Healthcare Alarm Safety—What We Can Learn From Military Alarm Management Strategies

Lockheed Martin (LM) Advanced Technology Laboratories

Daniel McFarlane, Sc.D. of LM Advanced Technology Laboratories provides insight on ways to enhance hospital alarm management, reflecting upon innovative alerting systems utilized by the Navy to improve warfighter awareness and capabilities.
About the Healthcare Technology Safety Institute (HTSI)

Founded within the AAMI Foundation, the 501(c) (3) charitable arm of AAMI, the HTSI is a community of leaders throughout the healthcare system who are dedicated to one common vision, “No patient will be harmed by medical technology.” HTSI’s mission is “To engage the entire healthcare community in multi-disciplinary safety initiatives that strengthen the development, management, and use of medical technology for improved patient outcomes.” HTSI engages the healthcare community in research, education, consensus, and partnerships related to the challenges facing healthcare technology industries, regulatory and accrediting bodies, clinicians, caregivers, and patients.

Permission to Copy
We encourage you to share this paper with your colleagues. You may freely reproduce this publication for educational purposes only, provided that proper attribution is made as follows: Copied with the permission of the AAMI Foundation and the Healthcare Technology Safety Institute. This publication may not be copied in part or in whole for commercial use.

The views expressed in this publication do not represent the views of the AAMI Foundation or HTSI. The work of the AAMI Foundation is intended to be a helpful resource for healthcare delivery organizations, so that every organization does not have to reinvent the wheel or start their technology management work from scratch. It does not constitute legal, regulatory, operational, or procedural advice, nor does it constitute a standard of care. It is essential that each healthcare delivery organization assess the material in the context of its own organizational needs, culture, technology, and priorities.
Introduction

Deep within the center of a naval warship is a military combat information center that utilizes both human and computer-based intelligence to understand its surroundings and to identify nearby objects, decide if they are friendly, neutral, or hostile, and determine whether they require a response from the warship. Military decisions on identifying objects and labeling them as potential or actual threats must be done in real-time so only necessary action is taken. If decisions made by military combat information center personnel are not accurate, the consequences are significant at best or severe at worst, with potential international implications. The process for making these decisions is far from easy. Operators within the combat information center carefully watch complex screens, scrutinizing every movement in the outside situation looking for any sign of concern. At the same time, alarms announced with buzzers are firing off to alert personnel to any recognized pattern of change that was pre-decided to merit human attention. This includes a mix of alarm types, and deciphering the importance of each is often relative to the changing situation. These alarms must all be interpreted by operators simultaneously. As an example of what this requires, warship operators during the first Gulf War were receiving extremely frequent alarms; one class of operator, for example, received a new alarm every 11.5 seconds on average. Turning a deaf ear to alarms is not an option for the military operators, as some alarms have life or death consequences.

Over the years, defense researchers have spent significant time and resources examining how to maximize a warfighter’s performance as they monitor screens of information and deal with a multitude of automated notification systems and alert interruptions. The military recognized years ago that while automated notification systems provide constant warnings, they do not necessarily result in the needed recognition by operations personnel. Research from the defense research community has shown that people have cognitive limitations that affect their ability to cope with alert-based interruptions. Ultimately, individual decision quality is significantly reduced as a consequence of these limitations. For the military, dealing with the risks associated with human error led to the development of a new solution and way of thinking about alarm management. The solution was found in the use of software that helps maximize human performance, regardless of the type or multitude of alarm interruptions. Interactive software provides “negotiation-based
coordination” services that empower operators to quickly understand the importance of every alarm relative to the current situation, and triage their own attention to focus on what is most important.

Applying Defense Logic to the Health Care Setting

In the health care setting, alarm management can be as crucial to making life and death decisions as it is in the warship. Nurses and the expanded health care team are expected to appropriately respond to alarms, using judgment while listening to alarms that fire off on a frequent basis. For a nurse working a 12+ hour shift, these alarms eventually may fade into background noise, and even when they are recognized, most alarms give no direct actionable information that provides immediate support for decision-making.

