NIST Handbook 161

Usability Handbook for Public Safety Communications

Ensuring Successful Systems for First Responders

Mary Theofanos
Yee-Yin Choong
Shaneé Dawkins
Kristen Greene
Brian Stanton
Ryan Winpigler

This publication is available free of charge from:
https://doi.org/10.6028/NIST.HB.161

National Institute of Standards and Technology
U.S. Department of Commerce

NIST Handbook 161

Usability Handbook for Public Safety Communications

Ensuring Successful Systems for First Responders

Mary Theofanos
Office of Data and Informatics
Material Measurement Laboratory

Yee-Yin Choong
Shaneé Dawkins
Kristen Greene
Brian Stanton
Information Access Division
Information Technology Laboratory

Ryan Winpigler
Emergency Services Office
Management Resources

This publication is available free of charge from:
https://doi.org/10.6028/NIST.HB.161

May 2017

U.S. Department of Commerce
Wilbur L. Ross, Jr., Secretary

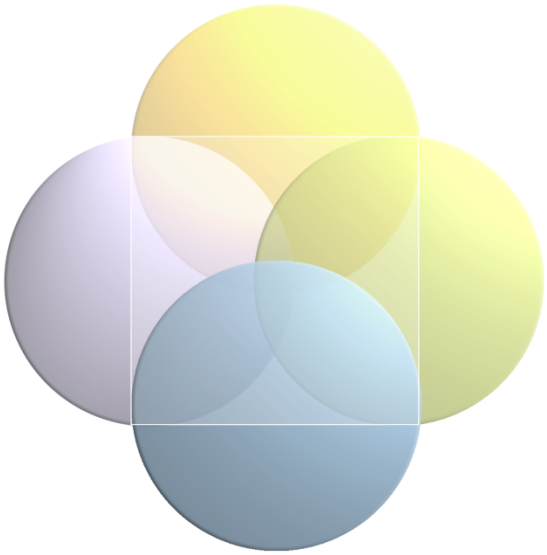
National Institute of Standards and Technology
Kent Rochford, Acting NIST Director and Under Secretary of Commerce for Standards and Technology

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

PSCR

Usability Handbook for Public Safety Communications

Ensuring Successful Systems for First Responders



MAY 2017

ABSTRACT: This handbook provides an overview of the user-centered design process and examples of how the process can be applied to the design and development of communications systems for the public safety community.

KEYWORDS: Public Safety; Public Safety Communications Research; Requirements Analysis; Usability; Usability Testing; User-Centered Design; User Evaluation; User and Task Analysis.

CONTACTS

This handbook was developed by the Public Safety Communications Research Usability Team at the National Institute of Standards and Technology (NIST).

National Institute of Standards and Technology
Communications Technology Laboratory
Gaithersburg, MD 20899

Mary Theofanos
Computer Scientist
301.975.5889
maryt@nist.gov

Yee-Yin Choong
Industrial Psychologist
301.975.3248
yee-yin.choong@nist.gov

Shaneé Dawkins
Computer Scientist
301.975.4464
shanee.dawkins@nist.gov

Kristen Greene
Cognitive Scientist
301.975.8119
kristen.greene@nist.gov

Brian Stanton
Cognitive Scientist
301.975.2103
brian.stanton@nist.gov

Ryan Winpigler
Firefighter/EMT
Emergency Services Division
301.975.6190
ryan.winpigler@nist.gov

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to many subject matter experts for their valuable discussions enabling us to gain deeper understanding of users in the public safety communications space. Special thanks to Barry Luke of NPSTC; PSAC members; Casey Grant of NFPA; Mark Reddish of APCO; NIST Fire Chief Stephen C. Shahan; NIST Police Chief Eric C. Perez; FEMA USAR (Urban Search and Rescue); and Fire, EMS, Law Enforcement, and Bomb Squad personnel in the northeast corridor.

FOREWORD

As the National Institute of Standards and Technology (NIST) usability team began to study public safety communications technologies and applications, it became evident that many of our partners in the Public Safety Communications Research (PSCR) community were unfamiliar with usability terminology and methodologies. Part of fostering an effective partnership is communicating the value and benefit of the usability discipline. As visibility and interest in our usability and public safety communications research increased it became clear that a handbook introducing usability would benefit the community as a whole. This document was created to serve that purpose.

This handbook provides a common understanding and vocabulary for usability to encourage collaboration between usability and public safety communications researchers and practitioners. It begins by examining public safety communications technologies evolution and the influence of the user and user characteristics. We examine the concept of usability and how it is defined. We introduce the user-centered design process and the value of the process to the development of public safety communications systems. The elements of the user centered design process including context of use, user and organizational requirements, design solutions, and evaluation techniques are defined and described. Finally, a list of usability methods and techniques are elaborated.

We hope that this handbook will be useful in continuing to promote a collaborative research environment between the public safety communications research and usability research communities.

PREFACE

The public safety community performs the vital mission of protecting lives and property – from day-to-day operations to large events and emergencies. Yet, the public safety community faces communications challenges including interoperability and network capacity, coverage and service.

The Middle Class Tax Relief and Jobs Creation Act of 2012 (PL 112-96) created the First Responder Network Authority (FirstNet) to develop a high-speed backbone, Nationwide Public Safety Broadband Network (NPSBN), for public safety to take advantage of new innovations and enhance their communications and information sharing. The FirstNet network will enable law enforcement officers, firefighters and paramedics to send data, images, video, and location information in real-time. These new capabilities will help first responders perform their live-saving mission more safely, efficiently, and effectively.

THE PUBLIC SAFETY LANDSCAPE

The public safety community is undergoing a transition. Over the next 20 years, technology advancements will enable data, video, and eventually voice communications to migrate from disparate Land Mobile Radio (LMR) networks to a nationwide Long Term Evolution (LTE) broadband network. Emerging technologies within this new infrastructure present opportunities and challenges for public safety and the process of modernizing responder communications.

To facilitate the transition from LMR to LTE, the National Institute of Standards and Technology's (NIST) Public Safety Communications Research (PSCR) program is leading a coordinated, multidisciplinary research effort. This effort includes the development of multiple technology roadmaps that present the highest-priority technological trends, capabilities, gaps, and R&D opportunities facing public safety over the next 20 years. Each roadmap focuses on a specific emerging technology sector that has the potential to greatly increase the response capabilities once the public safety community migrates to the NPSBN. The current three roadmaps are Location Based Services, Public Safety Analytics and Enhanced User-Interfaces.

THE PSCR USABILITY CHALLENGE

User interface was selected by PSCR as an important R&D opportunity area given the demonstrated high leveragability, feasibility, impact, and return on investment to the public safety community. User interfaces, human-computer interaction (HCI) and usability are critical components to the adoption and success of the NPSBN. The challenge is for developers to design communications technologies with intuitive interfaces which are easy to use by the public safety community.

To address this challenge, NIST's PSCR program initiated a user interface and usability effort to focus on new interfaces, interaction paradigms, and the public safety users and human factors of public safety communications systems. The goal of this effort has been to conduct research to determine requirements for developing a testing environment that

measures the efficiency, effectiveness, and user satisfaction of public safety communications technologies in a repeatable and reproducible manner. An additional goal is to provide resources (such as this handbook) for designers and developers of public safety communications systems.

This handbook[1] will work to introduce designers to the concept of usability and showcase the ways in which a properly implemented user-centered design process can improve a system's effectiveness, and efficiency, and user satisfaction.

For more information on this handbook and other NIST usability and PSCR projects, please visit https://www.nist.gov/ctl/pscr/newsroom/

PURPOSE AND AUDIENCE

This handbook is intended for use by designers, developers and researchers of public safety communications technologies.

The goal of this document is to provide information and resources for design and development organizations and researchers that will ultimately improve the usability of public safety communications systems.

[1] This handbook was funded by the NIST PSCR program.

TABLE OF CONTENTS

List of Tables

List of Figures

Chapter 1
Public Safety Communications Technologies

THE TECHNOLOGY VIEW

To date, the design, development and evaluation of public safety communications for the Nationwide Public Safety Broadband Network (NPSBN) has understandably been focused on system performance and functionality, for example, end to end quality priority and pre-exemption, audio quality, speech intelligibility, and LMR and LTE interfacing, among other factors. In the beginning stages of development, it is necessary to focus primarily on the performance of communications systems. As these new technologies mature, it's important to begin to evaluate other factors, including the user interfaces and usability of these systems.

One aspect of public safety systems that has not always been thoroughly considered is the user. The user brings innate characteristics and experiences to the interaction that affect performance. Without a careful consideration of user characteristics and experiences, system designers and evaluators may struggle to make significant improvements, which advances in technology alone cannot achieve.

The early development and design view of the public safety communications process typically focuses solely on the technology. This view of the system and technology is presented in the illustration (Figure 1) below.

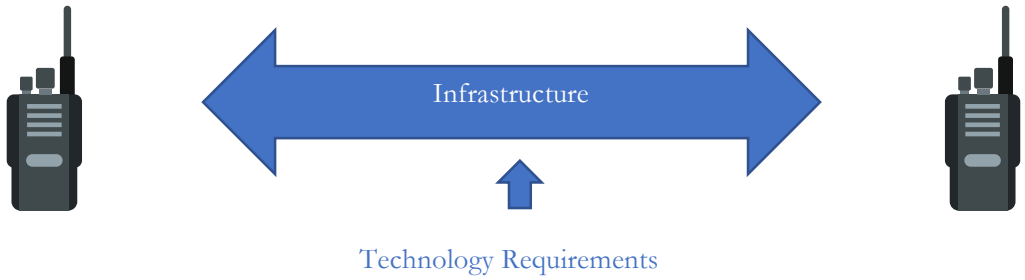


Figure 1: The Technology View

In order to make more substantial improvements to the performance of public safety communications technologies, it is essential to take the user into consideration. We can no longer focus on one half of the problem. It is necessary to examine the human and usability. One could argue that the user has been in some sense forgotten from the process, yet the user is initiating and/or receiving the information and acting on the communication. To make the right decision, it is critical that first responders receive the right information at the right time and delivered in the right way.

THE USER VIEW

Users are a key component in the communications process, as users ultimately begin and end the communication. Their interaction with the system is essential to a holistic understanding of the communication process. No matter how good the technologies may be with respect to quality, accuracy, and completeness, if the user interface or delivery method is not usable or is confusing, the data are not actionable and could cause harm.

Beyond focusing on the limitations and capabilities of a technology, it is equally important to consider the impact a user's characteristics, experience levels and abilities will have on a system. As an example, consider the consequences of a poor user interface: the Three Mile Island nuclear power plant accident, the most investigated accident in the history of the commercial nuclear industry [Meshkati, 1991]. Because the design of the control room did not emphasize the user interface, operators experienced problems locating and accessing the tools and information they needed. The following interface issues were identified:

- System controls were not located near the instruments that displayed the condition of the system. For example, operators could not view the indicator display for the high-pressure system while operating the throttle valve to adjust pressure.
- Some instruments located near one another looked very similar but controlled different functions.
- Some instruments were difficult to read because of glare from poor lighting or obstruction by other controls.
- Throughout the control room, there was no consistent meaning of indicators such as lights and alarms) or function of instruments (such as levers and knobs) between controls.
- At the time of the accident, operators in the control room heard three alarms and saw more than 1 600 blinking lights.

Despite being highly trained, the nuclear power plant operators were overwhelmed with all the incoming data in the stressful environment. The information was not delivered effectively or efficiently for the operators to make the right decision at the right time. Public safety first responders operate in similarly stressful situations and must rely on a great deal of incoming information to act and make quick decisions.

The diagram (Figure 2) below illustrates the two-way interaction, or relationship, between the user and the system during the public safety communication process.

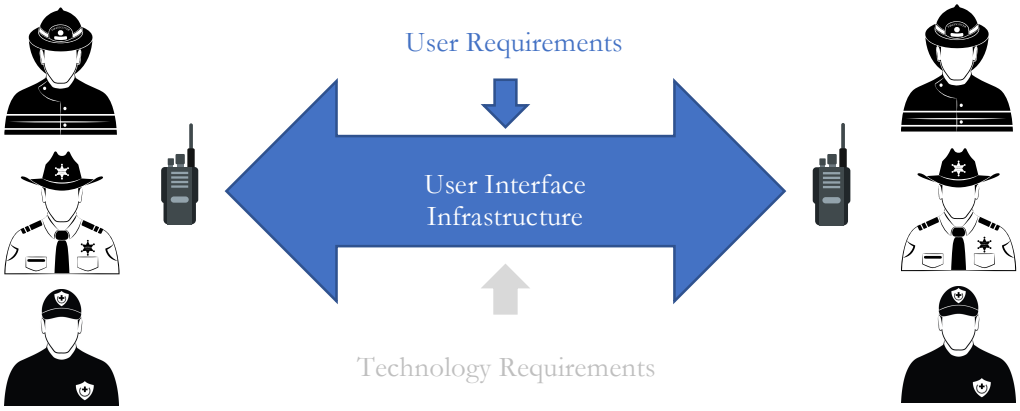


Figure 2: The User View

Not only does the user play an integral role in communication, a user's innate characteristics have a substantial impact on the ultimate success of a communications system.

DEMOGRAPHIC CHARACTERISTICS

Innate characteristics can significantly affect a user's performance and influence the ability of the system to perform successfully. For instance, consider the impact of the following characteristics on the design of a public safety system:

- Age
- Gender
- Experience
- Abilities
- Innate human limits

By designing with these characteristics in mind, developers can produce a system that is more effective and efficient. With a focus on users and the usability of systems for first responders, design teams have the opportunity to reduce users' cognitive load, minimize alert fatigue, and minimize competition for users' attention, thus improving efficiency and reducing errors while maintaining safety of the first responders.

