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Human Engineering Design Criteria Standards Part 3: Interim Steps

FY10-14 DHS S&T TSD Standards Project

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EXECUTIVE SUMMARY

The Department of Homeland Security (DHS) requires general human systems integration (HSI) criteria for the design and development of human-machine interfaces for the technology, systems, equipment, and facilities employed by its user population. HSI is the relationship between humans and their environment and in particular how systems are designed and used relative to that relationship with the goal of ensuring a safe and effective environment that meets the mission. In general, HSI addresses hardware, software, and processes.

However, systematically adopting and applying HSI criteria within DHS will be a challenge because of the department's large and extremely varied user population. The DHS personnel who operate and maintain the department's technology and systems carry out a variety of different tasks in operating environments ranging from airports and border points of entry to subways and Coast Guard vessels. Other DHS users include public health officials; state and local first responders; travelers to be screened; bystanders; and the general public.

DHS sought help from the National Institute of Standards and Technology (NIST) Visualization and Usability Group (VUG) regarding standards and guidance for HSI criteria. Working in partnership with DHS, VUG designed a three-phase project that would help DHS meet its goals.

In Phase 1 of this project, VUG identified and reviewed the body of existing human factors and HSI standards, best practices, and guidelines. These standards are described in Part 1 of the *Human Engineering Design Criteria Standards* Part series.

In Phase 2 of the effort, VUG researchers identified core, high-impact processes performed by different DHS directorates, then interviewed and (when possible) directly observed end users who performed those tasks. The results of the Phase 2 study highlighted five critical areas where there is a need for HSI standards related to interfaces, described in Part 2:

1. Client-side interfaces for real-time, remote software applications, which are vital to many of the tasks performed by DHS end users.
2. Hand-held and mobile devices, such as smartphones and tablet computers, which many interviewees identified as being critical to mission success in the future.
3. Touch interfaces, which are the default means of interaction with almost all contemporary mobile devices.
4. Interfaces for biometric collection devices, in terms of usability and language-independent symbols for multi-cultural user populations.
5. Accessibility for both DHS agents and the populations with whom they interact; this applies to Web pages, application interfaces, and biometric collection processes.

Phase 3 of the project entails determining where DHS may use existing HSI standards and where there are gaps in those standards that the organization must address by creating new standards to fill its needs, particularly to address the gaps described above. NIST recognizes that developing and adopting appropriate HSI standards to address the previously described gaps will take time – roughly three to five years. This document, Part 3, offers recommendations on steps DHS can

take in the relatively near term to improve its usability posture and build an HSI-oriented organizational culture.

First, DHS should seriously consider conducting research (similar to the effort in Phase 2) in order to understand the context of use for the technologies employed by its end users. Context of use is a particularly important consideration for DHS, since users from different directorates may perform broadly similar tasks but do so under very different circumstances. For example, personnel from U.S. Citizenship and Immigration Services (USCIS) and the Coast Guard (USCG) both collect biometric information: however, USCIS agents primarily work in an office, while USCG agents work primarily on ships – and so must contend with sun glare, fog, darkness, rough waters, moisture, and other environmental conditions that can significantly affect their equipment and their ability to perform their tasks effectively.

Secondly, while DHS is very forward thinking with respect to technology – always looking for new technology solutions to help it carry out its missions – the organization needs to expand its focus to include the people who use that technology. This includes both primary users (DHS agents) and secondary users (the populations they work with). The most effective and impactful way to improve DHS' usability posture is to explicitly address HSI and usability concerns during the technology procurement process. This document lists and summarizes standards and guidance that DHS can use to incorporate HSI into its technology acquisition process through user-centered design (UCD) activities.

Finally, DHS needs to conduct some type of user acceptance and usability testing of potential new technologies before deploying them in the field. Performing this kind of evaluation is part of the UCD process described earlier, but it deserves special emphasis because it can help DHS proactively address usability problems early in the technology acquisition process.

Following these recommendations will ensure that DHS equipment and processes are appropriate to their context of use, which will translate into fewer adverse effects on user health and safety; increased accessibility and sustainability; and improved user satisfaction as a whole. DHS end users will be able to complete their tasks more efficiently and effectively, and the organization as a whole will realize a greater return on its technology investments.

1 INTRODUCTION

The Department of Homeland Security (DHS) requires general human systems integration (HSI) criteria for the design and development of human-machine interfaces for their technology, systems, equipment, and facilities. The goal of the DHS Science & Technology (S&T) Human Factors and Behavioral Science Division Human System Engineering Project is to identify, develop, and apply a standard process to enhance technology and system design, system safety, and operational efficiency.

