	Intl Association Fire Chiefs	4025 Fair Ridege Drive Fairfax, VA 22033	gbriese@iafc.org 703-273-0911
6.	Nelson Bryner	Building and Fire Research Laboratory, NIST	100 Bureau Drive MS 8661 Gaithersburg, MD 20899	nelson.bryner@nist.gov 301-975-6868
7.	Terry Clausing	Chairman ASTM E07.10.04 Infrared NDT Methods	P. O. Box 44055 Cincinnati OH 45244	terryc@virtualspectrum.com 513-831-9625
8.	Chris Coombs	GB Solo North America, Inc.	504 Lake Drive Middletown DE 19709	gbsolona@dca.net 866-442-7656
9.	Stephen Costello	BAE Systems	2 Forbes Road, LEX01-112 Lexington MA 02421-7306	stephen.costello@baesystems.com 781-863-3325
10.	Paul Domich	Building and Fire Research Laboratory, NIST	100 Bureau Drive Bldg. 226, Rm. B228, MS 860	domich@nist.gov 301-975-5624
11.	Brian P. Duggan	International Association of Fire Chiefs, Northampton Fire Department	26 Carlon Drive Northampton, MA 01060	bpduggan@comcast.net 413-587-1039
12.	John Farley	Naval Research Laboratory	Code 6180, Attn: John P. Farley 4555 Overlook Ave. SW Washington DC 20375-5320	farley@ccs.nrl.navy.mil 202-404-8459
13.	Mike Fergus	International Association of Chiefs of Police	515 N. Washington Alexandria, VA 22314	fergus@theiacp.org 703-836-6767 x811
14.	David Fisher	ISG Thermal Systems USA, Inc.	190 Stanley Court Lawrenceville GA 30045	dfisher@isgfire.com 404-403-5343

Workshop on Thermal Imaging Research Needs for First Responders				
	Name	Affiliation	Address	Email/Phone
15.	William Grosshandler	Building and Fire Research Laboratory, NIST	100 Bureau Drive, MS8660 Bldg. 224, Rm. B252 Gaithersburg, MD 20899	william.grosshandler@nist.gov 301-975-2310
16.	Anthony Hamins	Building and Fire Research Laboratory, NIST	100 Bureau Drive, MS8663 Bldg. 224, Rm. A269 Gaithersburg, MD 20899	anthony.hamins@nist.gov 301-975-6598
17.	William E. Haskell	NIOSH/CDC/ National Personal Protective Technology Laboratory	P. O. Box 18070 Pittsburg PA 15236	whaskell@cdc.gov 978-590-7882
18.	James Kaye	E2V Technologies, Inc.	4 Westchester Plaza Elmsford NY 10523	james.kaye@e2vtechnologies-na.com 800-342-5338 x845
19.	David Kearney	L3	Dallax, TX	kearney@Raytheon.com 972-344-2168
20.	Ron Klug	Scott Health & Safety	4320 Goldmine Road Montrose, NC 28110	rklug@tycoint.com 704-291-8412
21.	Bob Knabbe	SAFE-IR	7 Brooker Drive Newburgh, NY 12550	bobk@SAFE.IR.com 845-551-0676
22.	Larry Konsin	MSA & American Council for Thermal Imaging	1304 Appleridge Ct. Gibsonia PA 15044 or Corporate address: P.O. Box 426 Pittsburg PA 15230	larry.konsin@msanet.com 412-327-0005
23.	Meredith Lawler	US Fire Administration	USFA Emmitsburg, MD	meredith.meglesl@dhs.gov 301-447-1421
24.	Courtney Liedler	Nat'l Transportation Safety Board	490 L'Enfant Plaza, East, SW Washington, DC 20594	liedlec@NTSB.gov 202-314-6350
25.	Philip Mattson	Office of Law Enforcement Standards, NIST	100 Bureau Drive, MS8102 Bldg. 220, Rm. B218 Gaithersburg, MD 20899	philip.mattson@nist.gov 301-975-3396

Workshop on Thermal Imaging Research Needs for First Responders				
	Name	Affiliation	Address	Email/Phone
26.	Tim McDonald	International Safety Instruments	922 Hurricane Shoals Road Lawrenceville GA 30043	mcdonald@intsafety.com 770-962-2552
27.	Shaun F. McNally	Fire Dept. of New York (FDNY)	409A Shore Road Fort Totten NY	
28.	Joe Rice	Physics Laboratory, NIST	100 Bureau Drive, MS8443 Bldg. 216, Rm. A105 Gaithersburg, MD 20899	joe.rice@nist.gov 301-975-2133
29.	Paul Robinson	FDNY (R&D)	409A Shore Road Fort Totten, NY	718-281-8490
30.	Mike Scholten	DRS-Infrared Technologies	13544 N. Central Expressway Dallas, TX 75243	mjscholten@drs-irtech.com 972-560-5921
31.	Wesley Sheridan	Sage Technologies	2500 Maryland Rd., Suite 502 Willow Grove, PA 19090	sheridanw@gosage.com 215-658-0500
32.	Gary Simpson	Bullard	112 Sheldrake Ct. Georgetown KY 40324	gary_simpson@bullard.com 859-588-3404
33.	David Smialeck	BAE Systems	2 Forbes Road, LEX01-112 Lexington MA 02421-7306	david.c.smialeck@baesystems.com 781-863-4150
34.	Louis Stern	Draeger Safety, Inc.	101 Technology Drive Pittsburgh, PA 15275	lou.stern@draeger.com
35.	Dr. Yi Su	Diagnostic Instrumentation and Analysis Laboratory Mississippi State University	205 Research Blvd., Research & Technology Park Starkville, MS 39759-9734	su@dial.msstate.edu 662-325-3286
36.	Bill Terre	Indigo Systems	70 Castilian Drive Goleta, CA 93117	wterre@indigosystems.com 805-964-9797
37.	Bruce H. Varner	Santa Rosa Fire Department	955 Sonoma Avenue Santa Rosa, CA 95404	bvarner@ci.santa-rosa.ca.us 707-543-3500
38.	Robert Vettori	Building and Fire Research Laboratory, NIST	100 Bureau Drive Bldg. 224, Rm. B252, MS8661 Gaithersburg, MD 20899	robert.vettori@nist.gov 301-975-6577

APPENDIX 3.A-

Workshop Goals and Logistics
Anthony Hamins, Building and Fire Research Laboratory, NIST

Workshop on Thermal Imaging Research and Performance Standards Needs for First Responders

Building and Fire Research Laboratory (BFRL)
National Institute of Standards and Technology (NIST)

December 9 and 10, 2004

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Workshop Objectives

- identify thermal imaging needs of first responders, with an emphasis on standards.
- create a research agenda and a roadmap for continued development of thermal imaging technology.
- present and obtain feedback on draft performance metrics developed at NIST.

NIST Workshop on Thermal Imaging Research Needs for First Responders (12/9/04)

Standards

Why standards?
- improve product effectiveness
- may lead to increased demand
- ad-hoc testing being conducted by agencies
  - expensive to develop
  - may miss key elements
- improve safety for first responders and the public

Standards Organizations
- advocating scientifically-based consensus codes and standards
- American Society for Testing and Materials (ASTM)
- National Fire Protection Association (NFPA)

National Fire Protection Association
The authority on fire, electrical, and building safety

NIST Workshop on Thermal Imaging Research Needs for First Responders (12/9/04)

ASTM Standards

- Test methods: E 1933-99a, E 1543-00, E-1862-97, E-1897-97
- ASTM standards do not address typical use conditions - such as a fire


Designation: E 1543 – 00
Standard Test Method for Noise Equivalent Temperature Difference of Thermal Imaging Systems[1]

Standard Test Methods for Measuring and Compensating for Reflected Temperature Using Infrared Imaging Radiometers[1]

Designation: E 1897 – 97 (Reapproved 2002)
Standard Test Methods for Measuring and Compensating for Transmittance of an Attenuating Medium Using Infrared Imaging Radiometers[1]

Designation: E 1933 – 99a
Standard Test Methods for Measuring and Compensating for Emissivity Using Infrared Imaging Radiometers[1]

NIST Workshop on Thermal Imaging Research Needs for First Responders (12/9/04)

NFPA Standards

- Committee on Electronic Safety Equipment (ESE)
  - standards for fire fighter equipment
  - Self-Contained Breathing Apparatus (SCBA), 1981
  - Personal Alert Safety System (PASS device), 1982
  - IR Imagers - life-critical instrumentation lacking standards

Agenda: Workshop on Thermal Imaging Research Needs
Day One – December 9th, 2004

8:45 Opening Remarks – Workshop Goals and Logistics *(Dr. Anthony Hamins, NIST)*

8:55 Self Introductions

9:00 Visionary Presentations - End User's Response to these Questions:
How do you currently use thermal imagers?
How important are technical qualities?
How important are physical qualities?
What is the value of features (bells & whistles)?
What info do you currently use to make purchasing decisions?
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10:00 Break

10:10 The Industrial Point of View
10:10 Perspectives from TI Camera Manufacturers *(Larry Konsin, P. E., American Council for Thermal Imaging)*

10:30 Perspectives from a Detector Manufacturer *(Tim McCaffrey, Raytheon)*

10:50 Standards Development and Government Agency Involvement
The performance standards creation process and.Government agency contributions to thermal imaging technology
10:50 DOJ/NIJ *(Chris Tillery, Research and Technology Development, NIJ)*

11:10 DHS/OLES *(Phil Mattson, Office of Law Enforcement Standards (OLES), NIST)*

11:30 NRL *(John Farley, Navy Safety & Survivability, Naval Research Laboratory)*

11:50 Standards Development Procedures *(Terry Clausing,Chair, ASTM E-7 Committee on Non-Destructive Testing)*

12:10 Lunch

Agenda: Workshop on Thermal Imaging Research Needs
Day One – December 9th, 2004

1:20 Thermal Imaging Science and Research Activities
1:20 Overview of NIST Efforts to Support Fire Fighter Technologies *(Nelson Bryner, Leader, NIST)*

1:35 Overview of NIST Thermal Imager Project *(Dr. Francine Amon, Analysis and Prediction Group, NIST)*

1:50 Testing Spectral Responsivity of IR Cameras *(Dr. Joseph Rice, Optical Technology Division, NIST)*

2:05 Perspectives from the Night Vision Lab *(John O'Neill, Night Vision Laboratory)*

2:25 Break
2:40 **Purpose and Guidelines for the Working Sessions** *(Anthony Hamins)*
- What are the prioritized research needs for thermal imaging for first responders?
- What performance metrics are needed? How do they differ from current methods?
- What standards are needed?
- What technological advances are needed?

2:55 Working Sessions
Session 1: (Bldg 224/Rm B245) Coordinator: Nelson Bryner
Session 2: (Bldg 224/Rm A369) Coordinator: Anthony Hamins
Session 3: (Bldg 224/Rm A312) Coordinator: Francine Amon

4:00 Tour of NIST Large Fire Laboratory, AML, and Thermal Imaging Facility *(Bldg 205, AML & Bldg Rm B347)*

5:00 Adjourn for the Day

Agenda: Workshop on Thermal Imaging Research Needs
Day Two – December 10th, 2004

8:00 Coffee and Refreshments (Building 224, Room B245)

8:30 Reconvene Working Groups (Rooms B245, A312, A369)
Review working session purpose, progress, questions and issues.

10:00 Break

10:10 Reconvene Workshop *(All Participants)*
Sessions provide summary of their discussions

10:40 Group Discussion *(Nelson Bryner, moderator)*
Deliberation on working session topics:
- What are the prioritized research needs for thermal imaging for first responders?
- What performance metrics are needed? How do they differ from current methods?
- What standards are needed?
- What technological advances are needed?

12:15 Wrap-Up *(Nelson Bryner)*

12:30 Adjournment

Purpose and Guidelines for Working Sessions

- What are the prioritized research needs for thermal imaging for first responders?
- What performance metrics are needed? How do they differ from current methods?
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2:55 Working Sessions
Session 1: (Bldg 224/Rm B245) Coordinator: Nelson Bryner
Session 2: (Bldg 224/Rm A369) Coordinator: Anthony Hamins
Session 3: (Bldg 224/Rm A312) Coordinator: Francine Amon
4:00 Tour of Labs

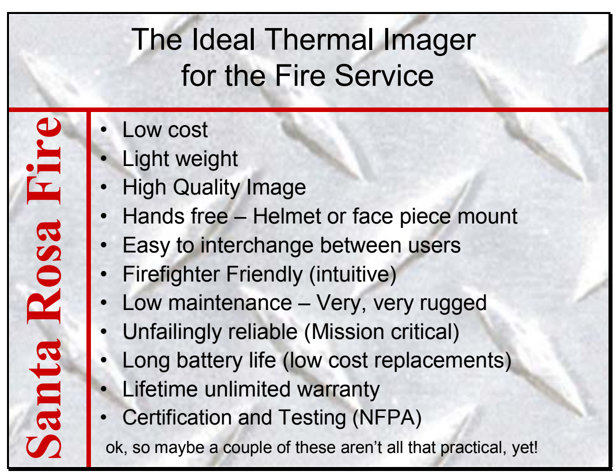
APPENDIX 3.B-

The Ideal Thermal Imager for the Fire Service: A Fire Chief's Perspective
Bruce Varner, Fire Chief, City of Santa Rosa Fire Department, CA

A Fire Chief's perspective on the ideal Thermal Imager for the fire service should start with affordability (low cost) so as to assure the ability to place at least one imager on every fire company in the department. The preference would be to place a unit on every interior position, with each sector (division, group) officer and command. The additional officer units should be of a design that allows for effective use in daylight conditions to evaluate the structure. In preparing for the Workshop on Thermal Imaging at NIST several fire chiefs and senior fire officers were consulted to develop the following list of items considered important from a fire chief's perspective.

- Low cost
- Light weight
- **Unfailingly reliable** (Mission critical)
- High Quality Image
- Hands free – Helmet or face piece mount
- Easy to interchange between users
- Firefighter Friendly (intuitive)
- Low maintenance – Very, very rugged
- Long battery life (low cost replacements)
- Long term warranty (or option to buy extended warranty at reasonable cost)

The list is not all-inclusive nor in a particular order of importance. Cost has had an impact on the ability of the Fire Service to get units on all companies and indeed has limited the ability of some departments to have even a single unit available. Various public and private grant programs have had a positive impact on the ability of departments to obtain imagers in the past couple of years. The ability to use a Thermal Imager for size up, interior evaluation, and indeed as an effective tool for search and rescue lies in having at least one imager available on the first arriving fire department resource.



The sizes, they are a changing

Santa Rosa Fire

Low Cost, we're getting closer

Santa Rosa Fire

Temp 084F

- $75,000.00
- $25,000.00
- $16,000.00
- $12,000.00
- $ 8,000.00

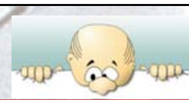
The Fire Department has had a camera for a year, and would like to have them on every piece of fire equipment, but the cost is prohibitive, said Capt. Bill. Following the save of 2 firefighters in flashover incident.