Following is an example demonstrating design questions that project teams must consider in the development of a system. Please note, this list is not an exhaustive list of design considerations. Rather, it is intended to stimulate design teams to begin thinking about the needs of users and the potential impact of users' inherent characteristics on the performance of a system.

Age

- What role does age play, if any, in users' abilities to learn and use a system?

Gender

- What role does gender play, if any, in the use of a system?

Experience and Abilities

- What role does experience play in users' abilities to use a system?
- Do first-time users struggle more than experienced users?
- Do infrequent users struggle more than frequent users?
- How does past experience affect a user's interaction with a system?

Innate Human Limits

- What are the limits of human perceptual (visual, auditory, tactile, etc.) processing?
- How can systems best support innate human limits to avoid cognitive overload, especially in high-stress environments?
- How many alerts can users accurately attend to without experiencing alert fatigue?

In addition to these demographic characteristics, it is also important to consider other opportunities to enhance the usability of a system through the use of user-centered feedback and alerts, greater awareness of anthropometrics, and enhanced affordances.

To that end, we have provided some additional design questions related to these issues below:

SYSTEM FEEDBACK, ALERTS & INSTRUCTIONAL GUIDES

- What types of feedback and alerts should a system provide to users, keeping in mind human perceptual limits? Auditory? Visual? Sensory?
- At what point should the system provide feedback and alerts? How frequently should feedback and alerts be given? What is the most effective and efficient way to provide feedback alerts?
- When used to present system feedback and alerts, can symbols, colors and iconography be understood by all intended users?
- Will users need instructional materials in order to use a system? What is the most effective way to deliver instructional materials?

ANTHROPOMETRICS

As measurements used to describe the user of a product, anthropometrics provide data on average body dimensions that exist in the larger population. Gathered by taking measurements from a large number of users in a variety of positions, anthropometrics provides designers with information needed to create more usable systems. For example:

- How can designers use established anthropometrics standards to design the physical characteristics of a system?
- Can anthropometric data be used to inform the optimal size of the components of a system?

AFFORDANCE

First introduced into the world of human-computer interaction by Donald Norman in the book "The Design of Everyday Things" [Norman, 1988], affordance refers to the properties of an object that allow a user to perform an action. In designing systems, developers often look to create a sense of affordance so that users understand that they can interact with a product or system. With regard to public safety systems, this interaction may come in the form of a physical design (do users understand from the design of the hardware what actions they should take) or in the form of a systems' interface (does the software interface invoke users to interact with the system in an appropriate manner).

While actual affordance is a key component of any given system, it is also important for designers to consider perceived affordances. For instance, do users expect an action to occur when in actuality the function doesn't exist? Understanding how users expect a system to perform is just as important as understanding how users interact with the intended affordances.

- Do users understand what to do when they encounter a device or system?
- What actions do users perceive are available?
- What information does the system provide to users to communicate the actions users should take?

By taking into consideration a users' inherent demographic characteristics, as well as instructional guides and feedback, anthropometrics, and affordance, developers have a much greater chance of producing a truly usable, user-friendly system.

USER-CENTERED VIEW: USERS PLUS TECHNOLOGY

In its entirety, the user-centered process involves all facets of a public safety system. This holistic view involves not only the system and its response to stimuli (be it input directly from users or automatically generated from other devices such as sensors), but also the inherent characteristics of users and their interaction with the system.

The diagram (Figure 3) below integrates these essential usability components to illustrate a truly user-centered process that takes into consideration the needs and characteristics of users instead of simply regarding users as inactive participants in the process.

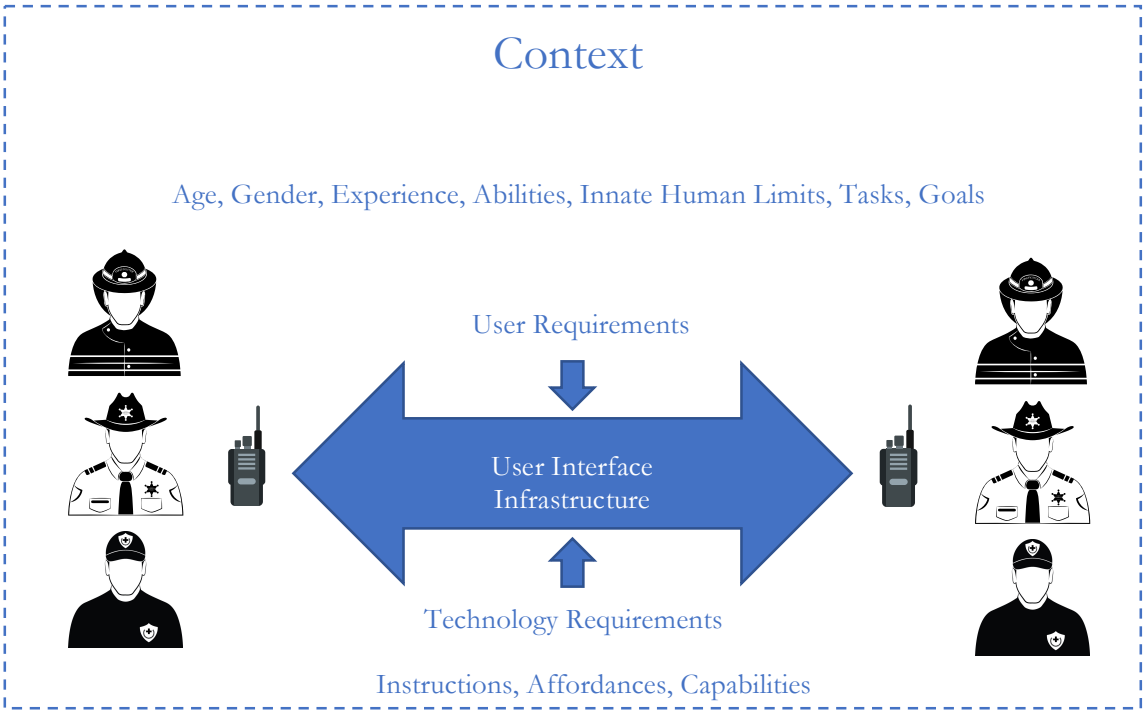


Figure 3: User-Centered View with User Attributes and Characteristics

By understanding the essential role, a user plays and viewing the process as a two-way relationship in which the system and user are partners with the same goal in mind, we can begin to have a substantial impact on the design and usability of these systems. By coming to terms with the inherent characteristics and interactions users have with a system, design teams can make better informed decisions, thus taking some of the guesswork out of the design process.

In the next sections of this handbook, we'll discuss a proven user-centered design process that will help designers and developers of public safety systems focus on the needs and characteristics of users in order to build a truly successful product.

CONCLUSION

In order to improve the usability of public safety systems, it is critical to take a holistic approach that considers the needs of users as well as the entire experience users will have with a system, including the hardware, software and instructional design of a system. Adopting a user-centric view is not only beneficial to the end users, but a user-centric view can also help to improve the performance and effectiveness of a system.

To understand the best way to improve the usability of a system, it is important to fully understand the components of a usable system. In the next chapter, we will take a closer look at the concept of usability and how it is defined.

Chapter 2
What is Usability

DEFINITION OF USABILITY

At its core, user-centered design is based upon the concept of developing a usable, useful system or product. To fully understand user-centered design, it is essential to understand the features inherent in a usable system.

Usability helps to ensure that systems and products are easy to learn, effective, comfortable and safe to use from the user's perspective. Defined by the International Organization for Standardization (ISO) as:

> "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use." [ISO 9241-210:2010]

Looking closely at the definition, usability goals such as effectiveness, efficiency and satisfaction, are specifically called out.

Additional attributes of usability that you may also want to consider include:

- Easy to learn (learnability)
- Easy to remember (memorability)

Examples are required to fully explain the usability concepts presented in this handbook. For demonstration purposes, we will use a self-contained breathing apparatus (SCBA) system and a mobile fingerprint device as described in the following paragraphs as primary examples throughout this document, supplemented by other examples as appropriate.

The SCBA is a critical gear worn by a responding firefighter. The SCBA consists of a frame, an air cylinder, pressure regulators, hoses, a mask, and accessories that may be stand-alone attachments or may be fully integrated. Accessories to the SCBA may include a pressure monitor, an end of service time (EOST) alarm (sometimes called a low-air alarm), a personal alert safety system (PASS), a heads-up display (HUD) in the mask, a voice amplifier, a central power supply for electronics, a telemetry system, an accountability system, a land mobile radio (LMR), environmental sensors, a biometric monitor, an electronic heater or cooler, a global positioning system (GPS), or a tracking or location system. [Grant *et al.*, 2015]. Since SCBAs are safety-critical gear, it is imperative that SCBAs are designed for effective and efficient use.

For law enforcement, mobile fingerprint device is an example of important technology used in the field. Mobile fingerprint technologies usually consist of a small, hand-held device with

fingerprint capture capability, a display and keyboard. Officers use the mobile device to fingerprint a person of interest and the fingerprints are sent to a remote database, such as the FBI's NGI (Federal Bureau of Investigation's Next Generation Identification) system for matching. The matching results are returned to the mobile device providing officers timely and valuable information in the field. A mobile fingerprint device can save officers time that it would take to fingerprint a suspect at the precinct. Identification of suspects in the fields allows officers to take proper precautions in dealing with possibly dangerous suspects. It is imperative that mobile fingerprint devices are easy to use and allow singlehanded operation, enabling officers to retain a free hand.

Table 1 below lists each of the usability goals and provides a short description of each, along with a few example questions for system designers to consider.

When designing a usable system, it is important to consider the various aspects of the user experience. For example:

Table 1 Usability Goals and Design Considerations

Usability Goals	Definition and Examples
Effectiveness	Measure of how well (accuracy and completeness) a user can perform a task: ▪ Can users *successfully* don and doff the SCBA? ▪ Can users *accurately* interpret alerts, signals, and information presented on the SCBA's HUD (e.g., air cylinder content, power source condition)? ▪ Can users *successfully* capture and submit fingerprints of a person of interest using the mobile fingerprint device? ▪ Can users *accurately* interpret information and alerts presented on the mobile fingerprint device (e.g., whether the results returned were a match)? ▪ Can users perform tasks without *errors*?
Efficiency	Measure of how quickly a user can perform a task: ▪ Can users *quickly* don and doff the SCBA? ▪ Can users *quickly* capture and submit fingerprints of a person of interest using the mobile fingerprint device? ▪ Do users have *adequate time* to react to alerts and warnings?
Satisfaction	Measure of user attitudes, perceptions, feelings and opinions regarding the system: ▪ Are users *satisfied* with using the system to accomplish their goals? ▪ Are users *frustrated* by using the system? ▪ How well does the system *avoid inducing user discomfort?*
Learnability	Measure of how rapidly a user can become productive: ▪ *How long* should it take a user *to learn* the system? ▪ Are users able to use the system (to some defined level of competence) after instruction or training?
Memorability	Measure of the extent to which a returning user remembers how to use the system: ▪ If a user has used the system before, can he/she *remember enough* to use it effectively the next time or does the user have to start over again learning everything? ▪ After not using the system for a period of time, how long should it take for the user to get up to speed? ▪ How do *rookie* users differ from *senior* users? ▪ How do *frequent* users differ from *infrequent* users?

Usability goals can, and should, be translated into measurable usability objectives for your specific product. Using these metrics, designers and developers can assess a system's usability. Examples of commonly used usability metrics are:

Success rates: Can users successfully don and doff the SCBA? *(Effectiveness)*

Error rates: How many failed attempts before a user successfully captures quality fingerprints of a person of interest using the mobile fingerprint device? *(Effectiveness)*

Time on task: How quickly can users don and doff the SCBA? *(Efficiency)*

Users' comfort level: Are users uncomfortable using the system? *(Satisfaction)*

Users' attitudes toward the system: Are users' attitudes toward the system positive or negative? *(Satisfaction)*

Time to learn a task: How long does it take a user to learn to use the device? *(Learnability)*

Memorability: Can users remember how to use the device? *(Memorability)*

Specific metrics and ways to measure usability will be discussed in more detail in the chapter on Evaluation.

In its narrowest sense, usability involves the evaluation of a system; in its broadest sense, usability involves users throughout the requirements definition, design, development and evaluation phases of a technology to produce a system which is measurably easier to use, learn and remember.

Too often usability evaluations are carried out after a product has been designed and developed. Although this can help to correct many of the things that should have been done right in the first place, it minimizes the impact a proven user-centered design process can have on a project. When usability evaluations are conducted at the end of a project lifecycle, recommendations and improvements are much costlier to make. By including users early in the design lifecycle, it is possible to integrate user feedback and usability recommendations into the initial designs and draft prototypes, when it is much easier and less costly to make changes.

The importance of including users early in the development process cannot be emphasized enough. The best and most successful systems involve users in the early stages of the design in order to continually evolve and refine the design in an iterative process.

CONCLUSION

A truly usable system takes into consideration the needs of users throughout the design, development and evaluation process. It involves:

- Analyzing the **context of use**

- Defining the **user and organizational requirements**
- Developing a **design solution** to meet those requirements
- Conducting **evaluations** to test the design against the defined requirements

The following sections of this handbook will introduce a user-centered design process that involves users throughout the product lifecycle to develop systems that improve ease-of-use, reduce product complexity, enhance system performance, increase users' satisfaction, and minimize the number of errors that may occur.

Chapter 3
User-Centered Design

INTRODUCTION TO USER-CENTERED DESIGN

User-centered design (UCD) is an approach to the design and development of a system or technology that aims to improve the ability of users to effectively and efficiently use the product. It seeks to improve the user experience of an entire system from hardware design to software implementation, involving all aspects of a technology, including a system's by-products, such as help documentation and training materials.