The project manager partnered with the National Institute of Standards and Technology (NIST) Visualization and Usability Group (VUG) in furtherance of this effort. As part of its mission, NIST performs research to develop the technical basis for standards related to measurement, equipment specifications, procedures, and quality control benchmarks for industrial processes (among others), for organizations and users in industry, academia, government, and other sectors, while remaining objective and vendor-neutral. VUG, part of the NIST Information Technology Laboratory, conducts research in HSI and human-computer interaction (HCI) technologies. Members of VUG are also active on the International Organization for Standardization (ISO) Technical Committees Working Groups in HCI.

NIST's work on this project consists of three phases:

1. Identify and review the body of publicly available existing human factors and HSI standards, best practices, and guidelines for applicability to DHS.
2. Apply a user-centered design (UCD) approach for the DHS organization in order to determine how existing HSI standards can be mapped to DHS needs, technology, and processes, and identify standards gaps.
3. Determine where DHS may use existing standards and where it may need to augment existing HSI standards and/or create new DHS HSI standards to address gaps and meet organizational needs.

Simply put, HSI is the relationship between humans and their environment and in particular how systems are designed and used relative to that relationship with the goal of ensuring a safe and effective environment that meets the mission. In general, HSI includes the integration of hardware, software, and processes (including design and acquisition processes).

HSI design criteria, principles, and practices will benefit DHS by:

- improving performance of personnel,
- reducing skill and personnel requirements and training time,
- enhancing the usability, safety, acceptability, and affordability of technology and systems, and
- achieving the required reliability and productivity of personnel-equipment combinations [1][3].

But most importantly for DHS, HSI Design Criteria Standards will foster design standardization and interoperability within and among DHS systems.

2 BACKGROUND

This is the third and final document in the *Human Engineering Design Criteria Standards* series. It should be noted that while Part 1 and Part 2 of this series align to Phase 1 and Phase 2 of this project respectively, this document – Part 3 – does not.

In Phase 1 of this project, the NIST team identified and reviewed the body of existing human factors and HSI standards, best practices, and guidelines. These standards are described in *Human Engineering Design Criteria Standards* Part 1.

Phase 2 focused on identifying and interviewing DHS employees for the purpose of understanding the end users' main tasks, technologies and devices they use to complete those tasks, and the context of use. These interviews allowed the research team to identify the "feature sets," e.g., interface characteristics, of identified devices and technologies and then map them to the standards identified in Phase 1 of the project. The mapping exercise also helped the NIST team identify where DHS may need to augment existing HSI standards and/or create new standards to meet organizational needs. The results of the interviews and subsequent mapping are described in *Human Engineering Design Criteria Standards* Part 2.

This document, Part 3, does not align exactly to Phase 3 of the project. Completing that phase – specifically, modifying and/or developing human factors and HSI standards to meet DHS' organizational needs - will take a long time (between three and five years, based on the experience of similar organizations). Rather, Part 3 describes interim steps that DHS can take to improve its HSI posture and reduce the incidents of future usability issues while the long-term effort to develop needed HSI standards is underway.

2.1 THE DHS USER POPULATION

Although numerous Federal standards exist that establish general HSI and human engineering criteria for design and development of systems, equipment, and facilities (including DoD MIL-STD-1472G Department of Defense Design Criteria Standard and NASA-STD-3000 Man-Systems Integration Standards, among others), each of these standards also contains very domain-specific information and focuses on specialized populations, types of systems, and system functions.

In contrast, the DHS user populations' characteristics are varied. The populations encompass not only Federal civil servants who operate and maintain the department's technology and systems, but also a variety of other personnel, including public health officials; state and local first responders; travelers to be screened; bystanders; and the general public. Therefore DHS must consider a much broader range of user dimensions, characteristics, abilities, and ages than those populations addressed by the existing standards. DHS operating environments are also very diverse, ranging from airports and border points of entry to subways and Coast Guard vessels.

Thus the existing standards may not be applicable based on differences in the populations and specific domains or context of use.

2.2 KEY CONCEPTS

This section provides definitions of three critical (and interrelated) concepts that are referenced throughout this document: Human Systems Integration, User-Centered Design, and Context of Use. These concepts help to bring the usability issues described in **Sec. 3** into sharper focus, and are foundational to the recommendations detailed in **Sec. 4**.

2.2.1 Human Systems Integration (HSI)

HSI emphasizes human considerations as the top priority in systems design/acquisition to reduce life cycle costs and optimize system performance [6]. Essentially, HSI is the relationship between humans and their environment – particularly how systems are designed and used relative to that relationship – with the goal of ensuring a safe and effective environment that meets the mission. As previously described, HSI includes the integration of hardware, software, and processes (including design and acquisition processes). In short, HSI is about improving the usability of technology. ISO defines usability 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" [2].