Ok, so when do I hear $2000.00 or less? Now we are beginning to talk about 1 for <u>every</u> riding position. We really will have the ability to see in the fire environment.

It becomes another piece of PERSONAL protective equipment.

BATTERY

Did I mention rugged?



Santa Rosa Fire

Let's review this again

Santa Rosa Fire

- Low cost
- Light weight
- High Quality Image
- Hands free – Helmet or face piece mount
- Easy to interchange between users
- Firefighter Friendly (intuitive)
- Low maintenance – Very rugged
- Unfailingly reliable (Mission critical)
- Long battery life (low cost replacements)
- Lifetime unlimited warranty
- Certification and Testing (NFPA)

APPENDIX 3.C-

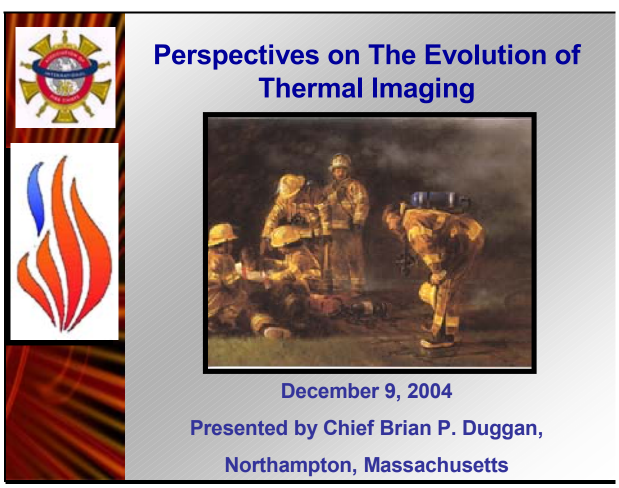
IAFC Partners with the National Institute of Standards and Technology to Improve Thermal Imaging

Brian Duggan, Fire Chief, City of Northampton Fire Department, MA

During the NIST Thermal Imaging Workshop, The International Association of Fire Chiefs (IAFC) provided extensive user driven input from several fire service perspectives and emphasized the need for imager related training to increase operational safety and ability. Today's thermal imagers were recognized as life saving tools with significant limitations including ergonomics, power supply issues, a high cost that limits use and deployment, and a technology that lacks standardization. Working groups focused on research needs, testing and the development of standards that would facilitate technological growth but set minimum standards for the next generation of thermal imagers.

Reaching beyond the common requests of developing a smaller, cheaper, lighter and less costly imager our partnership with NIST focused on the future evolution of the imager, and explored uses in a wide variety of fire related operations, emergency medical services, and fire prevention. Although it is clear that the larger military and electronics markets limit the ability to develop a fire service specific technology, IAFC emphasized the need to integrate this technology into other systems. This presentation outlined the extensive amount of equipment required to properly outfit today's firefighter.

As this technology is enhanced, the IAFC took a strong position that this evolution needs to be driven by our needs. Priorities for improvement within the realm of imager technology focused upon providing better battery and charging systems, increasing image display quality, transitioning to color displays, providing pattern and hazardous condition alerting, and integration of the imager into a heads up display.



A Great Tool That Has Saved Lives and Increased Effectiveness

Many Uses:

- Structural/urban Search and rescue
- Search for the Missing person
- Detect hidden fire
- Detect malfunctioning electrical equipment

November 28, 2004

International Association of Fire Chiefs

A Great Tool

Limitations:

- Battery life
- Charging issues
- Calibration and repair issues
- Represents a technological Change, resisted by some

November 28, 2004

International Association of Fire Chiefs

A Great Tool That Has Saved Lives

Limitations:

- Takes away from traditional operations
- Requires more personnel but those personnel can do more
- Inconsistent deployment

November 28, 2004

International Association of Fire Chiefs

A Great Tool That Has Saved Lives

Limitations:

- Fiscal resources = price point
- Weight
- Hard to hold
- Another piece of equipment

November 28, 2004

International Association of Fire Chiefs

Other Perspectives

Fire Instructor:

- A training need exists
- False sense of security
- Not utilized to full potential

Graduate Students:

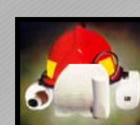
- Cultural acceptance
- Operational implementation
- Not maximized as a tool

November 28, 2004

International Association of Fire Chiefs

The Simple View of Improving Thermal Imaging

- Cheaper
- Lighter
- Smaller
- Easier to hold and use

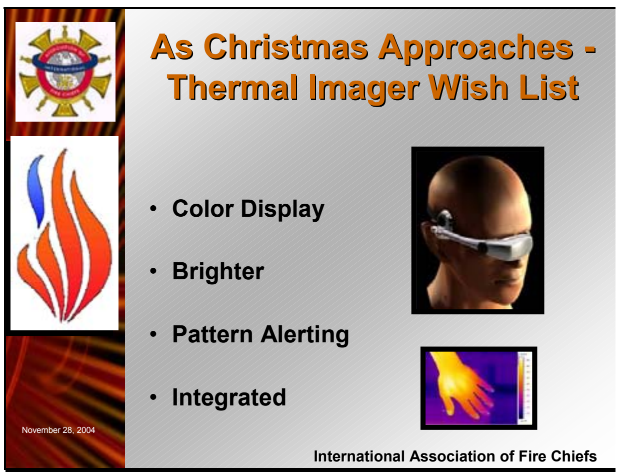


November 28, 2004

International Association of Fire Chiefs


The Firefighters Challenge
Often times the biggest challenges facing a firefighter as the end user is not the heat and smoke.
November 28, 2004
International Association of Fire Chiefs


It's Often the Gear Itself
November 28, 2004
International Association of Fire Chiefs


As Christmas Approaches - Thermal Imager Wish List
• Color Display
• Brighter
• Pattern Alerting
• Integrated
November 28, 2004
International Association of Fire Chiefs


As Christmas Approaches - Thermal Imager Wish List
• Heads-up display
• Rapid on/off Capability
• Location Transmitter
• Lifetime maintenance free battery
November 28, 2004
International Association of Fire Chiefs


A Partnership with the Fire Service
• Work together to find a balance that forms technology that is harnessed to provide a use driven tool
• Through standards we need to drive development as opposed to technology driving us.
November 28, 2004
International Association of Fire Chiefs

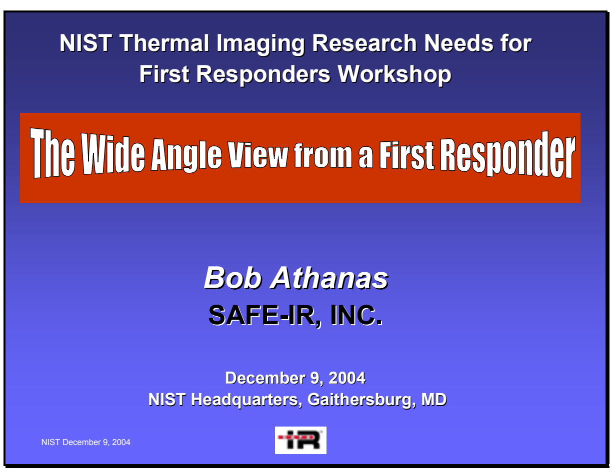

Questions ???
Contact Information:
Chief Brian P. Duggan
Northampton Fire Department
26 Carlon Drive
Northampton, MA 01060-2373
Telephone (413) 587-1039
E-mail Bduggan@city.northampton.ma.us
Web Address: www.northamptonfire.org
November 28, 2004
International Association of Fire Chiefs

APPENDIX 3.D-

The Wide-Angle View from a First Responder
Bob Athanas, President, SAFE-IR, Inc.

Webster's dictionary defines *Emergency* as "an unknown combination of circumstances which calls for immediate action." In today's society, that immediate action most often comes from first responders and, specifically, firefighters. Firefighters, like the military, utilize many tools or weapons. Their thorough understanding of these tools, their functions and limitations is essential for the proper application of the tool and often the safety and survival of the user. Thermal imaging cameras are rapidly becoming one the most valuable tools available for firefighters. Bob will briefly touch on the range of needs and applications of thermal imaging cameras for the fire service. He will discuss the unquestionable value of the more than 30 models of thermal imagers introduced to the fire service in the last 6 years and how their effectiveness is complicated and compromised by inconsistency. He will offer some examples of how thermal imaging cameras may be simplified through the establishment of standards for manufacture, display, and function. Then he will offer a common sense explanation of why these standards will positively impact the purchase, training and safe use of thermal imagers in the dynamic and stressful situations faced by firefighters.

Biography:
Bob Athanas is a 28-year veteran of the fire service who began using a thermal imager in 1991 and started teaching thermal imaging to firefighters 1996. He is currently assigned to FDNY Special Operations and is President of SAFE-IR, INC., an internationally recognized fire service thermal imaging training and consulting organization. Bob is an instructor for the NYS First Line Supervisors Training Program, FDNY Chief Officers Command Course and Technical Rescue School, FDIC, Firehouse Expo, and many colleges, regional, municipal and state fire schools. He represents end users as a member of the NFPA Committee on Electronic Safety Equipment.



American Fire Service

Resists Change -Newness

"Hundreds of years of tradition unimpeded by progress!"

Embrace

Simplicity

+ Consistency

SAFETY *Factor!*

NIST December 9, 2004

The Wide Angle View from a First Responder

APPLICATIONS

In every community across America, Thermal Imagers have the potential to positively impact almost every role firefighters are called upon to perform in today's society.

NIST December 9, 2004

APPLICATIONS

- **Firefighting**
  - -All Types
  - -All Phases
- **Haz-Mat**
- **EMS**
- **Technical Rescue**
- **Exterior Search & Rescue**
- **Public / Media Relations**
- **More!**

NIST December 9, 2004

APPLICATIONS

Although TIC availability exists in FD's

Users Operate with:

Inadequate, Inconsistent & Inaccurate:

Information

+ Terminology

+ Instruction / Training

Misinformed / Confused Users!

Thermal Imagers are greatly underutilized!

NIST December 9, 2004

APPLICATIONS

Since 1995 at any given time there may be as many as;

+ or – 10 TIC Manufacturers with

+ or – 20 TIC Models Available

Different Technologies BST,VoX,Asi,

Different Sizes, Shapes, Features

NO Consistency in Models or Technology!!

Even when made by the same Manufacturer !

NIST December 9, 2004

LIMITATIONS

NO Standards !

- **Proper Training / Understanding**
- **Terminology**
- **Features**
- **Power Supply**
- **Reliability**
- **Overall Performance & Testing**
- **More!**

NIST December 9, 2004

Switch Operation

- Press to **Turn On**
- Release to **Turn Off**
- Hold Down To **Turn Off**
- Press to **Turn Off**
- Release for **Stand By**
- Press for **Stand By**

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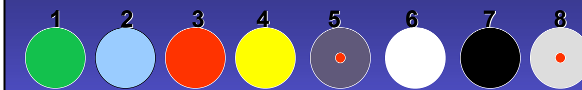
Switches/Functions

Match the correct switch color with the Function



a) On / Off
b) Stand By
c) Video Xmitt
d) Video Overlay
e) Image Capture
f) 2x Zoom
g) Manual Shutter
h) A,B
i) A,B,C,G
j) A,E,F

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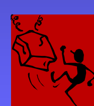
ICONS & INDICATORS

Standards MUST establish
1 Primary Indicator for each purpose!

NEED TO BE CONSISTANT & COMPATIBLE WITH PPE
TODAY FIREFIGHTERS USING DIFFERENT TI
MAKES
+MODELS
+MUTUAL AID



Confusion, Inconsistency = Rejection!

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Micro Bolometer "MODE" INDICATOR

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BATTERY POWER LEVEL

Operating Time-Full Charge

a) 1 Hour
b) 1 ½ Hours
c) 2 Hours
d) 3 Hours
e) 4 hours
f) 5 Hours
g) 7 Hours

Establish a MINIMUM Operating range!

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BATTERY POWER LEVEL

Power Standards

Power Level - Display
\+ Performance -Time ?
\+ Low Power Level-Time?
How Much Time??
% Means Nothing !!

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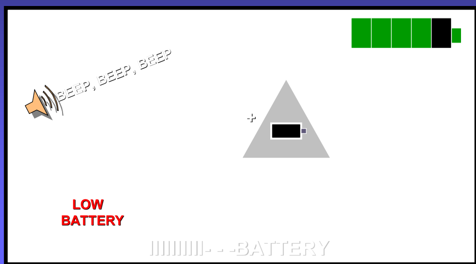
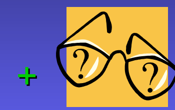
BATTERY POWER LEVEL

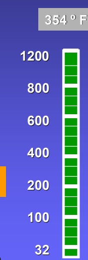


TEMPERATURE

DIGITAL ?
THERMOMETER ?
° INCREMENTS ?
CELCIUS ?
FARENHEIGHT ?
MK ?
MAX ?
CROSSHAIRS ?



Visibility & Accuracy?



WHAT DOES IT MEAN?

TEMPERATURE & COLOR

Consistency

- 2 COLORS
- 3 COLORS
- FULL COLOR
- Transparent Colors
- Color vs. Temp
- HOT = Color
- Cold = Color
- BLACK, WHITE SHADES OF GRAY

TEMPERATURE - COLOR

RED Appears in at least 10 Cameras!

- Appears @ different Temperatures
  288°F, 302°F, 392F, 600°F, 900°F, 1112°F……
- Appears then Disappears and
- Re-appears Again or
- Appears and stays on and on and on
  and on………

TESTING / STANDARDS

What the average Firefighter doesn't see
But relies on NFPA /NIST to prove:
Product Performance for HIS SAFETY!

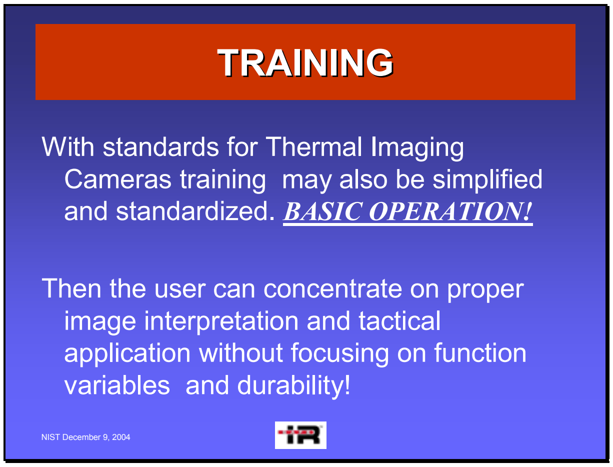
- HEAT
- FLAME
- WATER
- IMPACT
- DROP
- DUST
- ABRASION
- VIBRATION
- CORROSION
- RFI
- OVERALL PERFORMANCE !

PURCHASE

Allows for Product Comparison

- Specifications
- Terminology
- Tests
- Performance Results
- Numerical Representation

Standards will simplify this review!