By involving users in the design, development and evaluation of a system, user-centered design works to create more usable products that meet the needs of its users. This, in turn, reduces the risk that the resulting system will under-deliver or fail.

User-centered design involves [ISO 9241-210:2010]:

- an explicit understanding of users, tasks and environments;
- the involvement of users throughout design and development;
- a design driven and refined by user-centered evaluation;
- an iterative process whereby a prototype is designed, tested and modified;
- addressing the whole user experience;
- a design team including multidisciplinary skills and perspectives.

This process is illustrated below in Figure 4:

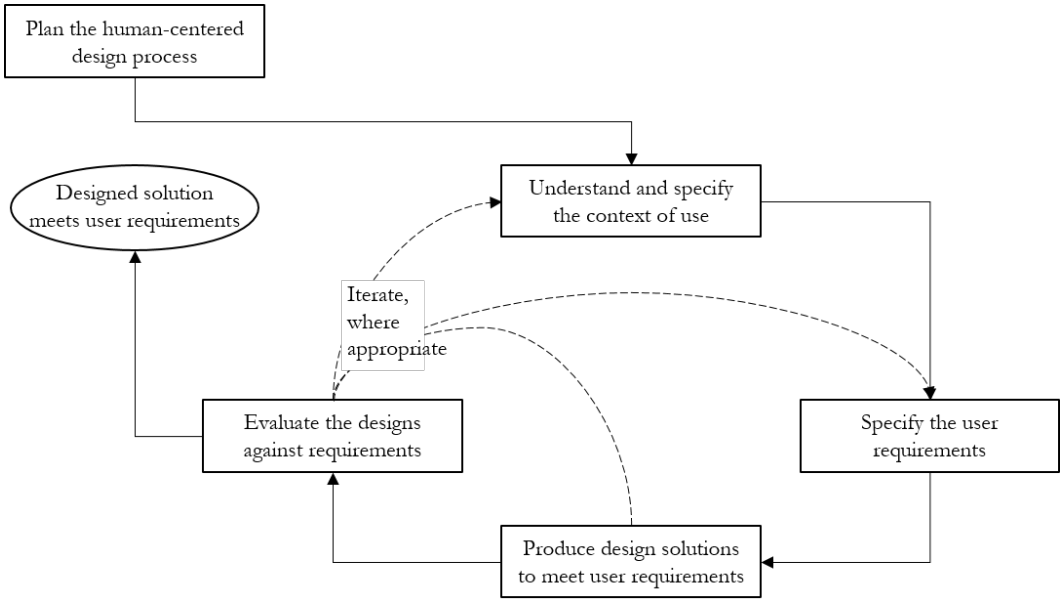


Figure 4: User-Centered Design Process [ISO 9241-210:2010]

Although there is a substantial body of knowledge and research regarding user-centered design and usability principles, much of this information is not yet integrated in the standard design and development processes of today's public safety communications systems.

USER-CENTERED DESIGN FOR PUBLIC SAFETY SYSTEMS

This handbook will outline a user-centered design methodology for the development of public safety technologies. This process is based on the International Organization for Standardization (ISO) standard mentioned above.

The user-centered design process outlined in this handbook includes:

- Defining the **Context of Use**
  Including operational environment, user characteristics, tasks, and social environment
- Determining the **User & Organizational Requirements**
  Including business requirements, user requirements, and technical requirements
- Developing the **Design Solution**
  Including the system design, user interface, and training materials
- Conducting the **Evaluation**
  Including usability and conformance testing

This handbook will outline each of the steps illustrated below (Figure 5) in order to enable developers and designers of public safety communications systems to implement this proven process on their own projects.

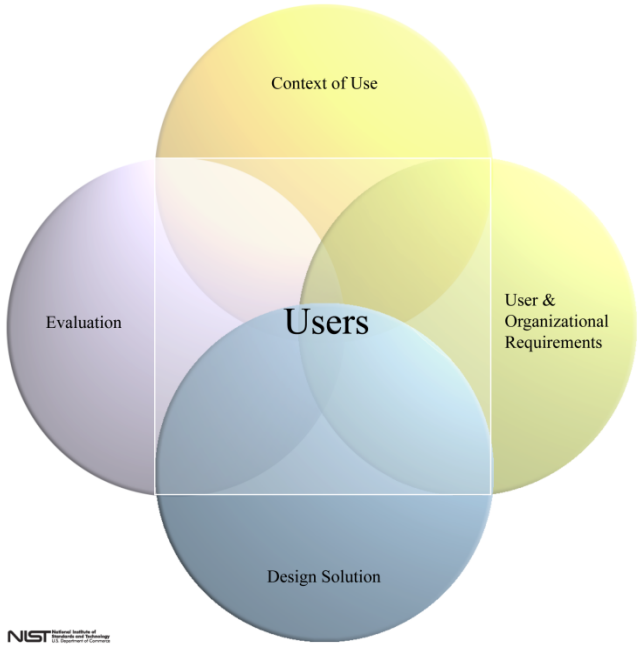


Figure 5: User-Centered Design Process for Public Safety Communications System

The key to this iterative process is that it is **User-Centered, Research-Based, and Performance-Driven.**

User-Centered:

- Identifies the types of users who will be using the system, including end users, system operators, and system analysts.
- Ensures that the needs of users are considered in the design and development of the system.
- Includes users' feedback through user research and evaluation.

Research-Based

- Employs research to learn about users, their needs, their tasks, their environment, their level of experience, etc.
- Conducts on-going research with users of public safety communications systems by observing users interacting with the actual system or product and identifying areas for improvement.

Performance-Driven

- Utilizes information gathered from users in the development to ensure that design decisions are data-driven.
- Elicits continual feedback from users and measures user performance to ensure that design improvements have a measurable impact on users' effectiveness, efficiency and satisfaction [ISO 9241-210:2010] with a public safety communications system.

Independent of any product design lifecycle, user-centered design works as part of other development lifecycles, including waterfall, spiral and agile models. It is an evolutionary process in which project teams design, test and continually refine a system.

By following this iterative, user-centered design process, development teams can have a measurable impact on the usability and ease-of-use of their systems.

BENEFITS OF USABILITY

Not only do usability improvements lead to better, easier-to-use products, they also lead to improved user performance and satisfaction as well as substantial cost savings. By designing a public safety communications system with usability in mind, development teams can enhance ease of use, reduce system complexity, improve user performance and satisfaction, and reduce support and training costs. Additionally, improved usability can result in a significant return on investment, including:

- Increased user acceptance
- Improved productivity and fewer errors
- Decreased user safety risks that may be induced by poorly designed systems
- Decreased support and training costs

CONCLUSION

In this section, the various facets of the user-centered design lifecycle were introduced, including four main components:

- Defining the **Context of Use**
- Determining the **User & Organizational Requirements**
- Developing the **Design Solution**
- Conducting the **Evaluation**

In the next chapter, we will take a closer look at the context of use and how it is defined. The remaining chapters of this handbook will discuss each of the user-centered design phases outlined above. Additionally, a chapter on Usability Methods has also been included to describe some of the methods discussed in this handbook.

Chapter 4
Context of Use

DEFINE CONTEXT OF USE

The first stage of the user-centered design process involves defining the "context of use."

The use of all products, including public safety communications technologies, takes place within a context. The actual conditions under which a public safety system is used must be considered at the forefront of any project to ensure that the design of the system will meet the needs of users and the objectives of the organization once the system is implemented in a real-world environment.

Awareness of contextual factors is important throughout the development process. Context of use does not simply involve the users' context of use, it involves a much broader view of context, including the *organizational environment* in which the public safety system is being developed (including existing systems and products), the *operational environment* in which the system will be used, and the *social environment* in which the system will be implemented. For purposes of this document, we will focus mainly on the user and operational environment and discuss the business environment more in the following chapter on User and Organizational Requirements.

To develop a usable product, the context in which the public safety system will be used should be considered from the very early stages of product design lifecycle, as illustrated in Figure 6 below.

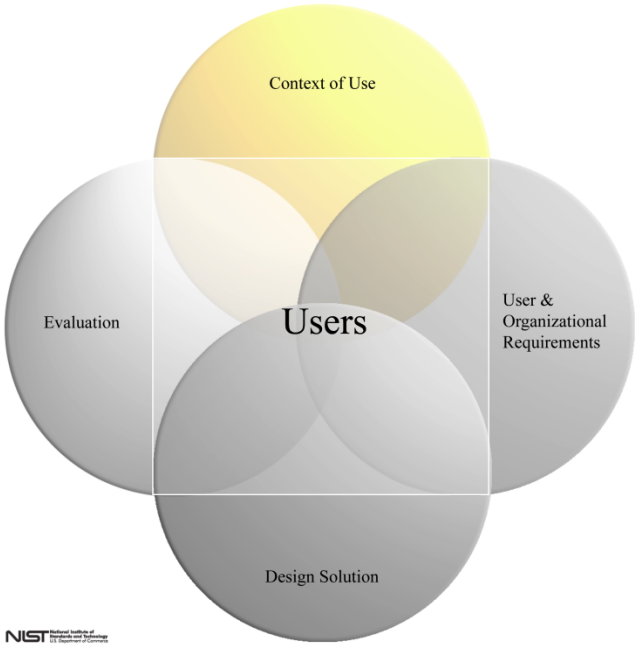


Figure 6: Context of Use within the User-Centered Design Process

Defining Your Users

The central objective of designing a usable system is to meet the needs of users within their operational context. To do this, it is imperative that users are involved throughout the design process. The design of the system should:

- Focus on users' needs and expectations
- Involve users throughout
- Integrate feedback from users into the design

But before you can focus on users' needs and expectations, you must first identify who your users are. There are several different ways to categorize user groups, including:

Primary users:	End users for whom the system is primarily designed.
Secondary users:	End users who interact with the system, but not for its primary purpose or users who interact with the system infrequently.

OR

Direct stakeholders:	End users who interact directly with the system.
Indirect stakeholders:	Individuals who may not directly interact with the system but their performance is affected by the interaction of the direct stakeholders with the system.

To begin, simply identify your audiences. Think about all of the types of users who may interact with your system on a regular basis and then create a list of these users. If your user population contains groups of people who use the system to perform different sets of tasks, or who have considerable differences in ability or experience, then divide them into separate user types.

Next, group the users into categories, such as primary users or direct stakeholders and secondary users or indirect stakeholders. In doing this exercise, consider the relative importance of each group and begin to create prioritized lists of user groups. Once this process is complete, begin to define the role each user will have with the system. See Table 2 below for the SCBA example.

Table 2 Defining SCBA Users

Defining Users for a SCBA

In considering SCBA design, there are at least three basic types of users:

USER GROUP	ROLE
▪ The firefighter	The person who uses the SCBA during incident response.
▪ The SCBA technician	The person who maintains and repairs the SCBA.
▪ The incident commander	The person who performs air management/accountability monitoring of his/her team's SCBA readings.

The firefighters and the SCBA technicians are *direct* stakeholders, in that they interact directly with the SCBA. The incident commanders are *indirect* stakeholders, in that they may not directly interact with the SCBA but their performance is affected by the interaction of the direct stakeholders with the SCBA.

While this analysis defines, at a high-level, the types of users who use the system, it is critical to define these audiences even more. For instance, within the firefighter user group, there may be subgroups, such as:

- Rookie firefighter
- Senior firefighter

While this is just a beginning, the tools and resources on the following pages will help the development teams to better define and identify their user groups.

See *Table 3* below for the mobile fingerprint device example.

Table 3 Defining Mobile Fingerprint Device Users

Defining Users for a Mobile Fingerprint Device

In considering design for a mobile fingerprint device, there are at least three basic types of users:

USER GROUP	ROLE
▪ Patrol officer	The person who uses the mobile fingerprint device to capture and submit fingerprints of a person of interest.
▪ Mobile fingerprint device technician	The person who maintains and repairs the mobile fingerprint device.
▪ System analyst	The person who interprets the results.

The patrol officers and the mobile fingerprint device technicians are *direct* stakeholders, in that they interact directly with the device. The system analysts are *indirect* stakeholders, in that they may not directly interact with the device but their performance is affected by the interaction of the direct stakeholders with the device.

While this analysis defines, at a high-level, the types of users who use the system, it is critical to define these audiences even more. For instance, within the patrol officer user group, there may be subgroups, such as:

- Rookie patrol officer
- Senior patrol officer

While this is just a beginning, the tools and resources on the following pages will help the development teams to better define and identify their user groups.

Understanding Your Users

Once you have identified and prioritized your users, the next step is to *understand* your users, their needs, interests and goals. Start by learning everything you can about your user audiences, including:

- Demographics and physical attributes
- Knowledge level, familiarity with the product, and skills
- Users' tasks and goals
- Users' environment and context in which they interact with the system
- Social environment

USER DEMOGRAPHICS

First consider the demographic and anthropometric characteristics of your users. The following list of characteristics is a sample list of attributes to consider. As you contemplate your design, take care to include any characteristic which may influence or affect the usability of your product, including:

- Age
- Gender
- Anthropometrics (body measurements like height, weight, shoulder width, etc.)
- Education, training and certifications
- Experience and knowledge level

DO DEMOGRAPHIC DIFFERENCES AFFECT A DESIGN?

Body armor is an item of personal protective equipment intended to protect the wearer from threats that may include ballistic threats, stabbing, fragmentation, or blunt impact [ASTM E3005]. Anthropometric differences between the torsos of men and women affect the fit of the body armor and its ability to provide protection to the wearer without restricting movement [ASTM E3003].

How do you define user demographics?