Dr. Daniel McFarlane of Lockheed Martin’s Advanced Technology Laboratory in Arlington, Virginia understands this scenario more than most. With over 25 years invested in the study of human attention theory on how people manage and focus their attention to make decisions, he sees an immense opportunity to learn from defense-related research and practices and to change how hospital systems manage alarms and ultimately save lives.

In 2012, after learning of Lockheed Martin’s efforts to improve systems integration in healthcare and of the company’s experience with military alarm safety management, AAMI asked Dr. McFarlane to serve as a subject matter expert and to utilize his work in human attention theory to provide recommendations on how the health care industry could improve its current alarm management systems. He made site visits to hospital and clinical care-settings and participated in standards workshops to learn more about current hospital-based efforts and best practices in alarm management. Site visits included spending time at Johns Hopkins Medical Center, Massachusetts General Hospital, Davita outpatient clinics, Palomar Medical Center, and Cedars Sinai Hospital. Dr. McFarlane reviewed how various health care settings managed alarms, examining everything from cardiac and neonatal hospital units to post-operation settings and outpatient dialysis units. What he discovered was that the approaches being used across the hospital industry and in other outpatient settings continued to present repetitive challenges—challenges the broad health care community has faced for years: ignored alarm signals, lengthy practitioner response rates to the alarms, and provider confusion over the importance of the alarms. Having worked with the military to improve alarm management and introduce software options to support decision making, he began to see that military-type solutions could provide hospitals a similar level of support, but to implement such a system(s) in the health care sector would require a shift in the mindset of care providers and a change in how medical devices ultimately work.

Drawing on his experience, Dr. McFarlane approached the task of helping to advise on alarm management with one primary question in mind: What does a health care worker need to know, and when do they need to know it in order to make a good decision? Once that question could be answered, he sought to focus on two specific efforts: (1) identifying which patient a nurse should be attending to now, and (2) determining what actions a nurse must take at this time.

Health System Observations

Dr. McFarlane observed several limitations in how medical devices function when producing alarms. Such limitations included the following:

- Alarm configuration settings on devices are limited to simple ranges, and most clinicians tend to rely on factory-default alarm settings rather than making adjustments.
- Alarm signals do not include sufficient metadata about the nature of the alarm to help a nurse determine its importance.
- There is no cross-device integration, as devices do not “talk” to each other. A ventilator from one manufacturer will likely not communicate data across a

Success to Alarm Management:

First, answer the question: What does a health care worker need to know and when do they need to know it in order to make a good decision? Then, respond by doing the following:

- identifying which patient a nurse should be attending to now; and
- determining what actions a nurse must take at this time.
network with a physiological monitor from another vendor.

- Alarms on devices connected to a patient are not connected to clinical information systems that can provide specific medical information a nurse can access while considering the reason behind a patient alarm.

As a result of these limitations, nurses largely do not trust that alarms are valid or useful, and they stop relying on the systems and their notification. This frequently results in a slower review and response time to patient alarms, at times having dire consequences for the patient.

Utilizing his training, Dr. McFarlane sought to dissect the problems he observed and to match alerts “in the hospital” to actionable data that is fed to the personnel responsible. He began to see distinct behavioral variances between the military warship setting and the hospital/clinical setting with advantages and disadvantages in relation to alarm management. For example, he realized that unlike a military command officer who observes a computer screen full of remote unseen objects and relies on alarms to sound off concerns that must be analyzed, a nurse walks into a command post already “armed” with more intelligence about the targets (patients) in question. A nurse has the benefit of patient medical charts and background information, distinguishing patients from one another, a distinct advantage over a military officer who knows very little about the targets being observed. Similar to the military setting, however, the nurse is without any definitive information on the true status of what the alarms represent when they sound.

Another distinct difference between the warship and the hospital is that the warship allows for stationary work, while the hospital requires mobile work. In the warship, the military operators are focused only on observing the screen and the images and the alarms being presented in front of them. In the hospital setting, nurses and other health professionals are anything but static; moving around a hospital wing or department non-stop, their days are focused on managing multiple patient-related tasks simultaneously.