TRAINING
With standards for Thermal Imaging Cameras training may also be simplified and standardized. BASIC OPERATION!
Then the user can concentrate on proper image interpretation and tactical application without focusing on function variables and durability!
NIST December 9, 2004

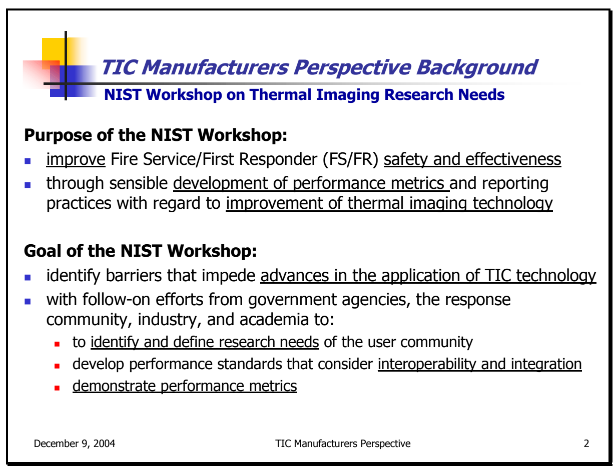

SUMMARY
STANDARDS will create:
Consistency
+ Reliability
+ Simplicity (Users)
+ Accountability
+ Responsibility (Mfrs.)
SAFETY for FIREFIGHTERS
NIST December 9, 2004

APPENDIX 3.E-

Perspectives from TIC Manufacturers

Larry Konsin, American Council for Thermal Imaging

TIC Manufacturers face many technological trade-offs in designing a Fire Service/First Responder (FS/FR) Thermal Imaging Camera (TIC). They find ways to keep infrared sensors operating in the harshest environments. The sensors are from sensor suppliers who design to military and large commercial requirements – generally not to FS/FR requirements. The FS/FR TIC market volume does not support an "applications specific sensor". Sensors are 70% of the cost of a TIC; therefore TIC Manufacturers do not have the flexibility to advance TIC technology much further than what the sensors offer. TIC Manufacturers performance test sensors to the specifications of the sensor supplier – and to the accepted standards of the FS/FR market. Currently, there are no NFPA TIC standards. Manufacturers anticipate new standards and are developing TICs to meet them. New standards have to balance the needs/wants of the FS/FR end-user with the limits of the sensor applications and cost. TIC Operational Standards are urgently needed to establish a common language and understanding for TIC safety and use. Over the years, TIC Manufacturers have meet the demands of the FS/FR market to eliminate "white out", measure temperature, reduce size/weight, improve imagery, reduce cost, and add value. The FS/FR market and NFPA, working together with the Manufacturers can continue to meet real needs in practical ways.



TIC Manufacturers Perspective Background

NIST Workshop on Thermal Imaging Research Needs

NIST suggestions for TIC Manufacturers Presentation:

1. What are the technological trade-offs that are faced in producing a TIC?
2. What performance testing is done and how can it improve?
3. What technological advances are on the horizon?
4. What performance standards are most important?
5. What are the most critical issues in establishing performance standards?

Possible *Working Session Topics* for group discussions:

- What are the prioritized research needs for thermal imaging for FS/FR?
- What performance metrics are needed?
- How do they differ from current methods?
- What standards are needed?
- What technological advances are needed?

1. What are the technological trade-offs that are faced in producing a TIC?

NIST Workshop on Thermal Imaging Research Needs

- Generally, infrared (IR) sensor design is driven by military and large commercial market applications, not Fire Service/First Responder (FS/FR) applications. FS/FR TICs are not produced in volumes large enough to justify the cost of an applications specific sensor. TIC Manufacturers, working with the Sensor Manufacturers, must find ways to enable the sensors to perform and survive the rigors of the "world's harshest environment" which includes:
  - high external heat, open flame, explosive and IDLH environments
  - drop (impact), vibration, corrosion, and abrasion (display & lens)
  - water immersion, water spray
  - particulate resistance
  - high internal temperature
  - radio frequency interference (RFI)

1. What are the technological trade-offs that are faced in producing a TIC?

NIST Workshop on Thermal Imaging Research Needs

- Additional design responsibilities of the TIC Manufacturer include:
  - power supply reliability and performance, display synchronization
  - housing integrity, cable connection integrity
  - FCC and CE requirements,
  - electronic end-user warnings such as:
    - low power/battery remaining
    - high internal temperature
    - high scene temperature
- The technological trade-off is that by using available, lower cost non-FS/FR sensors (rather than an applications specific FS/FR sensor), the TIC Manufacturers must find ways to keep those sensors performing in environments that they were generally never designed to operate in. Also, when the FS/FRs conduct TIC evaluations, they expect TICs to perform beyond what is normally encountered in most FS/FR TIC applications – therefore pushing TIC Manufacturers to do even more .

1. What are the technological trade-offs that are faced in producing a TIC?

NIST Workshop on Thermal Imaging Research Needs

- The sensor accounts for 70% of the cost of a FS/FR TIC, delivering 50% of the perceived value to the end-user. TIC Manufacturers control the remaining 30% of the cost – delivering the remaining 50% of end-user perceived value.

Table 1: ***Typical TIC Cost and Value to Fire Service/First Responder***

Components	Designer/Developer	% of Cost	% of Value
Infrared (IR) Sensor	sensor manufacturer	70%	50%
TIC Housing	TIC manufacturer	10%	30%
Support Electronics	TIC manufacturer	10%	10%
Display and Battery	3rd party suppliers	10%	10%

- Sensor costs heavily influence FS/FR TIC pricing. In the last 10 years, FS/FR TIC unit pricing has steadily declined by 65% from $25,000 to $9,000 largely due to sensor cost reductions.

1. What are the technological trade-offs that are faced in producing a TIC?

NIST Workshop on Thermal Imaging Research Needs

Table 2: ***End-user TIC Price Reductions Since 1995***

Year of Intro	Format/FPA	End-user Price	Price Driver
1995	Helmet Mount 100x100	$25,000	First to market
1997	Hand Held 320x240	$18,000	Lower sensor cost
2001	Hand Held 160x120	$11,000	Lower sensor cost
2004	Hand Held 160x120	$ 9,000	Lower sensor cost

- The technological trade-off is that in the price-sensitive FS/FR market, TIC Manufacturers do not have the flexibility to advance TIC technology much further than what the sensor has to offer.
- Other non-custom components also help keep costs down but hinder technological advances and performance. Additionally, FS/FR TICs go through several component changes over the life of the product due to inconsistent availability of those components.

1. What are the technological trade-offs that are faced in producing a TIC?

NIST Workshop on Thermal Imaging Research Needs

- For example: display technology is largely controlled by the large electronics manufacturers who design and develop applications specific displays, amortizing their costs over very large volumes. TIC Manufacturers source the display production overruns and excess inventory of the large electronics manufacturers to keep costs down.
- Consequently, most TICs have gone through several display changes due to inconsistent availability. Often a display changes requires TIC housing mold changes and/or new electronics.

Table 3: ***Additional FS/FR TIC Critical Non-Custom Components***

Component	Non-Custom Due To:	Critical Issue
Displays	low FS/FR volumes	Inconsistent supply, wrong specs
Connectors	low FS/FR volumes	Off-the-shelf supply limits design
Low $ Batteries	low FS/FR volumes	Batteries have special requirements
Low $ Optics	low FS/FR volumes	Needed for low cost TIC HUD design

1. What are the technological trade-offs that are faced in producing a TIC?

NIST Workshop on Thermal Imaging Research Needs

- Having to use off-the-shelf components, connectors, and switches somewhat limits optimization of a FS/FR design due to limited selection and availability.
- Most of these components are not designed to meet specific FS/FR requirements. Displays for example, have to be further protected from high heat since their 80°C (176°F) operating temperature limit is far below the extreme temperatures of the FS/FR market.
- The technological trade-off is again that in the price-sensitive FS/FR market, TIC Manufacturers generally do not have the flexibility to advance the technology beyond what the available components offer.

December 9, 2004 TIC Manufacturers Perspective 9

TIC Manufacturers Perspective Background

NIST Workshop on Thermal Imaging Research Needs

Purpose of the NIST Workshop:

- improve Fire Service/First Responder (FS/FR) safety and effectiveness
- through sensible development of performance metrics and reporting practices with regard to improvement of thermal imaging technology

Goal of the NIST Workshop:

- identify barriers that impede advances in the application of TIC technology
- with follow-on efforts from government agencies, the response community, industry, and academia to:
  - to identify and define research needs of the user community
  - develop performance standards that consider interoperability and integration
  - demonstrate performance metrics

December 9, 2004 TIC Manufacturers Perspective 10

2. What performance testing is done and how can it improve?

NIST Workshop on Thermal Imaging Research Needs

Sensor Performance Testing

- FS/FR TIC performance testing is generally conducted on both the Sensor and the Total Package (which includes other features, functions, components and the TIC housing).
- TIC Manufacturers conduct sensor performance testing to ensure that the sensor conforms to the published specifications of the Sensor Manufacturer, and that the sensor meets generally accepted standards within the FS/FR market.
- Since TIC Manufacturers generally do not have much investment or involvement in the design and development of the sensors (for many of the reasons explained previously) they tend not to test beyond what they control.

December 9, 2004 TIC Manufacturers Perspective 11

2. What performance testing is done and how can it improve?

NIST Workshop on Thermal Imaging Research Needs

- Also, since sensors used in FS/FR TICs have somewhat similar operational and performance characteristics, there are few additional sensor performance characteristics for the TIC Manufacturers to test.
- Similarly operating sensors allow TIC Manufacturers to mix brands of sensors in their product line – sometimes using a mix of sensors in the same TIC housing, providing greater selection for the end-user.
- In addition to the sensor testing done by the TIC Manufacturer, further applications testing is conducted by the FS/FR TIC end-user during performance evaluations (live burns, drops, dunks, etc.). This is to ensure that the sensor will survive the rigors of FS/FR applications and deliver the image quality and sensitivity over the range of temperatures that the end-user expects.

December 9, 2004 TIC Manufacturers Perspective 12

2. What performance testing is done and how can it improve?

NIST Workshop on Thermal Imaging Research Needs

Total Package Performance Testing

- The FS/FR market is very Total Package performance testing oriented. There is not a tool or piece of equipment used by FS/FRs that is not extensively tested for safety, durability, reliability and ease of use. This is "fit for use" testing that is taken to the extreme.
- Since 1896, the National Fire Protection Association (NFPA) has established safety codes and standards for FS/FRs worldwide. Even though there currently are no NFPA published standards for FS/FR TICs, existing NFPA standards for other FS/FR tools and equipment are setting the benchmark for TICs (examples: drop/impact, vibration, water/dust ingress, direct flame/heat exposure). As the NFPA moves toward establishing TIC standards, TIC Manufacturers anticipate those standards, and are developing TICs to meet them.

December 9, 2004 TIC Manufacturers Perspective 13

2. What performance testing is done and how can it improve?

NIST Workshop on Thermal Imaging Research Needs

How can Performance Testing improve?

- Sensor performance testing, above and beyond specification conformance and "fit for use" testing, generally does not exist. Three is no doubt that there will be NFPA sensor performance standards set for TICs in the future. These could include:
  - viewing range
  - field of view
  - sensitivity
  - scene dynamic range
  - sensor operating temperature.
- These metrics currently exist and once a NFPA standard is established, will be easily conformed to.

December 9, 2004 TIC Manufacturers Perspective 14

2. What performance testing is done and how can it improve?

NIST Workshop on Thermal Imaging Research Needs

- Total package performance testing will be improved once NFPA standards are established for TICs. Third party testing is currently in place for NFPA certification of existing tools and equipment for which NFPA standards have been established.
- Additional standards/performance testing will have to take into account the balance between the additional needs and wants of the FS/FR end-user – and the limits of sensor applications and cost.
- TIC Manufacturers will always attempt the meet the needs of the FS/FR market. Unlike other FS/FR tools and equipment though, TICs are not under the complete control of the TIC Manufacturer. Sensor performance testing on sensor attributes not controlled by the TIC Manufacturer will be an issue.

December 9, 2004 TIC Manufacturers Perspective 15

TIC Manufacturers Perspective Background

NIST Workshop on Thermal Imaging Research Needs

Purpose of the NIST Workshop:

- improve Fire Service/First Responder (FS/FR) safety and effectiveness
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  - develop performance standards that consider interoperability and integration
  - demonstrate performance metrics

December 9, 2004 TIC Manufacturers Perspective 16

3. What technological advances are on the horizon?

NIST Workshop on Thermal Imaging Research Needs

- Once FS/FR TICs become NFPA standards driven, the ongoing revisions of the standards will have an impact on how the FS/FR TIC advances technologically in the years to come.
- Outside of technological advances driven by the NFPA standard, Sensor Manufacturers who choose to stay in the FS/FR market will take more of the FS/FR requirements into account when designing and developing new sensors.
- In addition, sensor costs will continue to decline, making TICs more available and accessible to the larger FS/FR market.

December 9, 2004 TIC Manufacturers Perspective 17

4. What performance standards are most important?

NIST Workshop on Thermal Imaging Research Needs

- Outside of the Sensor and Total Package performance standards mentioned previously, there is the area of Operational performance standards that is most important in a newly developing market.
- Operational performance standards will establish a common language and understanding in the FS/FR TIC market that generally does not exist at this time. With FS/FR TIC market penetration at only 25%, the opportunity exists to establish operational performance standards that can create a universal understanding of how FS/FR TICs operate, especially with regards to safety.
- (A similar operational performance standard would be the FS/FR SCBA low air warning that alarms at 25% breathing air remaining. When the alarm sounds, every firefighter understands what it means – and what to do).

December 9, 2004 TIC Manufacturers Perspective 18

4. What performance standards are most important?

NIST Workshop on Thermal Imaging Research Needs

- An example of the confusion that exists due to a lack of operational performance standards for FS/FR TICs is the different settings and ranges established by the Manufacturers that could confuse FS/FR end-users when they switch from one TIC to another.

Table 4: ***Random Sampling of TIC Operational Settings and Ranges from TIC Manufacturers' Published Information and Specifications***

Red Pixels At:	Low Battery Indicator	Dynamic Range	Heat Test
500°F	Red LED – 15 min	Nominal 315°C	300°F – 15 min
1000°F	Flashing Red LED – 1 min	932°F Nominal	500°F – 5 min
887°F	'Low Bat' icon – 20% left	1100°F	80°C – 30 min
900°F	Battery Gauge icon	1,024 Temp Levels	500°F – 8 min

December 9, 2004 TIC Manufacturers Perspective 19

4. What performance standards are most important?

NIST Workshop on Thermal Imaging Research Needs

- In addition, there are several different terms used by TIC Manufacturers, that generally mean the same thing.

Table 5: ***Random Sampling of TIC Operational Terms from the TIC Manufacturers' Published Information and Specifications***

Sensitivity	Color Pixels	Temp Sensing
Nominal Sensitivity	Color Enhancement	Relative Heat Indicator
Variable Sensitivity	Heat Seeker	On-Screen Temp Readout
Temperature Sensitivity	Red Hot	Direct Temp Measurement
NETD	Red-Colorization	Relative Temperature Bar

December 9, 2004 TIC Manufacturers Perspective 20

4. What performance standards are most important?

NIST Workshop on Thermal Imaging Research Needs

- Also, TIC Manufacturers often have several different TICs in their product line, often with different settings and ranges due to the use of different sensors.
- This can create confusion when a Fire Department adds additional new TICs to its existing inventory of older TICs from the same TIC Manufacturer.
- Examples of the confusion between the two different models of TIC could be different warning signs (low battery, high heat) – and different setting for temperature measurement and red pixel activation.
- Even with training, usage is open to confusion when multiple models of TICs used, especially when TIC usage is sporadic.