- ☑ The User Demographics Tables (*Table 4* and *Table 5*) on the following page will help you identify the demographic characteristics of your users and will also be used in the next phase of the process – User and Organizational Requirements – to define possible user requirements.
- ☑ At this stage of the process, it is not necessary to define the user requirements, although a sample set of design questions have been provided in the following table.
- ☑ Please note, this exercise should be conducted *for each group of users* you identified in the previous section.

User Type: Firefighter for the SCBA example

Table 4 Firefighter Demographics

Characteristics	Questions to Consider: Defining the Characteristics	Questions to Consider: User Requirements
Age	*What is the average age range of this user group?* – *For example: 18-60.*	– *How does age affect the SCBA usage?*
Gender	*What is the gender distribution?* – *For example: 90% Male/10% Female*	– *How does gender affect the fit of the SCBA on users?*
Anthropometrics	*What is the average shoulder width of the population? What is the range?*	– *How does a user's shoulder width affect his/her comfort wearing the SCBA?*
Education, training and certifications	*What is the typical training level of your users?*	– *How does training affect the SCBA usage?*
Experience and knowledge level	*How many and what types of incidents have the users responded to?* *How regularly do the users use this system?* *What is users' familiarity level with the system?*	– *How does experience affect the SCBA usage: do rookie users differ from more senior users?*

User Type: Patrol officers for the mobile fingerprint device example

Table 5 Patrol Officer Demographics

Characteristics	Questions to Consider: Defining the Characteristics	Questions to Consider: User Requirements
Age	*What is the average age range of this user group?* – *For example: 18-65.*	– *How does age affect device usage?*
Gender	*What is the gender distribution?* – *For example: 70% Male/30% Female*	– *How does gender affect device usage?*
Anthropometrics	*What is the average hand size of the population? What is the range?*	– *How does a user's hand size affect his/her comfort holding the device?*
Education, training and certifications	*What is the typical training level of your users?*	– *How does training affect device usage?*
Experience and knowledge level	*How regularly do the users use this device?* *What is users' familiarity level with the device?*	– *How does experience affect device usage: do rookie users differ from more senior users?*

USER ENVIRONMENT

Once the user characteristics have been defined, begin to consider the context of use, including environmental factors, such as:

- When and where will users use the system?
- What is the environment like?
  - Weather?
  - Visibility and lighting?
  - Noise levels?

How do you define the user environment?

- ☑ The User Environment Tables (Table 6 and Table 7) on the following page will help you identify the context of use and will also be used in the next phase of the process User and Organizational Requirements to define possible user requirements.
- ☑ At this stage of the process, it is not necessary to define the user requirements, although a sample set of design questions have been provided in the following table.
- ☑ Please note, this exercise should be conducted *for each type of environment* the system will be used in.

User Environment: Fire, wildland–urban interface (WUI)

Table 6 Fire Environment - WUI

Characteristics	Questions to Consider: Defining the Characteristic	Questions to Consider: Potential Effects
Location	*In what environment will the SCBA be used?* – *Will the SCBA be used in high or low elevation areas?* – *What are the physical characteristics of this location? For example: areas where housing meets or intermingles with undeveloped wildland vegetation, etc.*	– *How does the physical environment of this location affect or influence the design and usage of the system?*
Weather	*What is the average temperature when the SCBA is used? What are the extreme temperatures? What are the wind conditions?*	– *How does the outside environment affect the performance of a system?*
Visibility and Lighting	*How heavy will the smoke be?* *When will the system be utilized, at night as well as during the day?*	– *How does smoke affect the readability or visibility of the SCBA's HUD?* – *How does the level of lighting affect the readability or visibility of the SCBA's HUD?*
Noise	*What is the noise level?*	– *Can a speaker's voice be distinguished from the noisy background?* – *How does the noise level affect an individual's ability to hear audio cues and alerts provided by the system?*

User Environment: Law enforcement, outside near police vehicle

Table 7 Law Enforcement Environment – Near Police Vehicle Outdoors

Characteristics	Questions to Consider: Defining the Characteristic	Questions to Consider: Potential Effects
Location	*In what environment will the mobile fingerprint device be used?* – *For example, will the device be used by the side of a busy highway or remote country road?*	– *How does the physical environment of this location affect or influence the design and usage of the device?*
Weather	*What is the average temperature when the device is used? What are the extreme temperatures? Is the area humid?*	– *How does the outside environment affect the performance of the device?*
Visibility and Lighting	*When will the system be utilized, at night as well as during the day?* – *For instance: natural light (sunlight), artificial light, etc.*	– *How does the level of lighting affect the readability or glare of the device screen?*
Noise	*What is the noise level?* – *For instance: quiet street, noisy highway, etc.*	– *How does the noise level affect an individual's ability to hear audio cues and feedback provided by the device?*

USER GOALS & TASKS

Once the user characteristics have been identified, it is time to turn your attention to conducting a user and task analysis, including answering questions such as:

- Why will these stakeholders use your system? What is the user's purpose?
- What are the needs, interests and goals of your users?
- How will users interact with the system?
- What are the key tasks a user must perform?
- Which tasks will users perform frequently?
- Which tasks are critical to a user's success with the system?

How do you define user goals and tasks?

☑ The User Tasks & Prioritization Tables on the following page (Table 8 and Table 9) will help you define the tasks that users will need to perform and rate the task based on considerations such as:

- Frequency of use *(How frequently will users perform this task?)*
- Importance *(How critical is this task to users?)*
- Feasibility *(How feasible is it to include this function in the design?)*
- Vulnerability *(Is there reason to believe that this task is prone to usability issues?)*

While the list above identifies commonly used considerations for user tasks and prioritization, other relevant factors may also need to be addressed depending on the users, their tasks, and the system.

☑ At this stage of the process, it is not necessary to define the feasibility of a task or the vulnerability of a task to usability issues. Feasibility and vulnerability will be addressed in the design phase and evaluation phase, respectively.

☑ During the User and Organizational Requirements phase, you will re-visit this table to prioritize users' tasks with regard to the organization's objectives.

☑ During the Design phase, you will evaluate the feasibility of each task to determine which tasks should be translated into system requirements.

☑ During the Evaluation phase, you will consider the vulnerability of a task to usability issues. Tasks that are susceptible to usability issues and are also important to users and the organization should be at the top of the list of things to evaluate.

☑ Please note, this exercise should be conducted *for each group of users* you identified in the previous section.

User Type: Firefighter, SCBA example

Table 8 Firefighter Tasks and Prioritization

Task	Frequency of Use?	Importance to User?	Importance to Business Objectives?	Feasibility?	Vulnerability to Usability Issues?
1. Inspect SCBA	*High/Medium/Low?*	*High/Medium/Low?*	*To be completed in the User and Organizational Requirements Phase*	*To be completed in the Design Phase*	*To be completed in the Evaluation Phase*
2. Don/Doff SCBA	*High/Medium/Low?*	*High/Medium/Low?*			
3. Test SCBA	*High/Medium/Low?*	*High/Medium/Low?*			

User Type: Patrol officer, mobile fingerprint device example

Table 9 Patrol Officer Tasks and Prioritization

Task	Frequency of Use?	Importance to User?	Importance to Business Objectives?	Feasibility?	Vulnerability to Usability Issues?
1. Collect demographic data from person of interest, including: name, date of birth, etc.	*High/Medium/Low?*	*High/Medium/Low?*	*To be completed in the User and Organizational Requirements Phase*	*To be completed in the Design Phase*	*To be completed in the Evaluation Phase*
2. Capture fingerprints from person of interest.	*High/Medium/Low?*	*High/Medium/Low?*			
3. Submit fingerprints to database for matching.	*High/Medium/Low?*	*High/Medium/Low?*			
4. Troubleshoot system errors.	*High/Medium/Low?*	*High/Medium/Low?*			
5. Receive and interpret results from matching.	*High/Medium/Low?*	*High/Medium/Low?*			

Once these high-level tasks have been defined, development teams should break each task down into its subcomponents. Many teams find that the development of use cases can be a particularly effective way to document this step-by-step process. Use cases are used by many software development teams to document the way a user interacts with a system, under various conditions. A use case is usually a text document (but it can be in the form of a process diagram) that describes the steps a user takes to accomplish a goal. For each step the user takes, a use case documents the system's response to the user's action. By documenting a user's interaction and the associated system response, use cases can be a very effective way to document system requirements that take into consideration a user's needs and interactions when accomplishing a task.

Researching Your Users

In the midst of defining, understanding and documenting user characteristics, the question usually arises, "What if I don't know who my user audience is?" or "What if I know who my audience is, but I don't know very much about them?"

When this occurs, there are several ways to go about learning about your users:

1. Begin by interviewing key stakeholders within the organization. Ask leadership and managers who they believe the target user audiences are.
2. Review existing data about your user population, including past results from surveys, focus groups, interviews, etc.
3. Conduct new research to learn about your audience.

Conducting research with users is an essential step in the user-centered design process. There are numerous ways to learn about your users at this stage of the process, including[2]:

- ☑ User Surveys
- ☑ Focus Groups
- ☑ User Interviews
- ☑ Contextual Inquiry / Naturalistic Observation
- ☑ Cognitive Walkthroughs
- ☑ Usability Testing

While primary research directly with users is far superior to the opinions of colleagues and management, it is not always feasible to conduct this type of research. Sometimes access to users of systems can be limited or resources/time do not allow for primary research to be performed. In these instances, it is best to talk with stakeholders within your organization who have had direct contact with users and to learn all that you can through this second-hand interaction.

Remember, time spent in the early planning phases learning about users generally saves time and development costs in the later phases, when usability issues are much more costly and time-consuming to fix.

CONCLUSION

A thorough analysis of your existing system (as-is analysis) and users' interaction or context of use with that system is a critical first step to designing a truly usable system. By understanding the users of your system and their tasks, including how their demographics, abilities and environment affect the use of your system, and its eventual success, your project

[2] Please see the section on Usability Research Methods for more detail on each of the methods listed above.

team will be better positioned to develop a successful product. In addition to the physical environment, the social environment is also important to consider for public safety communication. As part of the larger social environment, local, state, tribal, and federal public safety entities respond together based on the size and severity of an incident.

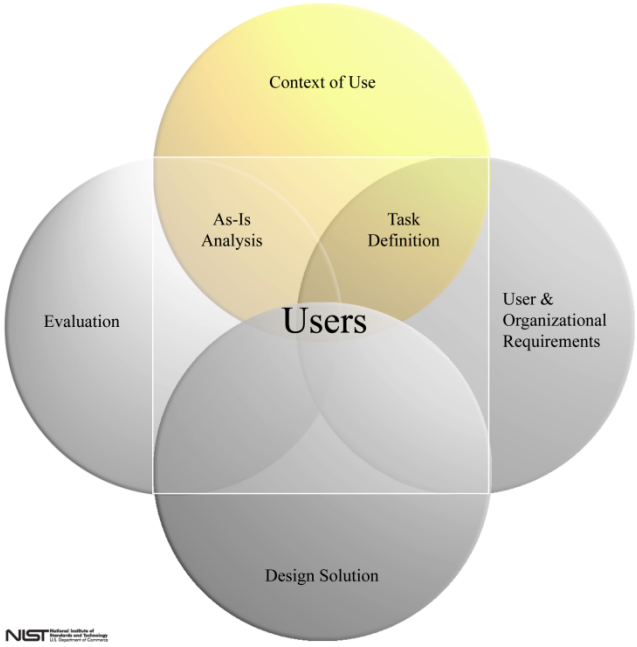


Figure 7: Components of the Context of Use Phase

This in-depth understanding of a system's context of use is key to identifying the user and organizational requirements that will ultimately impact the design and development, as illustrated in Figure 7 above. The following chapter will discuss how to use the information analyzed in the Context of Use phase to develop user requirements that will ultimately impact the performance of the system and the resulting success of the organization.

Chapter 5
User & Organizational Requirements

DETERMINE REQUIREMENTS

The requirements phase of the development lifecycle typically occurs after the product team has established a thorough understanding of the system's context of use and users.

The goal of any requirements analysis phase is to create clear, unambiguous requirements for a system so that the entire development team thoroughly understands what the system should do and how it should work. There are many types of requirements including:

- Business and Organizational Requirements
- Environmental and Physical Requirements
- Functional Requirements
- Nonfunctional Requirements
- Technical and System Requirements
- User Requirements

Each of these types of requirements may have usability components, in addition to other requirements. The requirements suggested in this document are not meant to be all-encompassing, but simply highlight some of the potential usability issues that may be documented as illustrated in Figure 8.

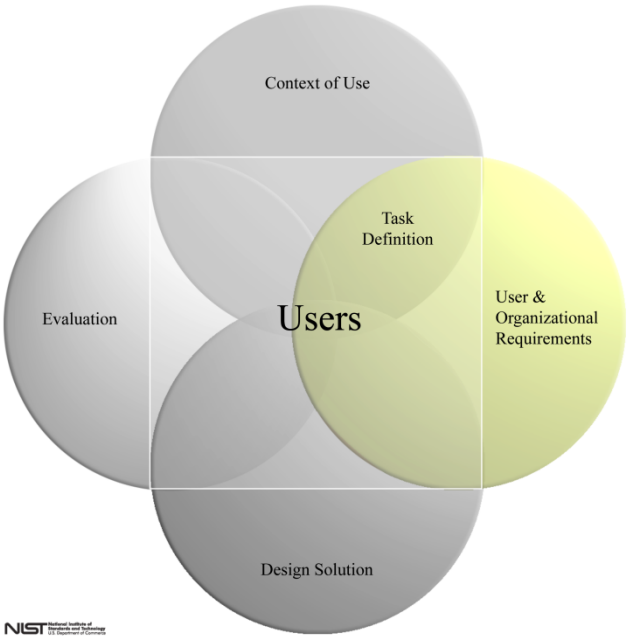


Figure 8: User & Organizational Requirements within the User-Centered Design Process

Understanding Different Types of Requirements

Requirements analysis can be quite detailed with varying levels of complexity.