“One of the first things I noticed during my site visits to hospitals and health clinics is that existing hospital alarm systems are not targeted at helping the care provider—the nurse—on the front lines who has direct patient care decision-making responsibilities. Current alarm systems don’t even allow nurses to get to the meta-level task of understanding which patient they should be attending to first.” His observation was that medical devices provide an audio or visual sign that an issue and potentially a problem exist, but they do not directly provide the nurse with any other information that could be used to prioritize their responses. For some hospital systems, nurses are provided pagers or other mobile devices as secondary notification that a patient alarm signal has been made, but most pager notification systems provide no other direct, actionable intelligence to the nurse to aid in decision-making or a response. For example, secondary notification systems sending alarms about a patient’s heart rate threshold crossing event, could additionally include information about the patient’s other vital states.

“The lack of actionable intelligence from alarm signals makes it impossible for nurses to effectively triage their multitasking among multiple patients,” said Dr. McFarlane. “The testing of new medical alarm designs seems to be often focused on whether it affects patient mortality rates. I think a more useful metric would be do these alarm designs provide a nurse the information needed to make a good decision about when to provide what care to patients.” To address this issue, Dr. McFarlane believes it would be useful to include nurses as stakeholders to help guide alarm safety research and development (R&D). Dr. McFarlane believes that identifying ways to help nurses improve in triaging their time would result in improved care for all patients.

Dr. McFarlane recommends that such an R&D effort should seek to “walk in a nurse’s shoes” and understand that nurses are typically assigned to two or more
Problem #1: The design of current alarm signal delivery is not focused on helping the nurses triage time across multiple patients.

Proposed Solution: Hospitals need to advise device manufacturers and the standards development organizations that specify device behavior in these areas that devices need to be designed to provide content (about a patient) to assist nurse decision making and multitasking.

Proposed Method for Addressing the Problem: Design a new research method for evaluating a medical device for how it helps the “front line workers” (e.g., nurses), and then test it in a high-fidelity patient simulation setting so that nurses can determine what works and what does not work for them.

patients at the same time, all in different rooms. As a nurse’s job requires frequent movement throughout a hospital wing, they are often blind to recent changes in their patients’ status. This situation too frequently results in missed opportunities to provide needed patient care, despite the presence of medical device alarm systems. According to Dr. McFarlane, “current alarm generation functions do not align with the multitasking needed to triage attention across multiple patients. Instead, each alarm feature considers only local conditions on separate sensors on separate instruments for separate patients. The result is an overwhelming rate of alarm signals from multiple devices associated with multiple patients that do not carry the context of information needed for nurses to understand the signals relative to their responsibility to triage their efforts.” He argues that an R&D effort must recognize the limitations of the nurses’ current work environment and seek to establish new mechanisms that address nurses’ needs given the mobility of their practice.

Advising Health Care Device Manufacturers

One of the primary challenges in relation to medical devices and alarm management, according to Dr. McFarlane, is that devices are built by a multitude of vendors. The alarms all sound similar even though the purpose of the alarms are all different, and perhaps most significant, the medical devices made by different manufacturers cannot talk to each other.

“As an engineer, I’ve learned that there can be a fatal error in how a machine is constructed. That error is due to false assumptions about how a machine will be used.” In Dr. McFarlane’s observations, medical devices are too often being designed as if the nurse is always standing at the bedside and can review the patient as soon as a device issues an alarm or visual signal. In his opinion, this is simply a false premise. “A good non-military example of a “system” is the automobile,” according to Dr. McFarlane. “Car-makers do not make most of the various different car compo-

The Future for Alarm Management

For Dr. McFarlane, the conclusion to the challenge behind alarm management can be summed up as follows: “Current alarm generation functions do not align with the multitasking needed to triage attention across multiple patients. Instead, each alarm feature considers only local conditions for a single sensor for a single patient.” The end result – a fire hose of alarm signal data that does not carry the context of information nurses need for understanding how to utilize the alarms to triage across the multiple patients they are responsible for at any one time.