December 9, 2004 TIC Manufacturers Perspective 21

TIC Manufacturers Perspective Background

NIST Workshop on Thermal Imaging Research Needs

Purpose of the NIST Workshop:

- improve Fire Service/First Responder (FS/FR) safety and effectiveness
- through sensible development of performance metrics and reporting practices with regard to improvement of thermal imaging technology

Goal of the NIST Workshop:

- identify barriers that impede advances in the application of TIC technology
- with follow-on efforts from government agencies, the response community, industry, and academia to:
  - to identify and define research needs of the user community
  - develop performance standards that consider interoperability and integration
  - demonstrate performance metrics

December 9, 2004 TIC Manufacturers Perspective 22

5. What are the most critical issues in establishing performance standards?

NIST Workshop on Thermal Imaging Research Needs

- Currently, the TIC and Sensor Manufacturers are meeting the growing needs of the FS/FR market. The evidence is seen in the market growth in the past several years.
- The FS/FR market has placed demands on the TIC Manufacturers – and to date all have been met. Examples are the elimination of "white out" in 1997, adding temperature measurement beginning in 1998, reducing size and weight beginning in 2001, the ongoing improvement of image quality and reduction in cost while adding value.
- The FS/FR market and the NFPA, working together with the TIC and Sensor Manufacturers can continue to meet real needs in practical ways through mutual understanding and cooperation.

December 9, 2004 TIC Manufacturers Perspective 23

5. What are the most critical issues in establishing performance standards?

NIST Workshop on Thermal Imaging Research Needs

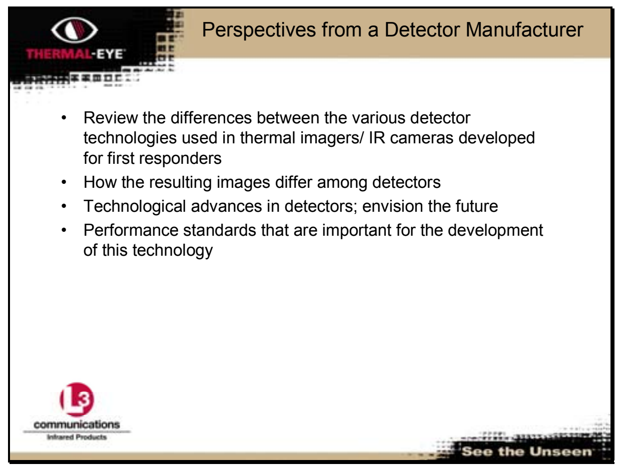
- NFPA will help in establishing Operational and Total Package and Sensor performance standards. The most critical issues in establishing Sensor performance standards is whether FS/FR TIC needs and budgets match up with the capabilities of the IR sensors.
- If a performance standard is established that requires a sensor for specific types of fires – or specific FS/FR applications, the standard could segment the market, requiring both TIC and Sensor Manufacturers to develop a new FS/FR TIC that might not be viable (due to low volume and high cost). Then, no one benefits.
- Also, if a performance standard is established that requires a FS/FR applications specific sensor, once it is developed the industry could be reluctant to advance TIC technology beyond that sensor, realizing the initial investment/long payback period due to market segment size.

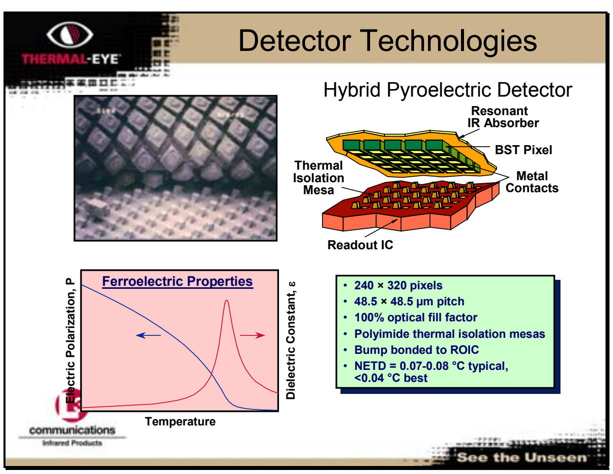
December 9, 2004 TIC Manufacturers Perspective 24

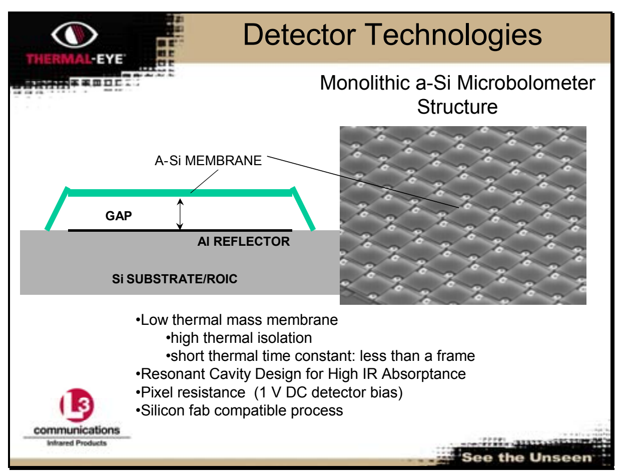
APPENDIX 3.F-

Perspectives from a Detector Manufacturer
Tim McCaffrey, Raytheon Commercial Infrared

Imaging Core makers have promoted Pyroelectric sensors and MicroBolometers for use in the Fire Service/ First Responder applications. Basic utility is now satisfied. For tomorrow, makers are focusing on smaller, more efficient engines creating sharper more informative images. Fruitful areas for study remain mainly in characterizing features of an image which cue the user or which enable greater utility and application. Future users must consciously stay in step with commercial motives to assure the widest availability of thermal imaging.







Comparing Existing Technologies

Bolometers …

- have demonstrated excellent potential for low NETD
- have essentially ideal MTF
- are monolithic and producible
- are limited by spatial noise
- But require occasional "touchup"
- But require factory calibration
- But require precision A/D converters, multiple-field memory, substantial processing capability

Pyroelectrics …

- have minimal spatial noise
- robust in highly variable scene and ambient environments
- require lower-bit A/D converter
- have low MTF
- But requires temperature stabilization
- But pixel size is not readily reducible
- But improvement potential is relatively low

See the Unseen

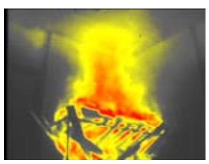
Image differences




- Other than on the fire ground

See the Unseen

Image attributes


- Glare obscures figures
- Detail lost in the shadows
- Is the un-burning wall a risk?
- Note the thermocline above the rescuer's Head
- See body and room detail in the presence of flame

See the Unseen

Advances in Detectors

OEM set priorities for core makers

Reduce camera, FPA and optics size, weight and cost

320x240 advancing to 1024x768

NETD's approaching 20mK

Reduced smear; smoother images, crisp images

Scene temperature ranges over 1000F

Ambient conditions from –40C to +85C

Power at the core under ½ Watt

See the Unseen

Performance Standards

- Dynamic Range management
- Wavelength of operation
- MRT vs. NETD et al
- Response of the eye to
  - Spatial noise
  - Temporal noise
  - Clarity, crispness
  - Contrast
- Performance at ambient extremes
  - Endurance at temperature
  - Startup
  - Stability of the Optics
  - Scenes colder or hotter than the camera
- Impact on domestic vs. International mkt.

See the Unseen

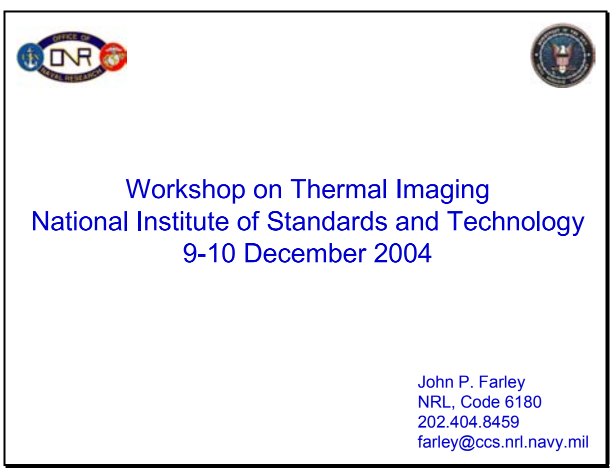
APPENDIX 3.G-

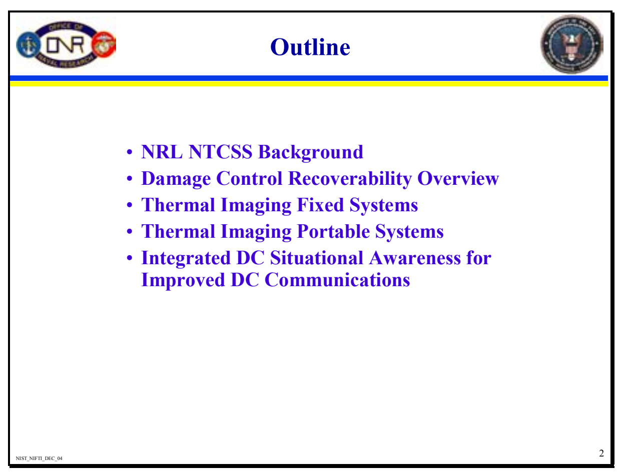
NRL Thermal Imaging Review
John P. Farley, Navy Safety and Survivability, Naval Research Laboratory, Washington DC

The Naval Research Laboratory's Navy Technology Center for Safety and Survivability reviewed the Navy's efforts related to developing the use of thermal imaging technologies for naval combatants. The presentation provided information on the Navy's full-scale RDT&E test ship, ex-USS SHADWELL, which is a major facility at the Naval Research Laboratory for the protection of life and property, under the auspices of the Navy Technology Center for Safety and Survivability. The presentation included insight into the on-going program efforts for developing both fixed and portable thermal imaging technologies, which included work related to the DD(X) Autonomic Fire Suppression System (AFSS), Flight Deck Engineering Development Model (EDM) Flight Deck testing, the CVN 21 Hangar Bay testing, and the development of Machine Vision technologies (Near IR capabilities). The presentation also included a Navy perspective for future hand held/hands-free portable thermal imaging requirements.

Biography:
Mr. John Farley is a Fire Test Engineer for the Naval Research Laboratory and is the Project Officer for the ex-USS SHADWELL responsible for testing and development of shipboard fire protection technology, procedures, and policy for the US Navy.

Security Classification of the Brief: UNCLASSIFIED

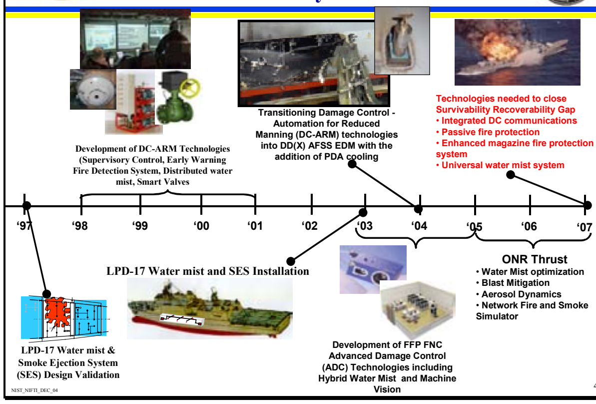




Navy Technology Center for Safety & Survivability

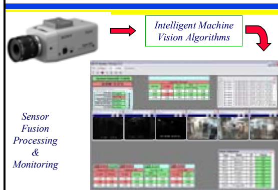
- Dedicated to studies on active & passive fire protection, flooding, and chemical defense
- Realistic, time-critical scientific measurement, modeling, and performance analysis
  - Sensors, materials, equipment, personnel, doctrine, tactics, and command & control
- Application of basic and theoretical research and development
  - Fire models, predictive tools, agents, sensors, systems, and technology
- Evaluation of hardware/software concepts and experiments with users
  - Systems Commands, OPNAV staffs, Navy Warfare Centers, Navy Laboratories, Fleet Commands, Training communities

Damage Control Recoverability Overview



Thermal Imaging Fixed System Initiatives

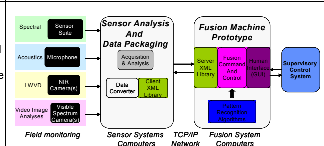
Multi-Sensory Video Image Detection System for Situational Awareness



Operational Capability: Under the ONR program, NRL is developing a damage control detection system using multisensory, multivariate methods and machine vision for motion and shape recognition, to detect flaming and smoldering fires, pipe and hull ruptures, and flooding. The modular architectural design allows this system to be expanded to new and different missions of interest to the Department of Defense and homeland security. Data fusion methods can be modified to provide surveillance and detection of these events. This technology is very attractive for mass transit systems because it combines surveillance with fire detection.
Performance Targets: The system will detect objects, unusual human behaviors, and unusual events, including fire detection. The system will monitor events, provide pre-alarm and alarm conditions for unusual events, store, archive and index alarms for easy recall.
Cost of Ownership: Cost is reduced by the reduced manning requirements, use of existing surveillance cameras and dual use of hardware for many functions.

Approach:
Use an innovative architectural design for a prototype real-time remote detection system based on existing and emerging technology. System will be modular and expandable using visible and near-infrared images, spectral and acoustic sensors with analysis by machine vision and pattern recognition. Data fusion and analysis methods will be configured for sensitive and selective early event recognition. Uses current advances in commercial video image fire detection.