Many teams may find themselves with several types of requirements documents, while other teams may only have one requirements document.

No matter the number of requirements documents, it's important that your requirements address the key factors affecting your design. In the following section, we will discuss some of the types of requirements you may want to consider for your development project.

User Requirements are requirements that are based on the needs of the users.

Business and Organizational Requirements are requirements that the development organization has for a product or system. These requirements are typically established to help the organization achieve its business goals and are usually focused on high-level business objectives.

Environmental and Physical Requirements are requirements about the physical environment that the system will be used in, or the context of use. These requirements are established to ensure that design teams take into consideration the physical attributes of the environment, including location, lighting, temperatures, noise levels, etc.

Functional Requirements are requirements that specify the features and functions that the system will support. In short, the functional specifications identify the tasks necessary to fulfill the business requirements. While the high-level business requirements specify the "why," the detailed functional specifications identify the "what." It is important to note that functional requirements do *not* specify the "how." Determining how to fulfill a requirement is something that is determined during the design phase.

Nonfunctional Requirements are requirements that cannot be described by a single feature or function. They are broader requirements for the product/system and may include things such as look and feel requirements, usability requirements, performance requirements, social requirements, legal requirements, etc. Although nonfunctional requirements are not tied to a specific feature or function and are used to describe the overall attributes and characteristics of a system, they can lead to more specific functional requirements.

Technical and System Requirements are requirements that detail the technical environment that the system will be built on, including hardware and software requirements. These requirements may also include items such as security needs, database structures, supported platforms, etc.

The following sections will describe each of these types of requirements in greater detail.

USER REQUIREMENTS

First and foremost, it is essential to document user requirements. These requirements should document what the system is required to do to meet users' needs, not what the system requires of a user. As designers of public safety systems, it is essential that you understand your users' characteristics and any implications for system requirements.

At this point in the process, re-visit the user analysis you completed for each audience and review the potential user requirements identified. Ensure that all of the requirements documents created address users' needs and requirements.

BUSINESS AND ORGANIZATIONAL REQUIREMENTS

It is essential to ensure that the product meets the needs of the development organization, as well as the needs of the users. The business requirements help to specify what the organization wants to achieve. Many times, business requirements are fairly high-level and do not address specific functionality.

Example business requirements:

- To create a product that will protect the health and safety of the end users.

- To design an intuitive system that is efficient and effective to use.

In order to determine the organizational requirements, begin by posing the following questions to your management team:

- What is the purpose of the system?
- What are the goals for the product?
- How would you describe the product or system?
    - From the organization's standpoint?
    - From a user's standpoint?
- What outcomes would you like to achieve?
- How would you define a successful system for your organization?

Once you've created a list of goals for your product or system, try to see how well your organization's goals match up with the goals you identified for your users. It is critical to the success of the product that these goals are closely aligned.

For instance, in the SCBA example:

Table 10 SCBA Organizational and Firefighter Goals

Organization's Purpose / Goals	Users' Purpose / Goals
To create a system that will protect the health and safety of the end users.	To use the SCBA for providing breathable air in an *immediately dangerous to life or health* situation.
To design an intuitive system that is efficient and effective to use.	To don/doff the SCBA as quickly and accurately as possible.

In Table 10 above, it is easy to see that the organization has goals to protect its users' health and safety, and to provide a system that supports efficiency and effectiveness; just as users have desires to stay safe and healthy while completing tasks as quickly and accurately as they can. In this instance, both parties want a system that will protect user safety and allow efficient completion of tasks without sacrificing accuracy.

Mapping organizational goals to user goals is a key step in the product development process to ensure that the system you are designing will meet both the needs of your organization and the needs of your users.

FUNCTIONAL REQUIREMENTS

Functional requirements define what a system must do; they do not specify how the system will be implemented.

In defining these requirements, it is essential to re-visit the user tasks identified in earlier stages of the user-centered design process. By considering users' tasks and their context of use, it is easier for design teams to develop workflows and requirements that will meet the needs of users and ultimately help improve the usability of a system. In defining functional requirements, begin by clearly stating the goal of the system. A SCBA example:

The system shall provide clear feedback to a user to let him/her know when the breathing air in the SCBA cylinder has been reduced to a pre-specified threshold.

Note that the requirement states the goal of the system, but does not define how the system will provide feedback. This decision is left to the design team to make once they have had an opportunity to review all of the system requirements.

Once all of the functional requirements are written down, you will want to formally document these requirements. There are several ways to document your functional requirements, including: use cases, Unified Modeling Language (UML), process diagrams, task flow diagrams, task scenarios, etc. Since many of the requirements documents are quite detailed, it is essential to document each feature step-by-step. By breaking down each task

into its subparts and creating task workflows, it is easier to create a functional specification that more closely matches the needs and experiences of users.

NONFUNCTIONAL REQUIREMENTS

Nonfunctional requirements identify requirements for a system that are not specifically tied to a single feature or function. They describe the overall attributes and characteristics of a system, they can lead to more specific functional requirements. Examples of nonfunctional requirements may include:

- Usability requirements – *Users will be able to successfully use the SCBA without assistance or help after the initial training.*
- User Experience – *The system will provide users with a consistent interface, interactions and affordances.*
- Performance requirements – *The mobile fingerprint device will accurately collect samples from 90% of persons of interest on the first capture.*
- Graphic design requirements (or look and feel) – *The design of the product or system will reflect the corporate branding of the organization.*
- Social requirements –*The system shall support the larger public safety social environment where local, state, tribal and federal public safety entities need interoperable communications technologies.*
- Legal requirements – *The mobile fingerprint device shall protect the data integrity of fingerprints captured and submitted from persons of interest.*

Nonfunctional requirements help to guide the development of the overall system.

ENVIRONMENTAL AND PHYSICAL REQUIREMENTS

Based on a review of the context of use, environmental requirements should be created to address the attributes and characteristics of the physical location where the system will be used.

In the SCBA example, these requirements may involve determining the optimal materials and dimensions for the SCBA components, and defining the HUD interaction styles based on noise and lighting levels.

While these requirements primarily depend on an evaluation of the physical surroundings, it is also important to review how users are affected by environmental factors and adjust the physical design of a system based on users' characteristics. For instance, the optimal materials and dimensions for the SCBA components should be based upon a thorough evaluation of the physical environment where the system will be used, but also should take into consideration common anthropometrics, such as the average body measurements of the user population to ensure appropriate fit. Additionally, these decisions should also be supplemented by observation of users in real-world settings to evaluate how users of

differing body measurements utilize the system. Based on an analysis of these factors, a suitable dimension should be defined and included in the requirements documentation.

Below are some example requirements for different types of environmental factors:

- *Noisy Environment*
  A requirement could be that the system relies on visual and other types of non-auditory feedback, as users may not be able to hear audio feedback in a noisy location.
- *Smoky or Low Visibility Environment*
  A requirement may specify that interaction screens, visual cues and colored displays are bright enough to be seen in locations with poor visibility. Or the requirement could specify that visual feedback is supplemented by audio or tactile feedback.
- *Natural Light*
  A requirement may stipulate that in outdoor settings, it is best to rely on audio and other types of sensory feedback as the direct sunlight might produce a glare, making it difficult to see visual feedback. Or the requirement could entail developing screens that do not reflect light and reduce the amount of glare.
- *Temperature and Humidity*
  A requirement might state that the system is able to sustain extreme temperatures and high levels of humidity. Or the requirement may state that the system must operate within a range of temperatures and humidity.

In each of the above examples, there may be more than one way to address an issue and therefore, the implementation may vary from project to project.

Additionally, since devices may be used under a variety of conditions and in a plethora of locations, it is essential to review the physical attributes of each location and define common environmental requirements to address the differing needs.

TECHNICAL AND SYSTEM REQUIREMENTS

In developing your system, it is also essential to document the hardware and software systems upon which the product will be based. The requirements should identify any issues or constraints regarding the technical environment and should also specify system requirements for the security and maintenance of the system.

Researching Your Requirements

In order to understand and document the requirements for your system, you will need to have a thorough understanding of:

- Your user audience
- Your organization and management objectives
- Your current system and goals for future improvements
- Your competitors' products

Additionally, you should be aware of the environmental, physical, social, and technical factors affecting your system. Armed with this knowledge, you should be able to create clear, unambiguous requirements which will drive the design and development of a usable system.

In order to ensure you have adequate information to write and develop effective requirements, consider conducting the following types of research: [3]

- ☑ User Surveys
- ☑ Focus Groups
- ☑ User Interviews (including interviews with internal leadership)
- ☑ Contextual Interviews/Naturalistic Observation
- ☑ Cognitive Walkthroughs
- ☑ Expert Reviews
- ☑ Competitive Analysis
- ☑ Usability Testing

CONCLUSION

In order to identify and define the requirements of your system, it is essential that your project teams take into consideration many types of requirements, including:

- user requirements,
- business and organizational requirements,
- environmental and physical requirements,
- functional requirements,
- nonfunctional requirements, and
- technical and system requirements.

[3] Please see the section on Usability Methods for more detail on each of the methods listed above.

To define these requirements, it is critical that you have a clear understanding of your users, their context of use and the tasks that they will use the system for. The design decisions that you make based upon the requirements set forth will ultimately have a great impact on the user experience of the system.

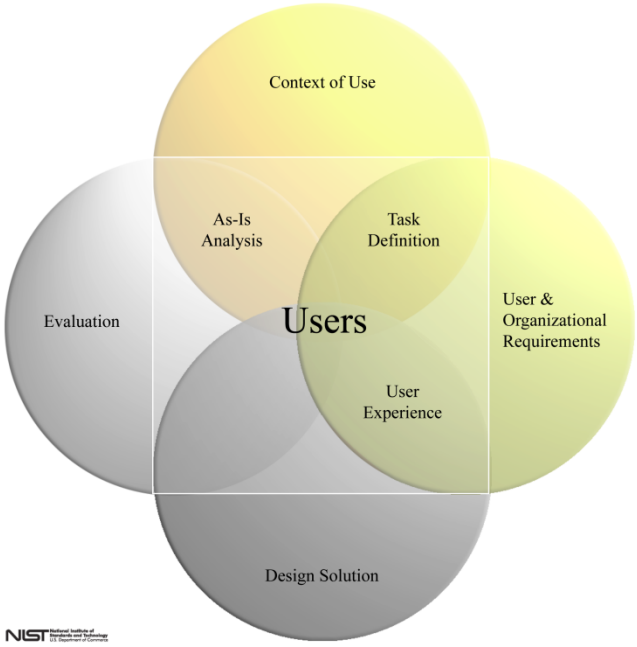


Figure 9: Components of the User & Organizational Requirements Phase

Figure 9 illustrates the interaction of the Context of Use and User & Organizational Requirements phases. The following chapter will provide additional detail on designing a usable system that not only improves the user experience, but also improves system performance.

Chapter 6
Design Solution

DEVELOP THE DESIGN

Once the requirements have been identified, the design team can begin to evaluate ways to address each requirement and specify a design solution, as illustrated in Figure 10. The design solution should encompass the entire product/system including the design that end users will interact with, as well as the design that operators and system analysts will use. It is important to note that the design considerations should not be limited to primary users, but should also take into consideration those secondary users identified earlier in the UCD process.

When considering solutions for the system design (hardware/software), the interface design (the way the system will interact with users); instructional design (method and materials presented prior to users approaching the system); and training/support design (help materials for end users to effectively use the system), consider the following two questions:

- What are the needs of primary users?
- What are the needs of secondary users?

Collectively, these design elements help to comprise the system's user experience.

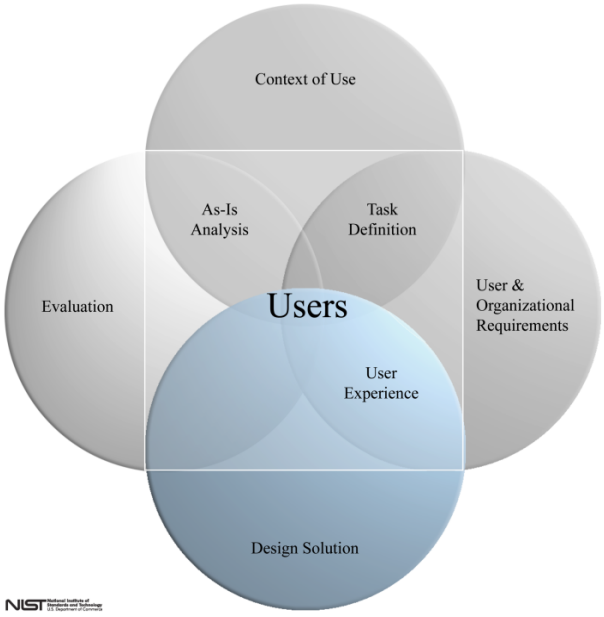


Figure 10: Design Solution within the User-Centered Design Process

When considering the design of a solution, it is important to consider both the interaction design, as well as the interface design. Ideally, these design elements work together to provide a seamless experience for users (both primary users and secondary users).

Interaction Design

Simply put, interaction design is a method used to define the way a system responds to a user's actions. The goal of interaction design is to define the behavior of a system, without implying any look and feel (or interface design) requirements. The interaction design is the foundation upon which the interface design will be built.

This process involves several steps that focus on the tasks a system will perform. To begin:

- Define the tasks that the system will perform, based on the task analysis conducted during the Context of Use and User and Organizational Requirements phases.
- Review each task and identify the sub-steps of each task.
- Identify user interactions for each task and the associated system response.
- Create a use case or workflow diagram to document these tasks and interactions.
- Define how the system will work for each step in your task flow or workflow diagram.