Alarm research needs to look at three distinct areas related to how alerts issued from medical devices can support patient care decision-making:

• Alert generation – The design of how medical instruments detect specified alarm conditions and then generate alarm signals.
• Alert mediation – How raw alarm events are managed to support end-users’ workflow needs. This can include implementation of a policy about how alarms should be managed and routed to which end-users. For example, an alarm delivery escalation policy can define a chain of people to forward an alarm to if the primary recipient does not acknowledge it within a specified time.
• Alert presentation – How the alarm signal is delivered to end-users. This
includes the visual and audio announce-
ments of alarms to end-users. Critical
alarms about a patient’s breathing
difficulty could be announced with
different sounds than alarms about
device batteries needing to be changed
before the end of the day.

Change the Look, Feel, and Scope of the Devices

Alert mediation is an important R&D focus
for improving the utility of alarms for
end-users. Lessons from military “systems”
thinking can be leveraged to inform a new
design that combines raw device-based
alarm signals with additional data to
support a nurse’s decision making in
response to a patient alarm. According to
Dr. McFarlane, “in current operations,
there is a high rate of alarm signals gener-
ated, but the majority of these signals do
not reflect clinically-significant events. The
main problem is that these alarms are not
being delivered to their nursing consumers
with enough contextual metadata to provide
an understanding of their meaning or
relative importance. Computer networked
data analytics are capable of dealing with
the current high rates of streaming data
and applying algorithms that can assess
that data.”

Dr. McFarlane advocates for research that
considers how to link alarms to patient data
through a secure computer network con-
ected to a centralized server. When an
alarm is generated, alarm mediation
technology could package the delivery of that
alarm with additional context information
about the patient, such as the patient’s
medication status. This would enable health
personnel to potentially understand the
relative importance of that alarm signal and
decide how to fit a response to the alarm
into their multitasking.

Once the alarm can be turned into
something actionable, after being paired
with patient information, the next chal-
lenge is how to deliver it to the nurse.
According to Dr. McFarlane “to be success-
ful in ensuring the nurse gets the right
information at the right time to respond,
the R&D effort must also consider how to
address the fact that a nurse is mobile and
does not work only at the bedside.
Researchers must consider how to get this
actionable information seamlessly into the
hands of the nurse. Through the use of
mobile technology – devices and apps –
information can be made available in a
matter of minutes.”

Problem #2: Many medical devices
are built by a number of different
vendors and cannot relate or talk
to each other.

Proposed Solution: Establish
standard interfaces for medical devices that
facilitate integration.

Proposed Method for
Addressing the Problem:
Consider a new model for provisioning
hospitals by buying hospital “systems” from
an integrator. If enough hospitals adopted
this model, the integrator would have
sufficient market power to motivate vendors
to conform to interface standards.

Problem #3: Nurses
are mobile and medical
devices are static.

Proposed Solution:
Get the information interface
for a medical device to where
the provider is located as
she/he moves around the
hospital. Proposed Method
for Addressing the Problem:
Use current technological
resources to deliver intelligent
information on medical
device alarms through such
processes as smart phone or
other electronic technology
and applications.

Contact Information:
AAMI Foundation
4301 N. Fairfax Drive, Suite 301
Arlington, VA 22203
Phone: +1-703-525-4890
Fax: +1-703-276-0793
Email: slombardi@aami.org
www.aami.org/foundation

Contributions and Donations:
To make a tax-deductible
donation, please complete the
donation form at
www.aami.org/foundation/
donate and mail
your check or money order to:
AAMI Foundation
4301 N. Fairfax Drive, Suite 301
Arlington, VA 22203-1633

Has your healthcare
organization
implemented any of
the strategies discussed
in this publication?
Do you know of a
healthcare facility that
has dealt with a
technology-related
issue and has a story
to share?
If so, we would love to
hear from you! Please
e-mail slombardi@aami.org.