PI: Dr. Susan Rose-Pehrsson, Naval Research Laboratory, Code 6112, Washington, DC 20375-5342, 202-767-3138, rosepehrsson@nrl.navy.mil
Sponsor: Office of Naval Research



Spectral-Based Volume Sensor (SBVS)

Strategy:
- Optical detection of fire, smoke, and other hazards
  - Detection methods outside visible spectral region
  - Potential security applications
- Integrate with and augment video/machine vision
- Match spectral window for detection to fire emission
- Limited to economical and reliable methods/devices

Approach:
Long wavelength video detection (LWVD):
- Nightvision:
  - Use extended red/NIR sensitivity of standard CCDs
  - Long wavelength filter suppresses visible image for higher contrast
- Augment visible cameras:
  - Detects reflected flame & hot objects
  - Modest thermal imaging

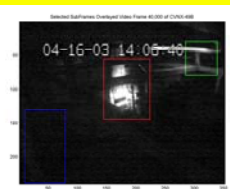
Discreet spectral sensors – SBVS Testbed
- COTS (IR/UV) detectors and novel in-house sensors
- In-house analysis of emission bands:
  - Standard (UV, IR)
  - Novel (vis/NIR photodiodes, 589 nm, 766 nm, NIR)

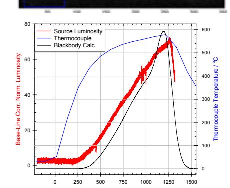
Long wavelength video detection

SBVS Testbed

LWVD Recent Progress

Long wavelength video detection (LWVD):
- Nightvision detection utilizing extended red/NIR sensitivity of standard CCDs
- Detects reflected flame emission and hot objects/bulkheads:
  - Filtered nightvision cameras and NRL luminosity algorithm
  - Minimum temperature for hot object detection ~ 400ºC
- Develop LWVD system for integration with data fusion / prototype
  - Stand alone implementation with multilevel output
  - Fusion system compatible output





VS1-24 Non-FOV Fire Source

Regular Video

Nightvision Video

DD(X) Flight Deck EDM Tests

Landing area fire suppression design concepts:

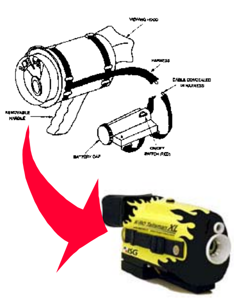
- AFFF tele-robotic firefighting nozzles (TFNs)
- AFFF deck nozzles
- AFFF hose reel stations
- Multipurpose Aviation Decking Material (MADMAT)
- Enhanced visual sensors (IR and visual cameras)

EDM Configuration – IR Cameras

- 2 Camera sets in EDM.
- IR and Visual Cameras
- Tilt / Pan / Zoom
- Multiple (4) windows on console screen in HCS.
- Cameras provide ability to control TFN operation both locally and remotely

Thermal Imaging Portable Systems

Portable NFTI Background



- Need identified during British Falklands War
- Initial technology based on valve tube (Vidicon, Pedican, Hevicon)
- Significant size/weight and maintenance issues
- Newer technologies have moved to solid state (micro bolometer sensor)

Future Portable NFTI Requirements

- Hands-free vs hand-held capability
- Wireless interface
- Ability to work in high humidity environments
- Tolerance to high heat environments
- Ability to distribute IR images

Integrated DC Situational Awareness for Improved DC Communications

•Based on actual shipboard casualties and 15 years of real scale tests with Fleet participants, communications continues to be the number one Damage Control issue which impedes DC performance
•Current DC Communications are inadequate and not integrated with DC systems and sensors

- Determine the efficacy of wearable computer/PDA for real-time DC communications
- Investigate the opportunities of integrating DC sensors and or machine vision technologies for enhanced DC communications network
- Build on NAVSEA/BIW RF network initiatives to provide a damage tolerant and compatible DC communications system
- Scope - transform existing stovepipe (stand alone) technologies into a fully integrated communications system
- **Fleet Number One Priority for Damage Control**

NIST_NIFTI_DEC_04

15

APPENDIX 3.H-

Standards Development Procedures
Terry Clausing, ASTM Committee E-7 on Non-Destructive Testing

What are "standards" and why are they important to us? The best answer to this question is illustrated in areas where we each, as individuals, have personal experience and interaction with standards in our lives. As individuals in a modern society communication with each other is critical. Imagine for a moment that each company that manufactures telephones used a different wiring scheme and different connectors on the telephones. We take for granted being able to plug that little connector from the phone into the wall outlet (both use a connector referred to as RJ-11) and use any telephone manufactured by a host of manufacturing companies. The wiring scheme and connector are governed by "standards" adopted by the industry. Those of you who are world travelers and computer users have a more intimate knowledge of how this simple standard that we all use in the USA impacts basic communications when traveling to other countries with "different standards".

Standards as they apply to this NIST Workshop affect a smaller percentage of the population but may be equally important in our everyday lives. The issue at hand has to do with understanding the needs of First Responders and Thermal Imaging Equipment. Those people charged with protecting our lives and property do so by risking their own. The purpose of creating a standard for thermal imaging for first responders applies the very principles of the primary purpose of all standards – "They should be universal achievements in science and shared hopes for health, safety and the environment." (James A. Thomas, ASTM President). Our purpose in this gathering is to understand better the needs of First Responders to form a basis of quantifying how thermal imaging equipment fulfills the role of protecting people and property.

Three organizations are recognized in the establishment of pertinent standards. ASTM establishes consensus standards for materials and testing procedures. NFPA establishes consensus standards for fire prevention and safety. And ASNT establishes supportive standards for establishing the education and training of personnel involved in infrared and thermal test methods.

This presentation discusses

- how standards are developed
- who participates in establishing standards
- who votes on the standards
- who is required to use the standards

Biography:
Mr. Clausing is chairman of ASTM E07.10.04 infrared non-destructive testing standards subcommittee and chairman of ASNT Infrared / Thermal Methods Committee.

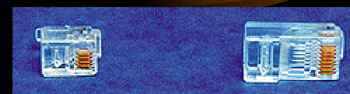
STANDARDS

L. Terry Clausing, PE

NIST Workshop on
Thermal Imaging Research Needs
for First Responders

Standards

- What are Standards?
- Why do they matter to us?



ASTM Standards: Two Basic Values

- ASTM Standards for Testing and Materials:
  - Quality:
    - A high quality standard meets the expectations of its users
  - Relevance:
    - A standard that is relevant has meaning in the marketplace

Standards: Quality and Relevance

- They should be the language and facilitators of trade, never the pawns of political ambitions.
- They should be universal achievements in science and shared hopes for health, safety and the environment.
  - James A. Thomas, ASTM President

Standards: How do they get developed?

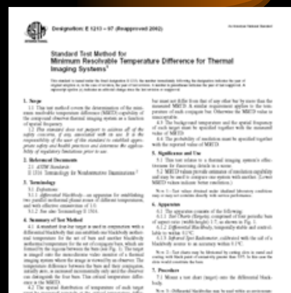
- Development of PC's
  - The original IBM-PC
  - The DEC Rainbow
  - The TI-PRO
  - The Apple LISA
  - All PC's,
    - Each different
- The Compaq:
  - First IBM-Compatible
  - A "STANDARD" is born!

Standards: Who can create them?

- Three guys from Texas Instruments who started Compaq Computer Corp.
- Who can create a standard?
  - Just about anyone
- The more significant issue:
  - What purpose does the standard serve?
  - And what value is it to others?

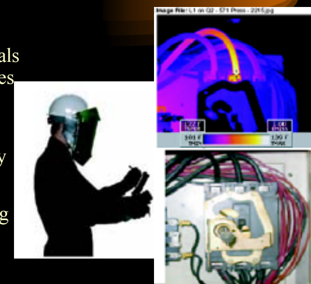
ASTM Infrared Standards

- Why did ASTM choose to create standards on NETD, MRT and MDTD
  - Scientific comparison
- Why not "contrast"?
  - What purpose?
  - What value to others?



Standards Purpose and Value

- ASTM –
  - Standards for materials and testing procedures
- NFPA
  - Standards for fire prevention and safety
- ASNT
  - Standards for training and certification of personnel



Standards Organizations

- National Consensus Standards
  - Developed by the same persons it affects
  - Adopted by a nationally recognized organization
- Example – The National Electric Code
  - Written by the NFPA
- Who uses consensus standards?
  - OSHA and local governments
  - Is the NEC "law"?

ASTM: How Standards Get Developed

- Identification of a need
- Form a new "Task Group" within the appropriate ASTM technical committee
  - Identify individuals with expertise and interest
  - Task Group members do NOT need to be members of ASTM to participate (but is encouraged)
- Develop a draft document, define objectives and register it as a new "Work item" at the annual meeting (Jan 05)
- Seek participation from the users of the standard
- Review ASTM Standards "Form and Style" document

ASTM Standards

- How long does it take?
- Who participates?
- Who votes?
- How are negative votes handled?
- Who uses the standard?

ASTM Standards Technological advancements

- Technology and needs change over time
  - Standards are reviewed every 5 years

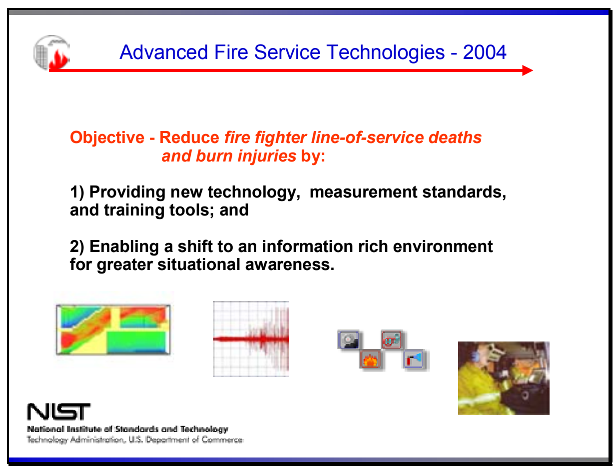
- ASTM Membership
  - $75 per year
  - Includes one VOLUME of ASTM Standards
  - Non-destructive Testing is Vol 3.03

APPENDIX 3.I-

Overview of NIST Efforts to Support Fire Fighter Technologies

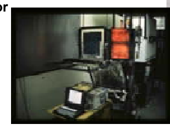
Nelson Bryner, Building and Fire Research Laboratory, NIST

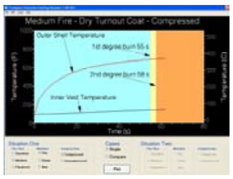
The goal of the Advanced Fire Service Technologies (AFST) Program is to enable a shift to an information rich environment for safer and more effective fire service operations through new technology, measurement standards, and training tools. The research currently sponsored by AFST focuses on fire fighter protective clothing, tactical decision aids, virtual fire fighter training, and thermal imaging camera performance evaluation methods. The fire fighter protective clothing research includes development of new clothing materials and heat transfer modeling software that captures heat and moisture transport and predicts burn injuries through fire fighter protective clothing. Tactical decision aids, such as methods by which structural collapse may be predicted, and building information systems that provide data to fire fighters en route to a fire scene, are also under development. Virtual fire fighter training and visualization software that will allow a fire fighter to “walk through” a burning structure is being investigated. Methods of measuring the performance of thermal imaging cameras used by fire fighters, based on the environment in which they are used, are being studied with the intend of providing the underlying science to future performance standards.



Heat Transfer Model for Fire Fighter Protective Clothing

- Comprehensive model of Heat and Moisture Transport
- Protective Clothing Performance Simulator
- Skin Model and Predicting Burn Injury
- Effect of Moisture, Compression on Burn Injury



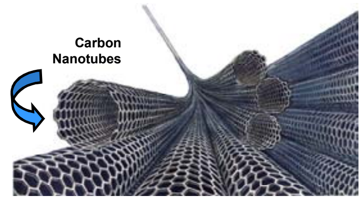


•Complete PPE material properties database for "used gear"

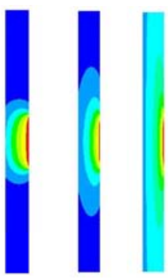
•Complete Heat Transfer Model GUI

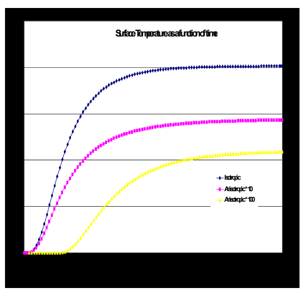
New Materials for Protective Clothing

Material	Thermal Conductivity (W/mK)
Carbon nanotube	37,000 – 2,500 (calc)
Graphite	100-200
Polymers	0.01 – 0.1

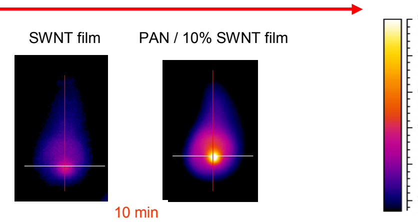


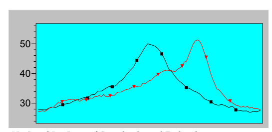
New Materials for Protective Clothing

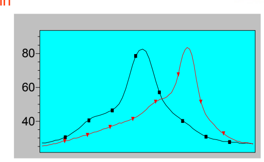




New Materials for Protective Clothing



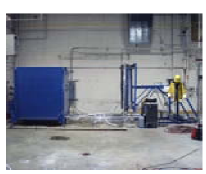




Full Ensemble Test Apparatus/Heat Transfer Model Validation

•To identify "thermally susceptible" areas of components in the protective ensemble.

•To assess the NIST PPE Heat Transfer model



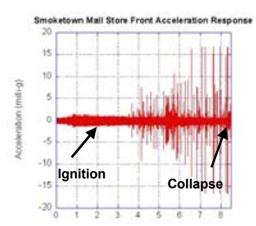
Structural Collapse Prediction

•Provide adequate warning to fire fighters of impending collapse
•Portable, quick, and easy to install

•Evaluated thermal imagers/cameras - unsuccessful
•Examined laser mappers - unsuccessful

Duron - Harvey Mudd College
•Adapt acoustic sensors for detecting leaks in hydroelectric dams

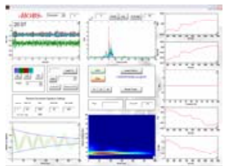
Field tested prototype
•Single family home
•Industrial warehouse
•Strip shopping mall



Structural Collapse Prediction

Health of Burning Structures (HOBS)

- A real-time acquisition and analysis capability
- The HOBS Panel provides real-time capabilities for
  - Multiple sensor data acquisition and storage
  - Signal processing
  - Collapse Index Analyses and Parameter adjustments
  - Fire-induced vibration and collapse index monitoring



- HOBS Indicators include
  - Root Mean Squared (RMS)
  - Power Spectral Density (PSD)
  - Frequency Bandwidth (FreqBand)
  - Shock Response Spectrum (SRS)
  - Random Decrement (RD)
  - Damping
  - Intensity

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Technology Administration, U.S. Department of Commerce

Tactical Decision Aids

Provide fire fighters with tactical information before arrival

- Information Rich Environment
  - Building sensors – data available at fire panel
  - Wireless transfer of floorplans and alarms on apparatus display
- Standards
  - What is being measured
  - How reported to fire panel – fire fighter
    - NFAC Task Group: 2002 NFPA 72 Annex Graphics Annunciator Panel Standard with Icons adopted
- Training tools
  - How to deploy search and suppression teams

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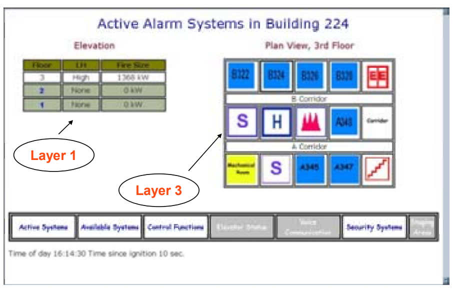
Tactical Decision Aids



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Tactical Decision Aids

Commercial Implementation (Siemens Fire Finder)

Available Systems

Active Systems

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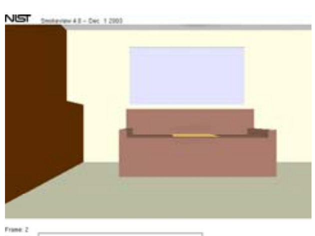
Virtual Fire Fighter Trainers