To simplify the process, begin with a very simple task and work your way to more difficult or complex tasks a system will perform. For each task, ask yourself:

- When will this process begin?
- What initiates the process? Does a user initiate a process, if so, how?
- How does the system respond to a user's action? What type of information does the system need to communicate with a user so that the user knows what to do next?
- When does the process end? How will the user know that the task is finished and that it was successful?
- If the task is not successful, how will the user know that there was an error? What types of feedback or messages will the system communicate to a user to help them correct the error and complete the task successfully?

These questions all focus on ensuring that the user and the system are working together, in a partnership, with the same end goal. Each step of the process is considered from a user's viewpoint as well as from a system viewpoint, taking care to identify the types of feedback needed to keep the interaction moving along.

Interaction design is similar to a conversation; a conversation between the user and the system. For each action a user makes, the system must respond. Thus, a solid interaction design specification is needed. This process takes into consideration how a system should behave throughout an entire task and also tries to consider the possibility for errors along the way.

At each point in the process, an error can occur. A user may become confused and not know what to do next, a user may not be able to tell when a task is finished, or a user may prematurely think a task is completed before it actually is. Numerous types of errors may occur at any point in the process. Therefore, it is necessary to consider how a system will work to avoid errors, and when errors do happen, how the system will provide feedback to a user, so that the user may continue the task. It is this type of feedback or conversation that is necessary for the system and the user to work in partnership toward the end goal.

For instance, let's look at the task of a patrol officer capturing fingerprints from a person of interest with a mobile fingerprint device. First consider:

- When does the task begin? Does it begin when an officer asks for demographic information from a person of interest?
- Once an officer initiates the fingerprint capture task, what types of feedback does the device provide to let the officer know that he/she is positioning the person of interest's hand/finger appropriately?
- How does the device let the officer know when the fingerprints have been successfully captured?
- If there is an error, what types of feedback are provided? Does the device let the officer know that the fingerprint quality is poor? Or that the positioning was off? What types of tips or guidance are provided so that the officer can correct the error?
- How does the device let the officer know the status of submission? Does the device let the officer know whether fingerprints were submitted successfully or whether there was an error during submission?
- How does the device let the device let the officer know when results are returned, and whether results were a match or not?

These are the types of questions that system designers need to consider when defining an interaction specification.

To create a successful interaction design for a system, developers need to think of each task as a conversation between the user and the system. Each step within the process needs to be considered so that a user and a system can successfully exchange information to accomplish a task. This information should be documented in an interaction design specification which will serve as the foundation for the interface design.

Interface Design

During the interaction design stage, the team focuses on "what" the system will communicate and "when" it will communicate with users, whereas, the interface design stage defines "how" the system will communicate with the user.

At this point in the process, developers begin to think about the best way to communicate with users. Consider a patrol officer capturing fingerprints from a person of interest with a mobile fingerprint device. Designers may consider many design options, such as:

- Should the device provide a graphical interface to users?
- Should textual messages, symbols, and/or icons be provided on the device?
- Should the device provide visual cues, such as lights or other cues?
- Should it provide audible cues?
- Should the hardware be shaped and constructed in a specific way?
- If there are physical controls (e.g., buttons), where should they be placed?

All of these design questions are focused on the interface and how the interface will work. When considering the interface design, it is important to consider providing feedback to users in multiple ways. If a system relies on only one method to provide feedback, it may fail to meet the needs of users who cannot understand the method selected. For instance:

- If the device has a graphical interface, will the information be presented efficiently and effectively? Does the information provided minimize the officer's cognitive load; displaying the appropriate amount of information at the appropriate times? Does the officer understand the information the device is communicating?
- If the device provides visual cues (such as delivering error message alerts), will those cues be visible during daylight hours if a system is used outdoors? Are officers able to identify and understand symbols and/or icons correctly?
- If the device uses color indicators, are the colors the sole means to communicate information (some users may be color deficient)?
- If the device relies on audible cues (such as delivering device status alerts), will those cues be heard in noisy environments, such as around vehicle sirens?
- Does the device help officers position the hands/fingers of the person of interest to properly capture their fingerprints?
- Does the device allow singlehanded operation, enabling officers to retain a free hand? Is the device light enough so that it is easy to carry? Does the device have appropriate size so that it is big enough to type and small enough to support one-handed operation? Does the shape of the device accommodate different hand shapes and sizes?

The design of a user interface is a complex process that must consider not only the content of the data presented, but also the most effective way to deliver the information.

CONCLUSION

The design solution should address the user needs of both the primary and secondary users. The goal of specifying the design solution is to determine how to provide the users with the data they need, at the proper time, using an appropriate method of delivery.

Since there are so many ways to design a system, it is helpful to try out several different designs and evaluate the success of each design with users. That way, the best elements from each design can be merged into the end-resulting system.

By involving users early on in this process when it is still easy to make changes to a design, system designs can have a much more measurable impact on a system's usability. Waiting until the end to solicit user feedback is dangerous, as many times the feedback is received too late to make any substantial changes.

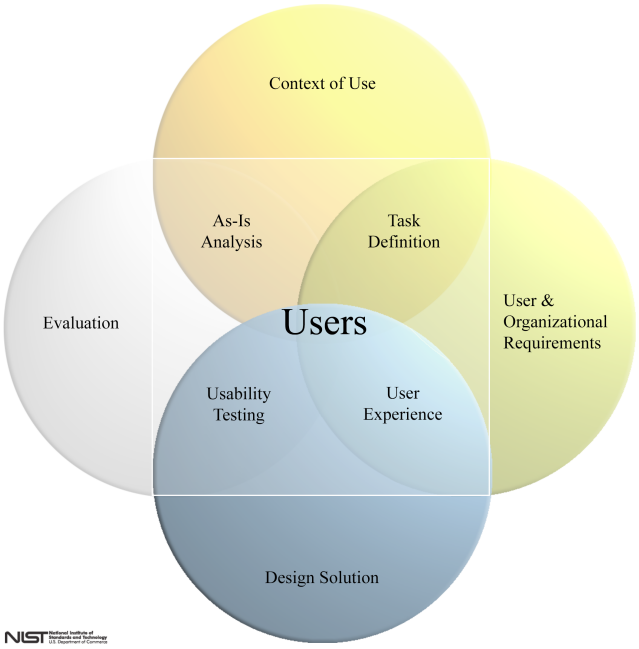


Figure 11 Components of the Design Solution Phase

Additionally, users are also much more willing to give critical feedback about a rough prototype that is still in design and are less likely to be critical about a fully functioning system. This is yet another reason to solicit feedback during the early stages of the design process. The design process should, in fact, be seen as an iterative process, whereby prototypes are evaluated with users and revised until a system is measurably easier to use. This process ensures that the system is being developed with users in mind and helps to prevent any show-stopping issues from being discovered too late in the process.

Figure 11 illustrates UCD phases discussed thus far (Context of Use, User & Organizational Requirements, and Design Solution). The following chapter will discuss the evaluation part of any project development lifecycle.

Chapter 7
Evaluation

CONDUCT THE EVALUATION

Evaluation is an essential part of any project development lifecycle, as illustrated in Figure 12. It ensures that the design is on the right track and helps to identify issues that still need to be resolved.

A well-conducted and well-planned project will have several rounds of evaluation, at varying levels of fidelity. By incorporating user feedback throughout the design of a system, it is easier to identify major problems or flaws in a system at a much earlier stage. In the diagram below, it is important to note that the evaluation and design stages overlap.

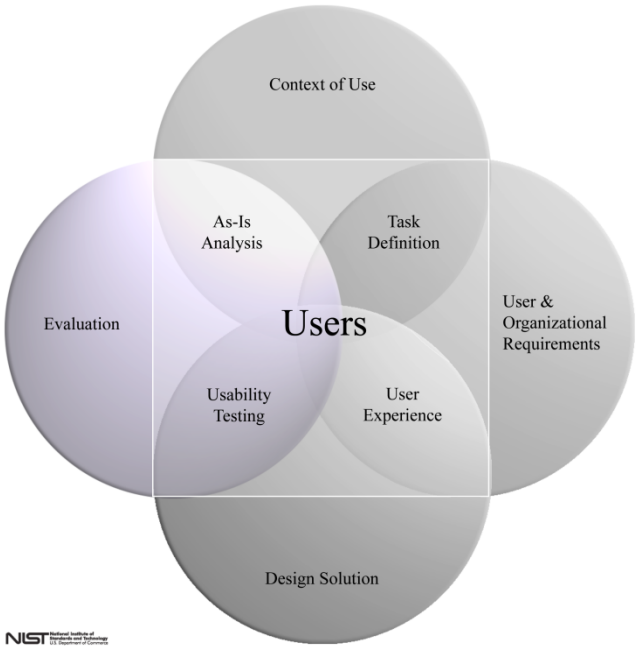


Figure 12: Evaluation in the User-Centered Design Process

Too often, design teams consider evaluation to be the final stage and wait to conduct any type of system evaluation until the entire system is nearing completion. This presents several risks. One major risk is that the evaluation may reveal major issues with the system that are too costly or too difficult to make in the latter stages of development. Therefore, we strongly suggest an iterative design process, wherein project teams share design concepts with users in the early stages of development, when it is easier to make design changes.

ITERATIVE DESIGN & EVALUATION

In an iterative design process, users are asked to review concepts throughout the design process and based on the results of the evaluation, the design is revised in order to improve user performance and satisfaction.

In order to involve users as early as possible, users may be asked to evaluate low-fidelity designs or even a series of paper prototypes. As the design process evolves, the fidelity of the prototypes is also likely to progress and eventually result in a high fidelity test of a functioning system.

It is also important to note, that the number of users involved in these evaluation processes it typically much lower than that required to test for performance measurements. Whereas it may require hundreds of thousands of users to test a system's performance, a usability evaluation may include as few as eight users. The small sample size required to conduct usability evaluations makes it much more realistic to conduct several iterative tests throughout the design and development of a system or device.

TYPES OF EVALUATION

During the design and evaluation phases, the types and frequency of the evaluation may vary. At the earlier stages of the design, the evaluation may be more qualitative, where users are asked their impressions or reactions to initial designs. In the latter stages of development, systems may be tested with users in a more quantitative usability test, where users' performance using the system is measured. The best approach to evaluation combines both qualitative and quantitative evaluations.

Repeatable testing conditions are critical for reproducibility of test results, which is necessary for valid evaluations. The nature of real-world public safety environments may make it difficult to reproduce the exact environmental conditions for each test. For example, consider the difficulty of controlling numerous environmental factors such as temperature and smoke density in a burn building. Similarly, it is difficult to fully replicate the many factors in an active shooter scenario. Virtual and/or augmented reality (VR/AR) may provide viable alternatives to simulating and controlling factors in dangerous public safety environments.

Qualitative Feedback

Qualitative feedback is important in the design of any system. This type of feedback may come in a variety of forms, including:

- Asking users about their expectations of what the system will do and how it will function
- Observing users interacting with a system while 'thinking aloud' and noting areas that cause user confusion or frustration
- Probing for suggestions from users and asking users about their level of satisfaction with the system

Users' comments and concerns can be an extremely important way to learn whether or not the design of the system matches users' expectations of how the system should act. Although users' comments can be extremely informative, it is also essential to understand how well users can perform using the system in order to quantitatively measure the effectiveness and efficiency of a design.

Quantitative Feedback

In order to evaluate the success of a design it is important to measure how well users are able to accomplish tasks using the system. Examples of quantitative measures that may be measured include:

- **Task Completion Rates:** Percent of users who successfully complete each task
- **Time on Task:** Time it takes for users to perform a task from beginning to end
- **Error Rates:** Number of errors made during the course of a task
- **Satisfaction Rating:** Satisfaction scores for the system

Many design teams will begin the design process with a quantitative usability test, known as a baseline or benchmark usability test. The results of this test are used to measure the effectiveness of future design improvements. Many teams use the Common Industry Format (CIF) [ISO/IEC 25062:2006] to document the performance of the system. The CIF provides a standard way for organizations to present and report quantitative data gathered in a formal test. This report can be used as a benchmark for future comparisons.

Following the benchmark test, design teams typically revise the system to improve the system's effectiveness and efficiency. Once the changes have been made, the design team may repeat the same test methodology as the baseline test in order to determine if the changes have made a measurable impact. Typically, design teams hope that the changes improved users' success rates, decreased the time it takes to perform a task, decreased the number of errors made by users, and increased users' satisfaction with the system.

It is these types of metrics that can help a design team stay focused on making data-driven, performance-based improvements. In this environment, project teams try to make recommendations for improvement that they believe will improve the performance of the system and have a measurable impact on the effectiveness and efficiency of the system's design.

To learn more about usability testing, please see the chapter on usability methods.

CONCLUSION

Evaluation is a critical component of any design process and product improvement lifecycle. Without continual feedback from users, design teams suffer and end up operating blindly, not knowing whether design recommendations will actually improve the usability of a system or worse case, make the system more difficult/confusing to use.

Armed with the results of an evaluation, design teams can operate much more efficiently and can focus their energy on design changes that will have the greatest impact on user performance and satisfaction, placing less emphasis on cosmetic changes that may only have a minor impact on the performance of their system. Teams that are able to effectively and accurately prioritize resources are much more cost-effective and productive in the long run.

Chapter 8
Usability Methods

The following sections will provide information on various usability techniques and research methods including:

- ☑ As-Is Analysis
- ☑ Cognitive Walkthroughs
- ☑ Competitive Analysis
- ☑ Contextual Inquiries / Naturalistic Observation
- ☑ Expert Reviews
- ☑ Focus Groups
- ☑ Parallel Design
- ☑ Usability Testing
- ☑ User Interviews
- ☑ User Surveys

AS-IS ANALYSIS

What is this method?