Fire Dynamic Simulator Computer Model –

Includes
- Chemistry & Physics
- Material Properties

Predict
- Temperature
- Gas concentration
- Thermal fluxes

Insert Fire Fighter
- Hose Stream
- Ventilation
- IR Camera



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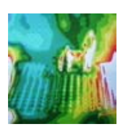
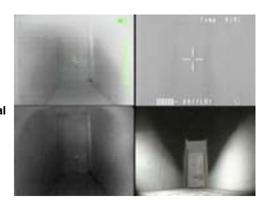
Evaluating the Performance of Thermal Imagers and Infrared Cameras



- Fire service use thermal imagers and infrared cameras
  - Locate "hot spots"
  - Track spread of fire
  - Locate downed occupants and fallen fire fighters
- Currently there is no performance standard for thermal imagers or infrared cameras

- Evaluate performance of thermal imagers and infrared cameras
  - Lab-scale experiments
  - Full-scale field tests
- Develop standard test protocol for evaluating critical performance characteristics



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Fire Fighting Technology Group - 2004

Project Leaders -

Dan Madrzykowski- (daniel.madrzykowski@nist.gov)
- Fire Fighter Safety Simulation
  - Recreation of Fire Patterns
  - Sim. Fire Burn Patterns w/Computer Models
  - College Dormitory Fires
  - Analysis of Indicators in Firesetting
  - NFA Training Program
  - Heat Transfer Model

Nelson Bryner (nelson.bryner@nist.gov)
- Equipment Standards for First Responders
  - Community Scale Fire Spread
  - Fire Safety and Preparedness
  - Meas. and Simulation of Real Ignition
  - Structural Collapse Prediction
  - Urban Wildland Fire Spread

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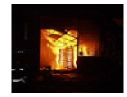
Fire Fighting Technology Group - 2004

Project Leaders -

David Stroup – (david.stroup@nist.gov)
- Structural Collapse Prediction
- Fire Performance of Building Design
- Method of Fire Resistance Determination



Nelson Bryner – (nelson.bryner@nist.gov)
- Thermal Imagers
  - Thermal Imager Performance
  - In-Situ Burning of Oil Spills
  - Advanced PASS Devices

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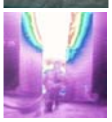
Fire Fighting Technology Group - 2004

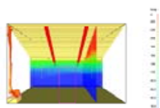
Project Leaders -



Doug Walton – (william.walton@nist.gov)
- Positive Pressure Ventilation
- In-Situ Burning of Oil Spills
- Hose Stream Effectiveness
- Fire Reconstruction/Recreation

Randy Lawson –(james.lawson@nist.gov)
- Fire Service Technologies and Guidelines
- Firefighter Protective Clothing
- Fire Codes & Standards
- Heat Transfer Model

Bob Vettori – (robert.vettori@nist.gov)
- Sprinkler Activation under Sloped Ceiling



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Fire Fighting Technology Group - 2004

Contact Fire at NIST ?

Website - http://fire.nist.gov
http://www.bfrl.nist.gov

FireDOC - on web
Fire Research Information Service
Gaithersburg, MD
Paul Reneke 301-975-6696

Fire Data - pubs/web
Models - pubs/web
Videos - call or e-mail

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APPENDIX 3.J-

Overview of NIST Thermal Imager Project
Francine Amon, Building and Fire Research Laboratory, NIST

Thermal imaging cameras are rapidly becoming integral equipment for first responders for use in structure fires. Currently there are no standardized test methods or performance metrics available to the users or manufacturers of these instruments. The Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST) is developing a testing facility and methods to evaluate the performance of thermal imagers used by fire fighters to search for victims and hot spots in burning structures. The facility is used to test the performance of currently available imagers and advanced fire detection systems, as well as serve as a test bed for new technology. An evaluation of the performance of different thermal imaging detector technologies under field conditions has also been performed. Results of this project will provide a quantifiable physical and scientific basis upon which industry standards for imaging performance, testing protocols and reporting practices related to the performance of thermal imaging cameras can be developed. The background and approach that shape the evaluation procedure for the thermal imagers are the primary focus of this presentation.

Overview of NIST Thermal Imager Project

Francine Amon
Building and Fire Research Laboratory
National Institute of Standards and Technology

NIST National Institute of Standards and Technology
Funded in part by the United States Fire Administration
1

Outline

- **Performance metrics**
  - Categories, types
  - Combinations & modifications
- **First Responder Conditions**
- **Testing Approach**
  - Full-scale
  - Bench-scale
- **Results**
- **Summary**

2

Types of Performance Metrics

- **Display and Button Conformity**
  - Temperature bar or indicator
  - “EI” symbol
  - Use of color
- **Design/Integrity Requirements**
  - Immersion, impact, heat, vibration, etc…
  - Power life, alarms, intrinsic safety
  - RF/EMF interference
- **How do you know if it passes a test?**
  - Optical performance

3

Conventional Opto-Electric Performance Metrics

Gain Response & Noise	*Geometric Resolution*	*Overall Image Quality*	*Observer Response*
SiTF, RL, DR, PRNU	Field of View: FOV & IFOV	Image Stats. Non-uniformity	Min. Res. Temp. Dif. (MRTD)
Temporal NEDT & NPSD	Slit Response (SRF)	Visual temporal noise	Auto-MRTD (req. other tests)
Spatial NEDT & NPSD	Ensquared Energy (EE)	Visual spatial noise	Min. Det. Temp. Dif. (MDTD)
3d Noise (NEDT)	Contrast Transfer (CTF)	Narcissus & Ghosting	MRTD Offset
Above tests vs. background temp.	Modulation Transfer (MTF)	Residual non-uniformity	
NER, NEFD, NEP, D*	Distortion (DIST) Boresight Align.	Bad pixel finder	

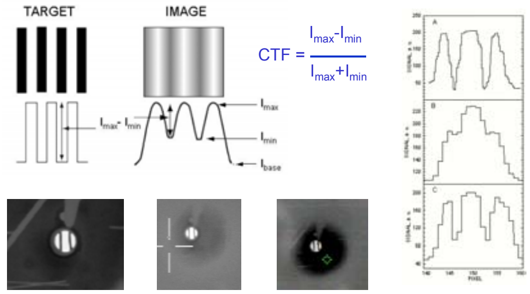
Soel et. al., Proceedings of SPIE, 2002
4

FFTIC Performance Metrics

- **Is there a simple way to characterize imager *optical* performance for this application?**
- **Can we combine/modify some of the conventional metrics?**
  - CTF & MRTD? NETD?
  - Independent of gain, offset, focus
- **Metrics shall not favor a particular technology**
- **How would the metric(s) be meaningful to the end users?**

5

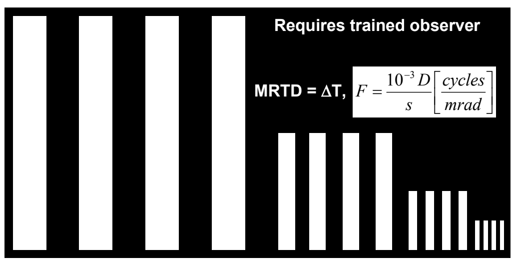
Contrast Transfer Function



The CTF measures the system response to spatial frequencies, usually graphed as function of frequency

6

Minimum Resolvable Temperature Difference (MRTD)



The MRTD measures the system response to radiation differences as a function of spatial frequency

7

Combine and/or Modify

- **Establish a set of tests that simulate firefighting environmental conditions**
- **Combine CTF & MRTD to measure spatial *and* temperature resolution?**
- **Consider use of other established metrics**
  - Field of View (FOV), Dynamic temperature range, NEDT, Ghosting
- **Report as a chart? Family of curves? Average over range of temperatures or ΔTs?**

8

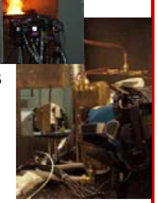
First Responder Conditions

- **Presence of smoke, dust, water, steam**
- **Elevated temperatures…in layers**
- **Flames in field of view**
- **Navigation tool in thick smoke**
- **Focus: 1 m to infinity**
- **Automatic controls/minimal user input**

9

Testing Approach

- **Full-scale tests with various targets**
  - Temperatures
  - Soot concentrations
  - Dust and water effects
- **Laboratory tests**
  - Well-characterized cell contents
  - Variable gas/target/background temperatures



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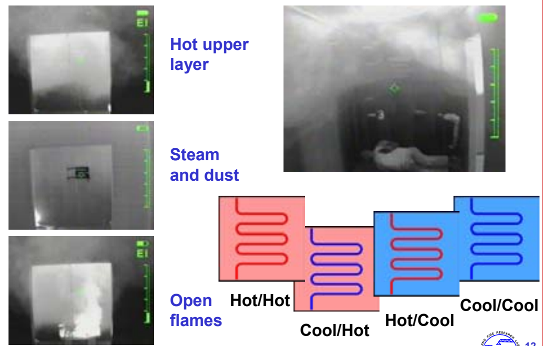
Full Scale Tests


- Cameras in upper and lower layer
- Targets: exit signs, mannequins, cold tubes
- Soot, dust, steam, varying fuels

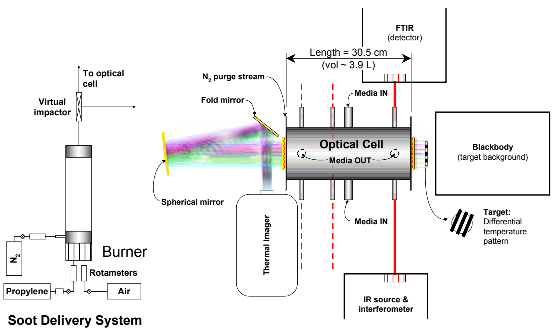
11

Target Design



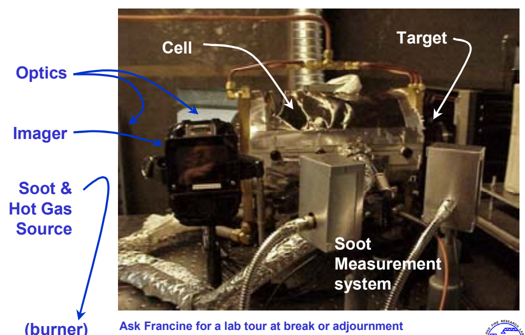
12

Bench-Scale Testing Facility (I)



13

Bench-Scale Testing Facility (II)



Ask Francine for a lab tour at break or adjournment

14

Summary

- Focus on *optical* performance…design/integrity standards also considered
- Combine or modify conventional testing: eliminate trained observer and include fire environment
- Bench-scale facility design derived from full-scale testing
- CTF results show vast differences in camera performance
- Product-neutral evaluation

16

Acknowledgments

Funds for this project have been provided by the United States Fire Administration and NIST.

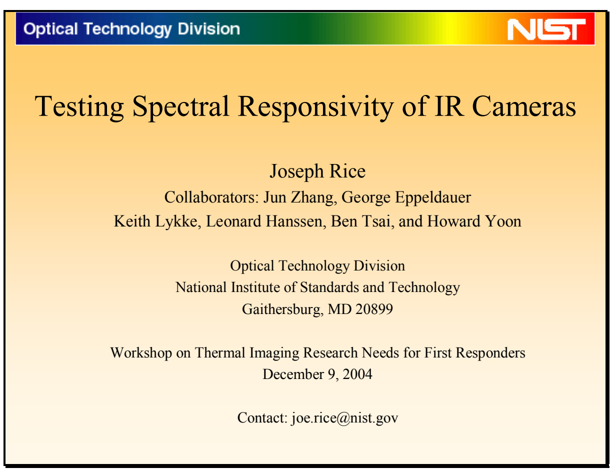
The assistance of the capable crew at the LFF is very much appreciated as well.

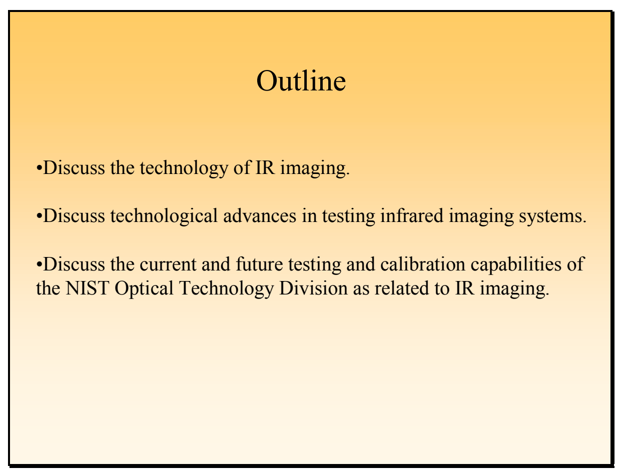
17

APPENDIX 3.K-

Testing Spectral Responsivity of IR Cameras
Joseph Rice, Optical Technology Division, NIST

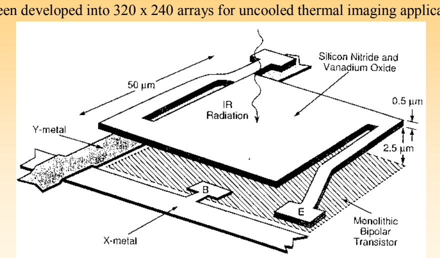
We discuss current measurement capabilities and new testing techniques being developed in the Optical Technology Division of NIST that may be applicable to testing device models used by designers of thermal imaging cameras such as those in use by first responders. Existing capabilities include calibration of customer blackbody sources, calibration of customer IR cameras using NIST standard blackbody sources, and spectral measurement of reflectance, transmittance, and emittance of customer supplied samples of IR materials. We describe a new capability, the measurement of spectral responsivity, which has recently been developed from near-IR out to 5 micrometers and applied to single pixel radiometers. We are extending this technique and generalizing it to enable testing of infrared cameras. We present preliminary results for uniform scenes where tunable infrared lasers illuminate an integrating sphere, diffusing the light to fill the imaging system optics. Results from these tests show that signal-to-noise ratio, uniformity, stability, and other characteristics are favorable for use of this technique in the characterization of infrared imaging systems. We also describe a proposed generalization of this technique, to include scenes with arbitrary, controlled spatial content such as bar patterns or even real scenes, by illuminating a commercially available digital micro-mirror device.





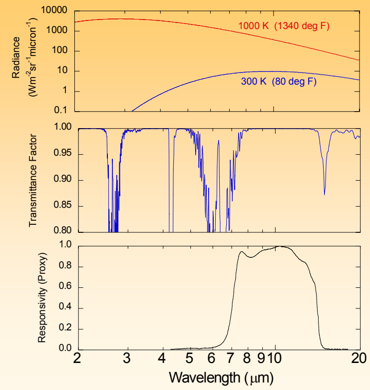
Technology Example: Microbolometer Pixel

- •IR radiation is absorbed in microbridge, heating it.
- •Supporting legs provide electrical contact and thermal isolation.
- •Vanadium Oxide microbridge electrical resistance changes when heated.
- •Monolithic pixel readout circuitry converts resistance change into electrical signal.
- •Has been developed into 320 x 240 arrays for uncooled thermal imaging applications.