An As-Is Analysis is a complete evaluation of the existing system in its current state.

When should it be used?

It is important to conduct an As-Is Analysis at the beginning of any project in order to better understand the current system, its strengths and its weaknesses. By conducting a thorough analysis of the existing system, design teams can effectively develop system requirements and design solutions that better meet the needs of users. These 'targeted' design decisions will be much more effective in designing a usable, user-friendly product.

While it is critical to conduct an As-Is Analysis at the beginning of any large design project, it is also essential to continually evaluate the design of your system throughout the entire project lifecycle. By continually monitoring the quality of your product, you are in a much better position to implement improvements that will have a measurable impact.

How do you conduct an As-Is Analysis?

An As-Is Analysis should collectively evaluate and measure as many facets of a product as possible. This may mean that you need to gather data from multiple sources. For example, consider firefighter use of the SCBA:

Performance data	▪ Success rate to don and doff the SCBA
	▪ Timing to don and doff the SCBA
	▪ Accuracy in interpreting alerts, signals, and information presented on the HUD (e.g., air cylinder content, power source condition)
	▪ Can firefighters perform SCBA tasks without errors?
Observational data	▪ How do firefighters currently use the SCBA?
	▪ When do they struggle?
	▪ Which aspects of the SCBA cause confusion or frustration?

User Feedback	▪ Do firefighters request assistance? ▪ What is firefighters' most common concern? ▪ Do firefighters require training? How long does it take them to learn how to use an SCBA? Where do they struggle the most? ▪ Do firefighters encounter difficulties when cleaning and maintaining the SCBA?
User Interviews and Surveys	▪ What do firefighters think of the SCBA? ▪ Which aspects do they believe are the most difficult to use? ▪ What suggestions for improvement can they offer? ▪ What do firefighters feel should not be changed?
Usability Testing	▪ Which aspects of the SCBA are the most difficult to use? ▪ Which are the easiest to use? ▪ What causes firefighters to struggle? ▪ What improvements can be made to address these issues?
Expert Reviews	▪ Which areas of the SCBA do usability experts believe are vulnerable to usability issues?
Competitive Analysis	▪ How does your product compare to your competitors? ▪ Are there aspects of your competitors' products that perform better than yours? ▪ How can you create a product that will outperform that of your competition?

What are the benefits/limitations?

An As-Is Analysis takes into consideration all of the types of feedback and evaluation conducted on your system to give design teams an overarching view of the system. This process is an extremely useful process and one that can be used to benchmark the performance of your existing system, so that the success of future design changes can be measured and quantified.

With a broad knowledge of the various facets of your system and your users, development teams can effectively target design decisions and changes. When requirements and design decisions are not based upon this deep foundation of knowledge, design teams are operating blindly, making choices that may or may not impact the actual system performance. Many teams have labored over system requirements and the various ways to implement a particular feature or function, only to have expended a lot of time, energy and resources on a feature that will not truly have an impact on the ultimate performance of a system and the users of that system.

It is critical to conduct a thorough As-Is Analysis, in order to make targeted, effective design decisions that will enhance the ease of use, reduce system complexity, improve user performance and satisfaction, and reduce support and training costs.

COGNITIVE WALKTHROUGHS

What is this method?

Cognitive walkthroughs are an 'inspection' method (which means that actual users are not involved in the process). It is a method in which a usability expert or a group of experts inspect the system by walking through a set of tasks as a user would, noting any problems or difficulties a user may encounter. Although typically conducted by a usability expert, cognitive walkthroughs can be conducted by anyone with a thorough understanding of the system including software engineers, system designers/developers, documentation specialists, subject matter experts, etc.

When should it be used?

Cognitive walkthroughs can be performed at any stage of design but typically occur during the early design stages and may be conducted on paper prototypes, low-fidelity prototypes or fully functioning systems.

How do you conduct a Cognitive Walkthrough?

The first step to conducting a Cognitive Walkthrough is to review the data gathered and analyzed during the Context of Use and User / Organizational Requirements phases. To conduct a Cognitive Walkthrough, begin by answering the following questions:

Users

- Who are the users of your system?
- Who are the primary users? Secondary users?

Consider all aspects of use, including the primary users and the secondary users.

Now select one user type for your cognitive review.

Tasks

- What tasks will users perform using the system?
- Is this a repeat task for users?
- What type of knowledge will users have going into this task? What is their experience with the system?

Once you have selected a set of tasks to evaluate, you must break each task down into its sub-parts. By breaking the task down into smaller sequential steps, it is easier to tell when the system does not meet users' expectations.

Once you have selected a user profile and a task, the individuals conducting the Cognitive Walkthrough use the system to perform the task as though they were seeing the system through the eyes of the user. By stepping into the role of the user, the experts evaluate the system looking for issues or problems that users may encounter.

What are the benefits/limitations?

Cognitive Walkthroughs can be very good at helping to identify potential usability issues early in the design phases. In order for the walkthroughs to be effective, it is essential that the individual or team conducting the walkthrough has a thorough understanding of the users in order to simulate their experiences with the system.

It should be noted that since Cognitive Walkthroughs are an inspection technique and do not involve real-world users, experts may not always pick up on subtleties in a design that could impact a user. While this technique does help to focus the design on the needs of users, it should not be the only user-centered methodology employed, as expert evaluations cannot replace the value of real-world input from users.

COMPETITIVE ANALYSIS

What is this method?

A Competitive Analysis is a technique that is used to evaluate the systems of your competition so that you may learn from others' design decisions and understand how another organization is attempting to fill a similar need. In the simplest of terms, you compare and contrast your system with that of your competition.

When should it be used?

Competitive Analysis can be conducted at any stage of the product lifecycle. It is typically important to conduct a Competitive Analysis if you are planning to make some improvements to your system or when your competitors release updates to their systems.

How do you conduct a Competitive Analysis?

There are several ways to perform a Competitive Analysis, ranging from very informal to very formal. In conducting a Competitive Analysis, begin by identifying your 'competition.' It's important to think outside of the box for this part of the process, as there may be others who are providing similar, but not identical services. By looking for examples from others, it is wise to gather a broad sample from several different products and systems.

A Competitive Analysis can be as formal or as informal as you would like it to be. It can be as informal as simply reviewing competitors' systems to identify the differences between the products. Or, it can be more formal, in that you actually conduct a Cognitive Walkthrough, contextual inquiry, expert review, focus group, usability test, user interview or user survey on the competing system. Depending on the detail needed, it is possible to conduct a blind A/B comparison, wherein users are asked about two (or more) products and asked to compare the systems. In this type of evaluation, it is essential that users do not know the affiliation of the person or group of people conducting the evaluation, as this knowledge may bias users' comments and performance. This type of A/B comparison can be extremely helpful in identifying which design options elicit improved user performance and decreased user frustration.

What are the benefits/limitations?

This technique is an extremely valuable way to learn about various design solutions before investing time and resources on system improvements. Not only does this method help project teams to improve upon good designs and to avoid design solutions that are not effective, it also helps teams to build a better understanding of the existing marketplace and the types of products and systems that users will be interacting with.

Since users will inevitably learn from their interactions with other systems and will make assumptions about the way your system should work based upon these previous experiences, it is important to have a thorough understanding of your competitors' products.

Armed with this information, project teams will have the necessary resources to make informed design decisions.

CONTEXTUAL INQUIRY/NATURALISTIC OBSERVATION

What is this method?

Contextual Inquiry is a method that allows you to observe users in a real-world environment, performing tasks as they would if they were not being observed. In contrast to other techniques such as usability testing, user interviews, user surveys, and focus groups, the evaluator travels to the user to observe them in a naturalistic setting and allows the user to 'drive' the session.

Contextual Inquiries take into consideration the entire process including the initial approach, instructional guides, physical and environmental conditions, situational factors, hardware design, software design, etc. It evaluates the entire process in order to provide a complete view of how users interact with a system in a real-world context.

When should it be used?

Contextual Inquiries can be conducted at any stage of the process, but typically tend to be performed on a fully functioning system.

How do you conduct a Contextual Inquiry?

During a Contextual Inquiry, a usability expert or team of experts typically travel to observe users in a real-world environment, such as a first responder training facility. Although typically conducted by a usability professional, the inquiry can be conducted by anyone with a thorough knowledge of the system and the system's users.

The individual performing the inquiry is typically very passive, allowing users to act naturally as though they were not being observed. During the inquiry, the usability expert may ask questions to better understand a user's actions, but typically questions are held until the end to avoid interrupting a user's normal workflow. The person performing the inquiry may also ask for permission to tape the sessions so that they may capture the entire process and conduct an in-depth review following the inquiry.

This process should be repeated with several users under varying conditions in order to identify trends in users, in the environment, and with the technology.

Following the observations, the individual conducting the evaluation will summarize their observations, noting workarounds or shortcuts that users have created, itemizing instances

where users deviated from the expected workflow, listing features that performed well, as well as features that were difficult for users to understand.

What are the benefits/limitations?

The benefit of a Contextual Inquiry is that you have an opportunity to observe users in the environment in which they will use the system. It helps to identify design issues that may arise because of environmental factors (e.g., the noise level inside a responding vehicle with its siren on may be too loud for users to hear audible cues that tested just fine in a usability lab), physical conditions or unexpected occurrences.

It is especially important to observe subtle, well-practiced behaviors that are so deeply ingrained that users may not be able to verbalize or demonstrate them in a laboratory setting. It is this type of subtle, but extremely important information that Contextual Inquires help to uncover.

One of the drawbacks to this technique is that there is sometimes so much data to analyze that it becomes a very time-consuming and labor-intensive effort.

EXPERT REVIEW

What is this method?

An Expert Review is similar to a Cognitive Walkthrough in that it is conducted by an expert or team of experts. The main difference between a Cognitive Walkthrough and an Expert Review is that an Expert Review evaluates a system against a set of best practices, design guidelines, and standards.

Expert Reviews are sometimes referred to as Heuristic Reviews as evaluators may choose to evaluate a system according to a set of heuristics (or design principles) such as Jakob Nielsen's 10 heuristic guidelines. [Nielsen]

When should it be used?

Expert Reviews can be conducted at any stage of the process and may be conducted on a paper prototype, low-fidelity prototype or fully functioning system.

How do you conduct an Expert Review?

During an Expert Review, a usability professional or team of usability professionals reviews the system for adherence to design guidelines and heuristics, noting where the system fails to meet certain standards. Based on the review, the usability professional will provide a set of recommendations and suggestions for improvement.

What are the benefits/limitations?

An Expert Review is a method that can be performed fairly quickly and inexpensively. However, just like the Cognitive Review, it is important to note that the review is being done by an expert or team of experts. Since experts do not have the same experiences and perspectives as users, they sometimes miss usability issues or identify issues that are 'false alarms' (issues that are not really usability issues).

In an effort to offset potential misses and false alarms, it is generally recommended that more than one individual be involved in an Expert Review. One approach is to have a team of usability experts conduct the review independently of each other and then share the issues they identified. The list of issues can then be reviewed to find issues that were identified by multiple usability professionals. While not a perfect solution, this principle can help to ensure that the most commonly identified issues are fixed first.

Like all 'inspection' methods, it is recommended that project teams also involve users in the design and development of any system.

FOCUS GROUP

What is this method?

A Focus Group is a large group interview or discussion that allows project teams to explore opinions and gather feedback from users.

When should it be used?

Focus Groups tend to be very useful at the beginning of a design project to gather information about users' needs and to ask for feedback on initial design concepts. However, Focus Groups do not tend to be a good evaluation technique, in that it is very difficult to gather meaningful data from a group evaluation. Since users will be using a system as individuals, it is much more helpful to gather this type of information in one-on-one interviews or usability testing.

How do you conduct a Focus Group?

To conduct a Focus Group, first begin by recruiting a group of users (8 – 12) who represent your user population. Next, select a moderator or facilitator. The moderator should be someone who can objectively ask questions of the group and is not tied to one particular design concept. It is also critical that the moderator be a skilled leader in order to drive the conversation of the group and ensure that each focus group participant has an opportunity to voice his/her opinions.

During the Focus Group, the moderator may ask users about previous experiences with the systems or devices, may try to probe into any issues or concerns users have had in the past, and finally may try to present some design ideas/concepts to gather the group's feedback.

The Focus Groups may be recorded or observed by other team members through a one-way mirror. Following the Focus Groups, the team will summarize the findings and recommendations resulting from the sessions.

What are the benefits/limitations?

Focus Groups are a good way to quickly gather data from several users within a user segment. They can be a helpful way to gauge users' opinions and gather early feedback on design concepts, however, they tend not to be as useful in the latter stages of the design, when other techniques such as usability testing are more effective.

PARALLEL DESIGN

What is this method?

Parallel Design is a method that enables large teams to generate many design concepts quickly in an attempt to bring the best design concepts forward by saturating the design space.

In short, it is a method that asks designers to each independently create a design. The group then shares their ideas and designers are asked to iterate their design concepts by improving upon the ideas shared. This technique helps designers to quickly build off concepts presented by their colleagues, and with each iteration, improve upon the ideas presented.

When should it be used?

Parallel Design should be used at the beginning of any design phase that will result in major changes to a system. It is a technique that works best in the early stages of a project.

How do you conduct a Parallel Design session?

Parallel Design sessions are a great way to generate a lot of design ideas very quickly. During a Parallel Design session, various members of the project team identify a particular feature that needs improvement and then focus their attention on creating a useful, usable solution. The session should include various members from the project team and can be conducted with graphic designers, hardware/software engineers, usability professionals, marketing specialists, documentation writers, etc. The sessions can be conducted with as few as three participants and with as many as a team feels comfortable including. A group of around 10-20 members tends to be just about right.

During the design session, the team will begin by discussing the feature to be designed (or redesigned). It is essential that the team discuss the users of the system, as well as the tasks to be completed. Lastly, the team should review any data gathered from other usability methods, including user interviews, usability tests, competitive analysis, expert reviews, etc.

Once the team has agreed upon the users and tasks, as well as some of the key requirements for the feature, each member of the group is asked to independently create a design. Once the designs are created, they are shared with the group. One easy way to share the designs is to have each person create their design on a large piece of paper and then post the paper prototypes around the perimeter of the room so that everyone can walk around the room and review the concepts.

After everyone has had a chance to review the concepts, the individual members are again asked to independently create a new design. In the new design, the parallel design participants are asked to integrate the best concepts from the other designs and attempt to improve each concept. After the designs are completed, they are once again posted for the group to review. This process can be repeated several times throughout a one or two-day session.

At the conclusion of the session, the group should select the best concepts from the designs presented and build one to two optimal design solutions.

What are the benefits/limitations?

Not only is this technique an effective way to quickly generate as many design ideas as possible, but it is also a very effective way to continually improve on the ideas of others in collaborative and cooperative fashion. By including team members from various parts of your project team, design ideas that are not normally thought of by a single system designer can have a very positive impact on the overall design of a system.

Additionally, this technique is a very useful way to gather buy-in from stakeholders throughout your organization, as team members feel as though they have had a part in creating the design of the system.

USABILITY TESTING

What is this method?

Usability Testing is an evaluation method that asks real-world users to 'try out' or test a design of a system, while a usability professional notes areas where users struggle or make mistakes. Sessions may be recorded or observed by members of the design team in order to identify usability issues with the system.

When should it be used?

Usability Testing is a technique that should be used throughout the entire design lifecycle. It can be conducted on paper prototypes, low-fidelity prototypes and fully functioning systems.

How do you conduct a Usability Test?

To conduct a usability test, it is important to identify the users you want to test as well as the tasks you'd like to evaluate. Once you've selected the user group you'd like to test, you'll need to recruit a representative mix of users who closely match your actual user population. Many organizations will test with eight users from each user group, while other organizations will recruit larger numbers of users. When conducting performance testing where the goal is to analyze quantitative data, you may want to recruit 30 or more users. But, if this is your first usability test, you may want to start out with eight users and then determine if you need a larger sample.

After you've defined your users, you'll want to select the tasks that you would like users to perform. Once you have a set of tasks, you'll need to translate these tasks into 'scenarios' or stories that ask a user to perform a task without actually telling a user how to do the task. The scenario should also try to avoid 'give-away' wording by not using the exact same terminology that the system does.

During the usability test, the participant works one-on-one with the facilitator. The facilitator gives the participant the scenarios one at a time and then asks the user to perform the task. During this time, the facilitator notes areas of concern or confusion and may also ask the participant to 'think aloud' in order to better understand why a user is behaving in a certain manner.

Following the test, the design team will report the findings of the usability test. For quantitative testing, many teams use the Common Industry Format (CIF) [ISO/IEC 25062:2006] to document the performance of the system. The CIF provides a standard way for organizations to present and report quantitative data gathered in a usability test, so that it can later be compared to the results gathered in subsequent tests.

What are the benefits/limitations?

Usability test sessions are an extremely valuable way to observe users interacting with your system and to note areas of concern.

Not only does usability testing provide an opportunity to observe users interacting with a system, it enables design teams to better understand why a user behaves in a certain way or why an individual is confused. By asking users to explain what they are doing as they are using the system and to probe or follow-up on interesting actions, design teams have an opportunity to see the system through the eyes of a user.

Usability testing not only provides insights into users' behavior, it also allows project teams to quantifiably measure the success of a system, including capturing metrics such as error rates, successful performance on tasks, time to complete a task, etc. This valuable data can be used to benchmark the performance of a system and subsequently measure the impact of future design improvements. In addition to the more quantitative measures, usability testing offers insights into more qualitative issues, such as the level of users' frustration, confusion, intimidation, and overall satisfaction with the system. The combination of quantitative and qualitative data can be very informative when developing recommendations to improve the system design.

While usability testing can be expensive and time-consuming it is also extremely useful in that the results are reliable and detailed.

USER INTERVIEWS

What is this method?

User interviews are a valuable way to learn what users think of your system in a one-on-one discussion.

When should it be used?

User interviews should be conducted throughout the entire design lifecycle.

How do you conduct a User Interview?

User Interviews are one of the simpler user-centered design techniques. A User Interview is basically a one-on-one discussion with a user. During the interview, an interviewer may ask questions about a user's past experience with a product, a user's needs in using a specific type of public safety systems, any concerns a user may have, etc. The interview may also ask users who've used the system to recall issues that they've encountered and propose ideas for improvement. Additionally, an interview may include presenting design ideas and concepts to a user and gathering feedback. This semi-structured method may explore the issues that are most important to the team at any given moment.

During an interview, the interviewer should have a basic list of questions that will be asked, but should also be able to follow-up and probe on interesting comments that a user makes. Some of the most valuable aspects of an interview can be gained from a probing question that was never part of the original interview script. Therefore, it's important that an interviewer be able to probe into interesting areas, as well as know when to bring the discussion back to the pre-defined list of questions.

What are the benefits/limitations?

Interviews are a wonderful way to learn about users' opinions, feelings and reactions to a system. Users tend to be very good at telling us what isn't working on a system or identifying where they have problems, however, they tend to not be able to recommend a solution. It's important to note that users are typically not good designers, which means that interviews should be used to help better understand an issue so that a skilled team of designers can architect an effective solution. Additionally, while users may be able to explain problems that they've encountered in the past, they are typically not able to remember all of the details of the situation or the issues that it caused. Therefore, interviews can never replace the value of user observation, whether in a Contextual Inquiry or Usability Test.

While extremely valuable, interviews can be time-consuming to conduct and analyze.

USER SURVEY

What is this method?

In a User Survey, users are asked a series of questions that are typically aimed at learning more about a user group or about users' views of a system. Surveys enable design teams to gather a lot of information very quickly which can be statistically analyzed.

When should it be used?

Surveys can be conducted throughout the product lifecycle and can be targeted to the issues that the team is dealing with at any given moment.

How do you conduct a User Survey?

In today's wired world, User Surveys tend to be conducted online which is less costly than mail or phone surveys. The online surveys may try to help a product team learn about its users, including demographic information, past experience with public safety systems, knowledge level with these types of systems, etc. Or, a survey may be more focused on identifying the top issues users have encountered with a system and soliciting ideas for improvement. Whatever the topic of the survey, it is important to design the survey with best practices in survey design in mind. For instance, it is important to ensure the survey does not ask leading questions and to ensure that the length of the survey isn't too long (which may detract some users from completing it).

When designing a survey, it is also important to balance the number of open-ended questions and close-ended questions. Open-ended questions are a wonderful way to gather deeper insights into users' opinions, however these types of questions are difficult and time-consuming to analyze. Additionally, since open-ended questions require more work on the part of the respondent, it is important to note that a survey with too many open-ended questions may prevent users from completing the survey.

Close-ended questions may not offer the same individual insights that open-ended questions do, but they also provide the ability to statistically analyze the data and to perform cross-tabulations with other close-ended questions.

What are the benefits/limitations?

Surveys provide an easy way to gather a lot of data very quickly, yet they suffer from many of the same issues as interviews. Since surveys are asking users to provide opinions and recall experiences, they cannot replace the value of user observation. Additionally, poorly-written

surveys can bias design decisions. The data gathered from a survey is only as good as the questions asked. Therefore, it is critical to pilot the survey instrument prior to launching a full-blown survey.

Another issue that can negatively impact the quality of a survey is the sampling methodology. It is important to note, that a survey may not include a representative sample of the user population. Since users have the ability to opt-in or to quit at any time, it is important to review the data to identify segments of the population who are underrepresented. The self-selection nature of surveys makes it extremely difficult to find a truly random sample.

While this technique is certainly more complex than some of the others, the insights that can be learned and the amount of data that can be gathered in a short period of time make this technique a very important part of any design process.

Chapter 9
Conclusion

Over the next 20 years, public safety communications technology advancements will enable data, video, and eventually voice communications to migrate to a nationwide Long Term Evolution (LTE) broadband network. During this transition, emerging technologies within this new infrastructure present opportunities and challenges for public safety communications systems.

A focus on device effectiveness, including system performance, functionality, reliability and precision, is important for new and emerging technologies. However, as technology evolves and the performance of these new devices improves, it is critical to focus our attention to designing usable and user-friendly public safety communications systems.

ENSURING SUCCESSFUL PUBLIC SAFETY COMMUNICATIONS SYSTEMS

In order to ensure the continued success of public safety communications systems and devices, it is critical that the traditional product development process evolve into a user-centric model that takes into consideration the essential role users play in the public safety communications process. By understanding the partnership between public safety communications systems and users, we can begin to have a substantial impact on the design of these systems, including:

- Improved ease-of-use
- Reduced product complexity
- Enhanced system performance
- Increased user safety and comfort

By focusing on these attributes, designers and developers can improve the usability of their devices and systems, and as a result, may also improve system performance, resulting in a significant return on investment, including:

- Increased accuracy and reduced errors
- Improved efficiency
- Improved productivity
- Decreased support and training costs
- Increased interoperability

Thus, usability improvements not only lead to better, easier-to-use products, they can also lead to substantial cost savings as a result of improved system performance.

USABILITY AND PUBLIC SAFETY COMMUNICATIONS SYSTEMS

In order to improve the usability of public safety communications systems and reap the benefits of improved system performance, it is critical to take a holistic approach in which users are a key component in the design of a system. By adopting a user-centered design process (Figure 13), wherein users become our design partners and have an integral role in the development of a public safety communications system, we can begin to have a measurable impact on a system's ease of use.

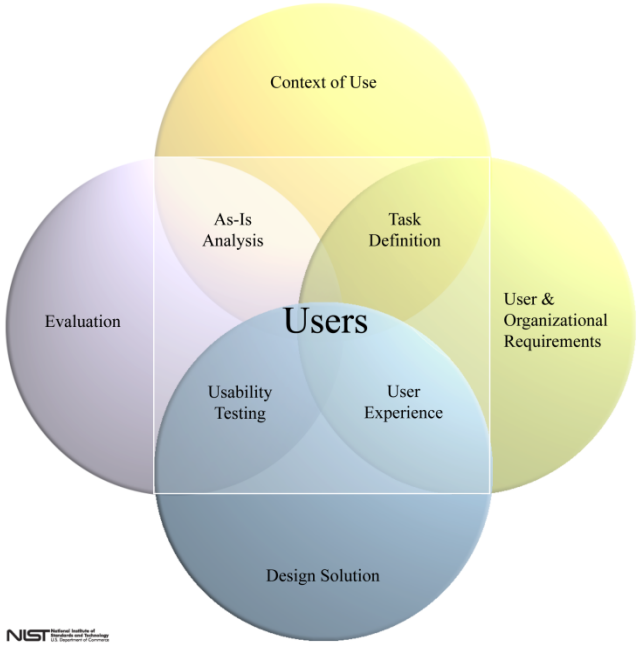


Figure 13: User-Centered Design Process for Public Safety Communications System

In this handbook, we've introduced some of the key concepts of this user-centered design lifecycle, including:

- Defining the **Context of Use**
  Including operational environment, user characteristics, tasks, and social environment
- Determining the **User & Organizational Requirements**
  Including business requirements, user requirements, and technical requirements
- Developing the **Design Solution**
  Including the system design, user interface, and training materials
- Conducting the **Evaluation**
  Including usability and conformance testing

While this handbook introduced some of the key user-centered design and usability concepts, it is only meant to be an introduction to a topic that has the potential to significantly improve the future of public safety communications systems. We've provided a basic outline and some key methods which will help designers and developers begin to incorporate usability throughout their product lifecycles. But, this is only a start: additional research in the field of usability and public safety communications is greatly needed.

At NIST, we've created the usability and public safety communications effort which is dedicated to providing resources, such as this handbook, in order to advance public safety communications and usability research. In addition to promoting the benefits of usability, we are working to conduct research on how users' interactions and characteristics affect the success of public safety communications systems, so that we may better understand these issues and their implications for the design of a system.

In an effort to improve the design of public safety communications technologies, we encourage others to conduct and share their research in this emerging area so that we can continue to improve the usability and ease-of-use of these systems and advance the future of public safety communications technologies.

For more information on this and other NIST usability and public safety communications projects, please visit https://www.nist.gov/ctl/pscr/newsroom/

Chapter 10
References

ASTM International E3003-15 (2016). Standard Practice for Body Armor Wearer Measurement and Fitting of Armor.

ASTM International E3005-15 (2015). *Standard Standard Terminology for Body Armor*.

Grant, C., Hamins, A., Bryner, N., Jones, A., & Koepke, G. (2015). *Research Roadmap for Smart Fire Fighting*. Retrieved from: http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1191.pdf

ISO 9241-210:2010. *Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems*.

ISO/IEC 25062:2006. Retrieved from International Organization of Standardization's Software engineering -- Software product Quality Requirements and Evaluation (SQuaRE) -- Common Industry Format (CIF) for usability test reports: http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=43046

Meshkati, N. 1991. Human factors in large-scale technological systems' accidents: Three-Mile Island, Bhopal, Chernobyl. *Organization & Environment*. 5: 133–54.

Nielsen, J. *Ten Usability Heuristics*. Retrieved from Useit.com: http://www.useit.com/papers/heuristic/heuristic_list.html

Norman, D. (1988). *The Design of Everyday Things*. New York, New York: Doubleday.