From: R. A. Wood, "Monolithic silicon microbolometer arrays," Chapter 3 of *Uncooled Infrared Imaging Arrays and Systems, Semiconductors and Semimetals 47*, P. W. Kruse and D. D. Skatrud, eds. Academic Press, San Diego (1997).

Signal = Radiance * Transmittance * Responsivity + Background



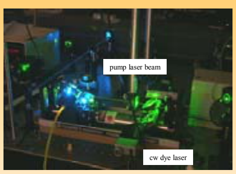
Radiance
- •Depends on scene (what we want to see).
- •Shown is blackbody.

Transmittance
- •Depends on environment.
- •Can be very complex.
- •Objects in path absorb IR and re-emit at other temperatures.
- •Shown is effect of 1 meter of air at 48% relative humidity.

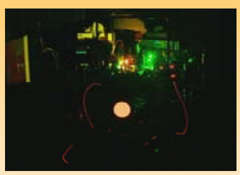
Relative Spectral Responsivity
- •Depends on camera design.
- •Not flat-topped.
- •Usually there is out-of-band.
- •Data not often available.

Basic Principles behind the SIRCUS Technique

A variety of tunable lasers



fiber-coupled into an integrating sphere



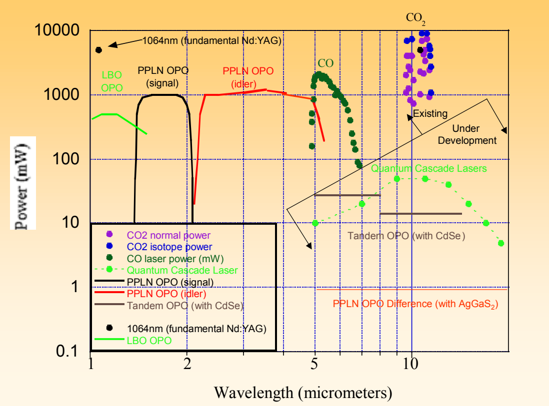
Producing a source that is
- **Spatially uniform (Lambertian)**
- **Monochromatic**
- **Tunable continuously over a broad range**
- **high radiance,**
- ***of (known) radiance***

Ideally suited for measurements of
- **In-band relative spectral responsivity.**
- **Out-of-band-spectral responsivity.**
- **Spatial characterization.**
- **Absolute radiometric calibration.**

Goal: Measurements at the 0.1 % level

SIRCUS = Spectral Irradiance and Radiance Responsivity Calibrations using Uniform Sources

Wavelengths and Powers for SIRCUS IR

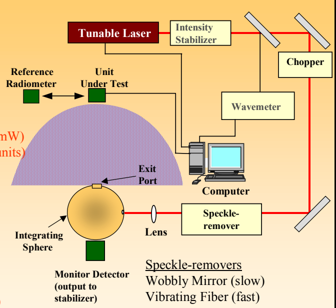


IR SIRCUS: Infrared Spectral Irradiance and Radiance Responsivity Calibrations with Uniform Sources

Wavelengths (microns)
1.064 YAG (10 W)
1.4 - 4.9 OPO (continuous, 0.5 to 1 W)
9 – 11 CO_2 (discrete 10 lines, W)
9-11 Isotopic CO_2 (discrete 10 lines, W)
4.8 - >6 CO (discrete, lots of lines, W)
5-12 OPO difference (continuous, mW)
4-12 OPO pumped OPO (continuous 10-100 mW)
8-12 Quantum Cascade (continuous, several units)

Reference Radiometers
Electrically Substituted Bolometer (ESB)
InGaAs (working standard)
Extended InGaAs (working standard)
Germanium, InSb, MCT (working standard)

Intensity Stabilizers
Fresnel Attenuator (broadband, slow response)
EOM (medium bandwidth, fast response, 1-5 µm)
AOM (narrow bandwidth, fast response)



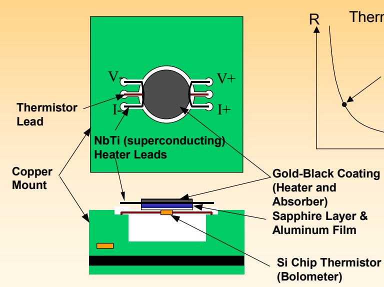
Speckle-removers
Wobbly Mirror (slow)
Vibrating Fiber (fast)

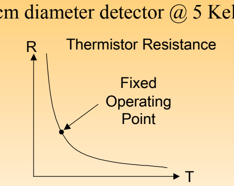
Black: Existing
Red: Under development

Acknowledgement The IR-SIRCUS facility at NIST is being developed with the support of the United States Air Force through the Calibration Coordination Group (CCG03-511). Development of the SIRCUS facility was also supported by the CCG.

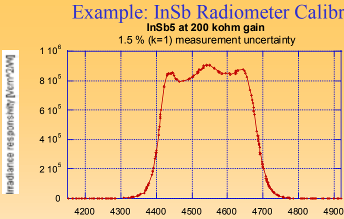
Electrically Substituted Bolometer (ESB): Reference Detector at IR SIRCUS

- •A liquid-helium-cooled bolometer stabilized with electrical substitution
- •NEP = 30 pW/Hz$^{1/2}$ @ 15 Hz for 1 cm diameter detector @ 5 Kelvin



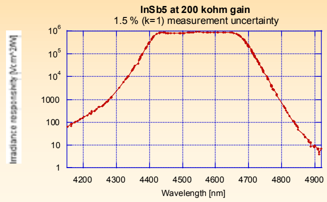


Example: InSb Radiometer Calibrated at IR SIRCUS



Linear Scale

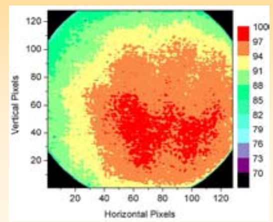
Log Scale



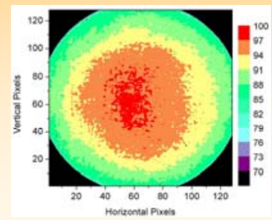
Response of a cooled InSb camera with laser tuned to 3.329 µm

•128 ×128 array focused on exit port (89 mm or 75 mm diameter) of integrating spheres.
•Acquire frame with laser-illumination and subtract frame without laser illumination.
•Color scale is percent of maximum count difference.

Spectralon Integrating Sphere



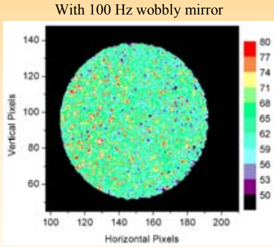
Diffuse-gold Integrating Sphere



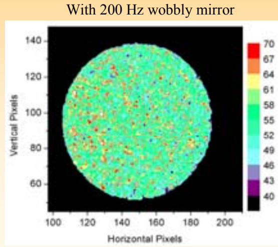
Response using an uncooled microbolometer array camera with laser tuned to 10.6 µm

•320 × 240 array focused on exit port (75 mm diameter) of diffuse gold integrating sphere.
•Acquire frame with laser-illumination
•Subtract thermal background frame (acquired without laser illumination).
•Color scale is percent of maximum count difference.
•Wobbly mirror was used to reduce laser speckle: Images show incomplete de-speckling.
•Complete de-speckling by vibrating a fiber feeding the laser into the sphere.

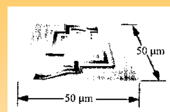
With 100 Hz wobbly mirror



With 200 Hz wobbly mirror



Dynamic Infrared Scene Generator Technology

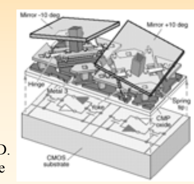


Emissive Scene Generators

•512 x 512 array of microresistors that can be individually heated electrically, thus emitting broadband IR radiation.
•Operation similar in principle to microbolometer run backwards.
•Used in some military IR scene simulation facilities.
•Systems tend to cost >$1M.

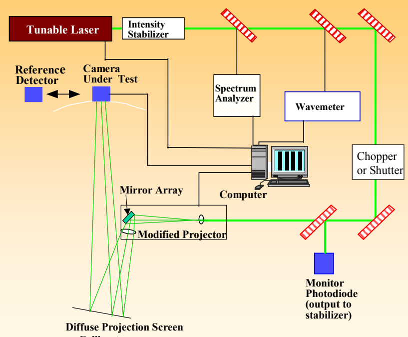
Reflective Scene Generators

•2-D array of aluminum micromirrors (TI's DMD) on a 12 to 17 micron pitch.
•Each mirror can be moved to either an ON position or an OFF position, separated by 20 degrees tilt angle.
•800 x 600, 1024 x 768, and 1280 x 1024 formats currently available.
•Spectral range determined by illuminating source and DMD.
•Blackbody-illuminated versions are commercially available in the $100 K price range.



Optical Technology Division NIST

Proposed Method: PIXSIR (PIXel Spectral Irradiance and Radiance Responsivity)
A laser-illuminated mirror array projecting tunable monochromatic structured IR scenes



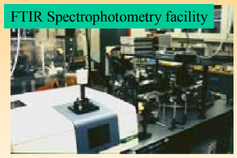
Optical Technology Division NIST

Current thermal-imaging testing and calibration capabilities.

•Spectrally characterize/calibrate single pixel IR detectors at IR-SIRCUS up to 5 micrometers.
•Calibrate customer blackbody sources used for thermal-imager testing/calibration (ABIR).
•Calibrate customer imaging cameras against accurate NIST blackbody sources (ABIR).
•Measure reflectance, transmittance, and emittance of customer-provided material samples at FTIR spectrophotometry facility.

Ambient Background Infrared (ABIR) facility

FTIR Spectrophotometry facility



Possible future thermal-imaging testing and calibration capabilities.

•Spectrally characterize/calibrate single pixel IR detectors at IR-SIRCUS up to 20 micrometers.
•Spectrally characterize/calibrate IR imaging cameras at IR-SIRCUS up to 20 micrometers.
•Test IR imaging cameras with a broadband dynamic scene generator.
•Test IR imaging cameras with a spectrally-tunable dynamic scene generator at IR-SIRCUS.

APPENDIX 4.A- BREAKOUT GROUP UNANALYZED RESULTS

Table 5. Chief Brian Duggan Group- Discussion Summary.

Research needs for first responders?	**What performance metrics are needed? How do they differ from current methods?**
Display- compensate for ambient light	Durability- drop test
Self test (automatic diagnostic)	Environmental limits of use
Effect of fire on battery- discharge curve, flammability	Ease of use
Verify battery duration needs- 1 charge per use?	Image quality- test and quantify (color, brightness, etc)
Intrinsic safety- shock, expl. (hazmat, fire, industrial)	Display quality- over temperature range
Pattern recognition/image interpretation	Stability- hot, cold
Ergonomics	Intrinsic safety
Image quality- what is acceptable image degradation?	Standard test target
Integration of equipment- location, data trans, turn out gear	Corrosion test
Scientific evaluation of image quality	EMF/RF interference- European RFI std. 89/36/EEC
Tracking an object- pattern recognition	Battery self test (minutes)
Human dynamic research and training (avoid danger)	Battery life (1.5 - 2 hours, fire)
Appropriate field of view	Temperature accuracy
Injury evaluation	Focal length
Conditions of use (environment, failure pts., live fire meas.)	Mission critical reliability
Test of imagers (limitations, temperature accuracy)	
User interface- temperature display: lights vs. numbers	

What standards are needed?	**What technological advances are needed?**
Durability	Battery operating life remaining in minutes
Environmental limits	Automated image/pattern recognition
Maximum weight	Batteries w/infinite life and zero maintenance
Image quality	Cheaper imagers
Display uniformity (icons, temp. gradients, colors, etc)	Broader temperature displays
Alarm- warning if imager isn't working properly	Image interpretation (artificial intelligence)
Immersion	Heads-up display
Battery time remaining- battery types, number	Depth perception- range determination finder
Consideration of equipment integration	Image fusion (visible and IR)
Draw on existing relevant standards and practices	**Uses:**
	Police: Search, target ID, helicopter/vehicle, night vision tactical decision aid
NOTE: stds to be minimum, to assure consistency and safety. No ceiling on technological advances, not design limiting, should be a living document.	Fire: Search, rescue, wildland, hot ballast, hidden fire, code compliance
	EMS: medical/health
	Command and Control (C+C)

Table 6. Larry Konsin Group- Discussion Summary

Research needs for first responders?	**What performance metrics are needed? How do they differ from current methods?**
Battery- User feedback	Sensitivity figure of merit (FOM)
Display- degradation with repeated exposure	How the image is displayed (contrast)
Image degradation when viewing thru weather	Scene dynamic range
Lower cost sensors- new processing, materials	Pixel saturation
Emissivity setting(s)	Battery and heat test profile
IR emitter for turn-out gear	Reliability mean time between failures (MTBF)
What standards are needed?	**What technological advances are needed?**
Operational functions- Icons, switches, etc…	Both standards and training
Dissect teach requirement and set the standard	Both AC-coupled and DC-coupled
ACTI* task group to study user interface	Heads-Up Display (HUD) and info on the screen
Reliability of performance	Establish minimums
Operational: human factors- color scale, palette	Improvements in reliability
Testing	Go from $8K to $2K, how?
Certification and Training	Hands free operation w/lower cost
User Interface Progression:	How good is good enough? (pretty good)
human factor	Internal sensors to check imager
quick utility value	Battery remaining time in minutes
proficiency	Smart charger technology (9 mo. old battery problem)
mastery	Default settings: draw on existing conventions
Draw on existing standards when possible	Battery static time vs. show time
Image quality standards- contrast?	Solid state technology improvements
Display standards	Smaller mass
Accelerated life testing	Goal: 5 yr life with 5 hr/yr at T > 250 ^{o}F?
Time left on battery	Display technology drives image quality
	NOTE: Phil Perconti ran displays group at NVL
	Sensors and read out integrated circuits specifically for first responders
	Ruggedness of housing
	Testing instrumentation
*Amercian Council for Thermal Imaging	

Table 7. Chief Bruce Varner Group- Discussion Summary.

Research needs for first responders?	**What performance metrics are needed? How do they differ from current methods?**
Is sensor or display limiting image quality?	Noise Equivalent Temperature Difference (NETD)
Find range of operation conditions	Frame rate
Establish design criteria	Subsystem metrics
Coatings for lens/display- condensation/deposition	Manual assemble lines
Find importance of image quality	Quick & dirty target- 3 or 5 bars, cheap, pass/fail
Field tests with videotape	
Sensors, displays, refresh rate, contrast, power, cost	
Intrinsic safety	
Human factors for user friendliness, intuition	
What standards are needed?	**What technological advances are needed?**
Shall not cause EMF/RF interference	Integration with other equipment
Shall not be effected by other equipment	Immediate need addressed: make current tech. work for now
Limit image transmission to 90 m (300 ft), per FCC	Water bottle package at $2K
IC out of range	Display- driven by avail. technology, function of packaging
Training- big step to see IR w/o full understanding it	Is sensor or display limiting image quality
Functionality across range of operation	Do we need a better display?
Image degradation due to smoke and dust	Long battery life
Impact resistance test	Coatings for lens/display (rain-ex?)
High and Low temperature performance test	Automatic shutter for lens/display
Abrasion of lens and display screen test	Hands free, non-distracting, vision unobstructed tech.
Deposition and condensation resistance test	Face-piece mounted display
Instrinsic safety test	"Stay ON" button- no sleep mode
Flame resistance test	Mode switch for electronic iris (EI or no EI)
Corrosion resistance test	Self test in field for operability- 3 bad pixels and out
Minimum operating criteria- go in, do task, get out	Smart, durable chargers
Guidelines for battery service	More informative icons
Consistent, meaningful icons- extended set optional	Battery life remaining in minutes
Require gloves-on operation	
Field test/calibration- simple and quick	
Housing inspection procedure	
Training and certification standard	
Performance standard	
Selection, Care & Maintenance document (SCAM)	

APPENDIX 4.B- TECHNOLOGICAL ADVANCES

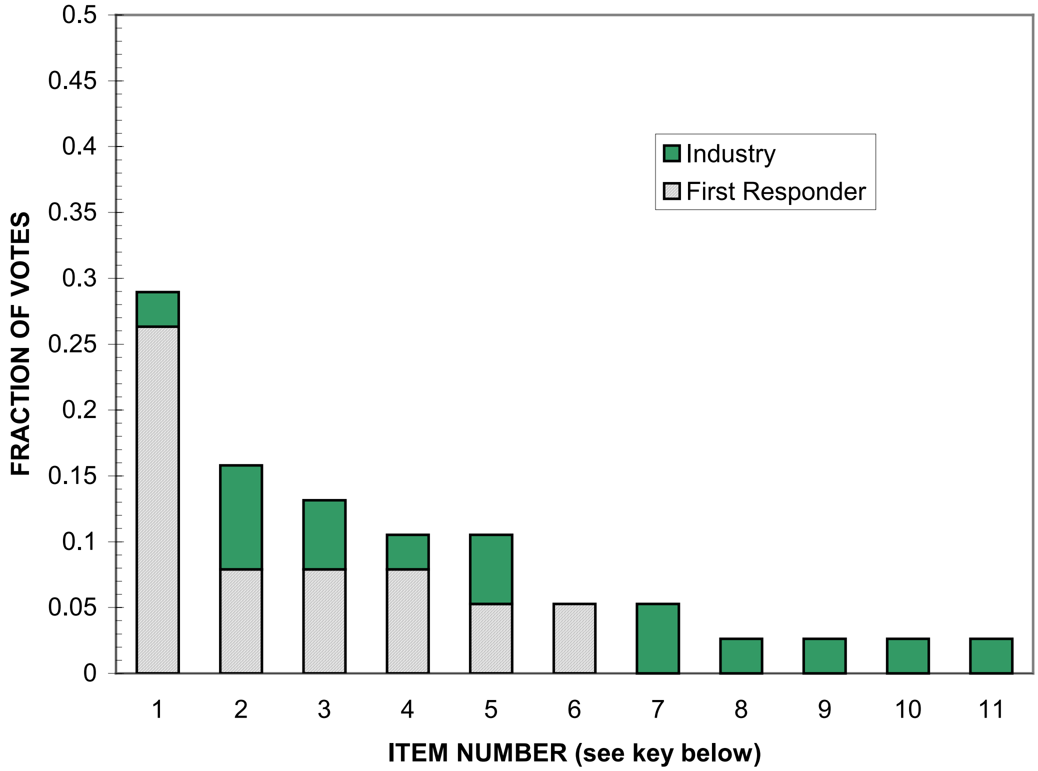


Figure 2. Voting results for responses to the question, "What technological advancements are needed?" Votes are shown as a fraction of the total number of votes cast in response to this question.

Voting key for item numbers in abscissa of Figure 2.

1. Reduction in imager cost ("water bottle" sized package priced at $2K)
2. Heads up or visor display technology
3. Battery charger technology improvements
4. Battery life/maintenance improvements
5. Compensation for ambient light (to see display)
6. Immediate need addressed- make current tech. work for now
7. Battery self-test technology
8. Depth perception technology
9. Intrinsic safety improvements
10. Battery life and heat exposure profile technology
11. Integration with other equipment

APPENDIX 4.C- RESEARCH NEEDS

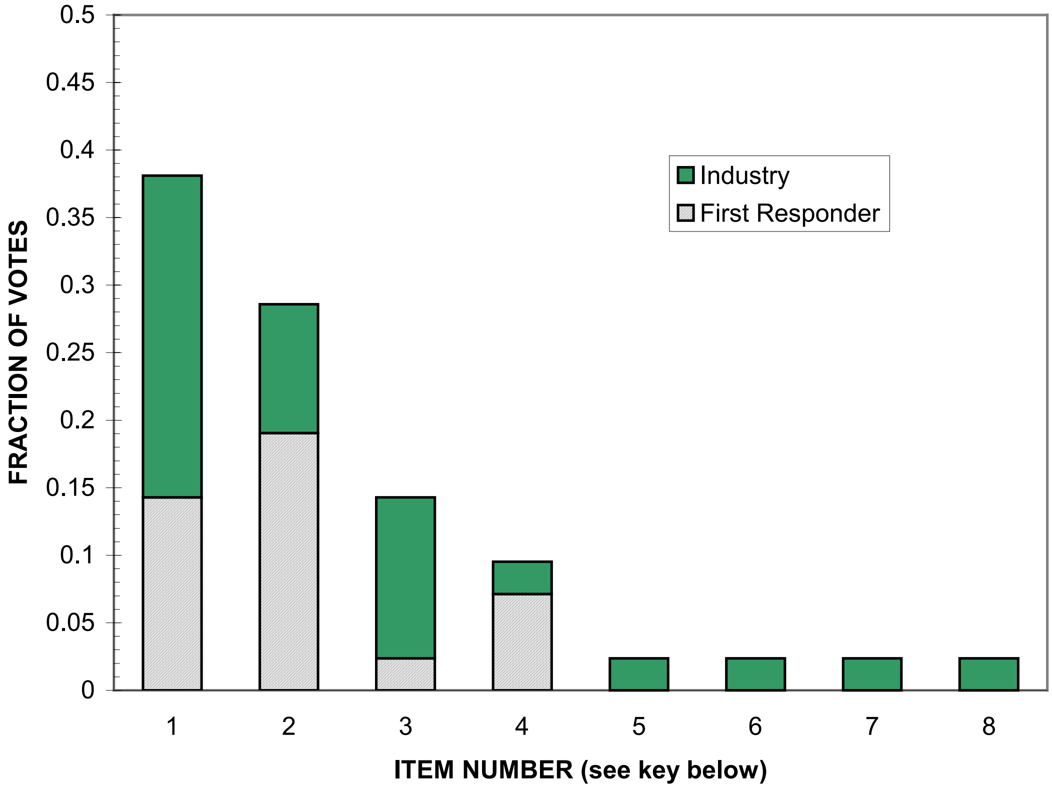


Figure 3. Voting results for responses to the question, "What are the research needs for first responders?" Votes are shown as a fraction of the total number of votes cast in response to this question.

Voting key for item numbers in abscissa of Figure 3.

1. Establish minimum/typical environmental test conditions
2. Human factor/ergonomic research (make imagers user friendly)
3. Image quality research (contrast, sensitivity)
4. Develop emissivity target for turnout gear
5. Identify performance limiting components: display? sensor?
6. Study feasibility of integration with other equipment
7. Human dynamic research and training materials (ex: avoid danger)
8. Develop a Selection, Care and Maintenance (SCAM) document

APPENDIX 4.D- PERFORMANCE METRICS

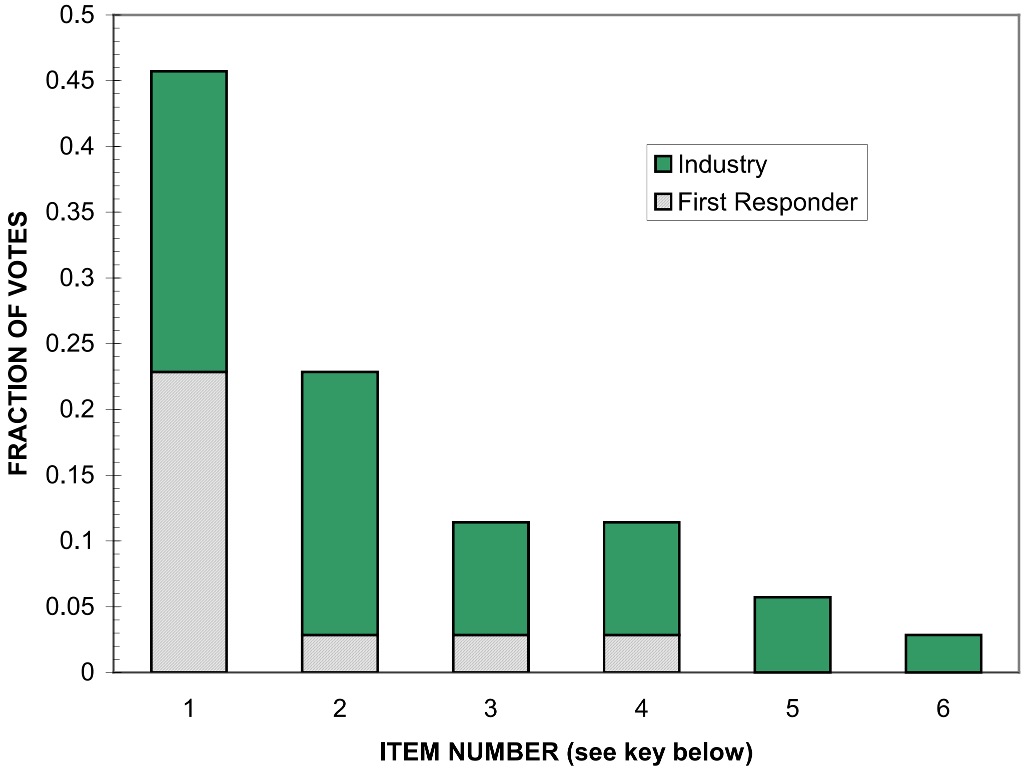


Figure 4. Voting results for responses to the question, "What performance metrics are needed and how do they differ from current methods?" Votes are shown as a fraction of the total number of votes cast in response to this question.

Voting key for item numbers in abscissa of Figure 4.

1. Thermal sensitivity metric
2. Image display metric
3. Durability metric
4. Imager quality metric
5. Reliability- Mean Time Between Failure (MTBF) metric
6. Scene dynamic range metric

APPENDIX 4.E- STANDARDS

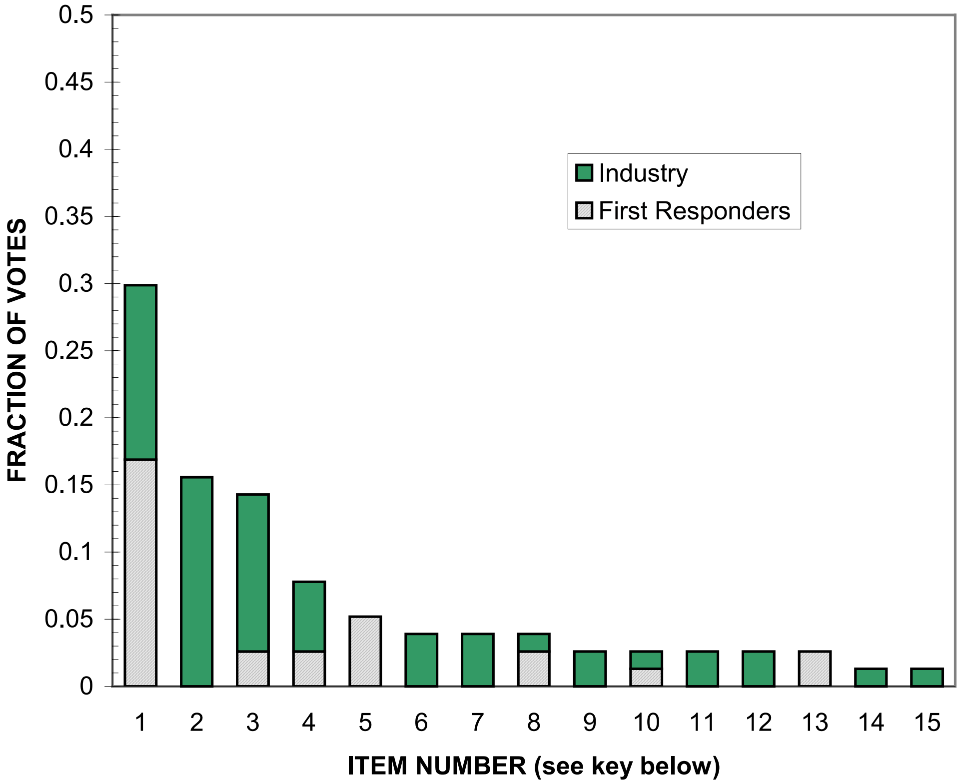


Figure 5. Voting results for responses to the question, "What standards are needed?" Votes are shown as a fraction of the total number of votes cast in response to this question.

Voting key for item numbers in abscissa of Figure 5.

1. Training and certification for personnel (includes environmental conditions)
2. Imager performance standard (image quality)
3. Casing/housing testing standard (impact, water immersion, corrosion, etc…)
4. Field test/calibration for imager using standard target
5. Lens/display integrity standard (abrasion, condensation, deposition, etc…)
6. Alarm or warning for nonfunctioning imager standard
7. Define minimum range of operation
8. User interface standard (display icons, buttons)
9. Battery self-test standard
10. Minimum battery life standard
11. Temperature measurement accuracy/calibration standard
12. Reliability MTBF standard
13. Maximum weight standard
14. RFI testing standard
15. Imager self-testing standard procedure

APPENDIX 4.F- VOTING COMBINATION KEY FOR FIGURE 1

The items listed in Appendices 4.B – 4.E were combined to form Figure 1 in the main proceedings body. The goal was to try to consolidate the information so that readers could get a sense of the voting results without getting deeply involved in the details of the four figures in Appendix 4. It is possible that individuals may interpret this information differently. In the following table each item listed in Figure 1 of the text is comprised of the sum of the corresponding source items from Figures 2 – 5 in Appendix 4 listed in the right-hand column of the table.

Table 8. Voting combination key for Figure 1.

Figure 1 item number	Appendix Figure – item number
1	Fig 3 – 3, Fig 4 – 1 Fig 4 – 6, Fig 5 – 2
2	Fig 2 – 9, Fig 4 – 3 Fig 4 – 4, Fig 4 – 5 Fig 5 – 3, Fig 5 – 5 Fig 5 – 12, Fig 5 – 14
3	Fig 5 – 1
4	Fig 3 – 1, Fig 5 – 7
5	Fig 2 – 8, Fig 3 – 2 Fig 3 – 7, Fig 5 – 8 Fig 5 – 13
6	Fig 2 – 2, Fig 2 – 5 Fig 4 – 2
7	Fig 2 – 3, Fig 2 – 4 Fig 2 – 7, Fig 2 – 10 Fig 5 – 9, Fig 5 – 10
8	Fig 2 – 1
9	Fig 3 – 4, Fig 5 – 4
10	Fig 5 – 6, Fig 5 - 15