2.2.2 User-Centered Design (UCD)

UCD is a well-established design approach that concentrates on developing usable systems by focusing on the system users, their needs, and requirements. The approach applies principles of human factors and ergonomics, as well as usability knowledge and techniques. The goals of the UCD approach are to:

- Enhance effectiveness and efficiency
- Improve human well-being
- Increase user satisfaction
- Improve accessibility and sustainability
- Counteract possible adverse effects of use on human health, safety, and performance

There is a substantial body of knowledge in both human factors/ergonomics and usability demonstrating how user-centered design can be organized and applied effectively. In addition, UCD is supported by three sets of formal standards: ISO 9241-210, ISO/IEC TR 25060, and ISO/IEC 25062 (described in more detail in **Sec. 4.1.1**).

2.2.3 Context of Use

For purposes of this study, the elements in the context of use for a particular product (which can be a technology, system, device, piece of equipment, or process) include: the intended users, their goals and tasks, associated equipment, and the physical and social environment in which the product can be used.

Understanding the context of use for a particular technology requires asking the right questions. For example:

- Why is this technology being used? What task and/or process is it being used to accomplish?
- Who are the end users for this particular technology? What are the characteristics of the end user population (e.g., age, physical and mental capabilities, technical aptitude)?
- What are the characteristics of the technology itself? What are its component features? Is it fixed or portable?
- When is this technology used? What triggers the process/task the technology is used to carry out? At what point in the process/task is this technology used? How frequently is this technology used on an hourly, daily, monthly, etc. basis?
- Where is the technology used? Are there any environmental characteristics – such as dust, lighting conditions, or noise – that may impact the functioning or effectiveness of this technology?

The standards and guidelines described in **Sec. 4.1** provide more detailed instructions on how to study, and capture data about, context of use.

3 HSI GAPS WITHIN DHS

The recommendations in this document are based on usability issues discovered during Phase 2 of the project. In Phase 2, the NIST research team applied a UCD approach for the DHS organization in order to illustrate how existing HSI standards (identified in Phase 1) can be mapped to DHS needs, technology, and processes. Researchers identified core, high-impact processes performed by six different DHS directorates:

- U.S. Citizenship and Immigration Services (USCIS)
- Transportation and Security Administration (TSA)
- U.S. Coast Guard (USCG)
- Customs and Border Protection (CBP)
- U.S. Immigration and Customs Enforcement (ICE)
- Federal Emergency Management Agency (FEMA)

The research team identified, interviewed, and (when possible) directly observed end users who performed the tasks associated with those processes. The information collected during the interview process allowed the team to identify the feature sets (e.g., device interface characteristics) of the equipment used by end users, map those features to existing HSI standards, and begin to identify any gaps not addressed by those standards.

While it should be noted that Phase 2 was not an exhaustive gap analysis, the study results do highlight major areas of need for HSI standards and practices within the organization. Both general and specific areas of need uncovered during Phase 2 are described in the following subsections.

3.1 Interviewee Identified Challenges and Future Technology Needs

During the interviews conducted with end users in Phase 2, NIST researchers queried interviewees about issues they have with the technology or devices they use to carry out their tasks and their perceptions of future technology needs. This section summarizes some of the most critical issues and future technology needs mentioned by interviewees in Part 2. All of these issues form the primary basis for the larger systemic HSI gaps described in **Sec. 3.2**, as well as some of the recommendations provided in **Sec. 4**.

3.1.1 Environmental Factors Affecting Equipment

A common theme of issues highlighted by interviewees was that of equipment performance being negatively impacted by environmental factors. A number of interviewees said that fingerprint scanners need to be dust-resistant and/or easy to clean, since dust buildup presents a problem in both high-traffic indoor environments and outdoor environments.[1] In a similar vein, interviewees from multiple directorates said that ambient lighting conditions often negatively affect the performance of their cameras – specifically, their ability to take adequate facial photographs.

For the Coast Guard, environmental factors and their effects on equipment are a particularly acute problem. The conditions of the shipboard environment in which they work include sun glare, nighttime conditions, fog, extreme temperature differences, the possibility of fall damage, and limited space. Much of the equipment in their biometric capture kits was not designed with these conditions in mind, resulting in significant usability problems for Coast Guard end users.

The findings of the Part 2 study indicate that environmentally related usability problems are fairly widespread, and that the negative impact of such problems – collectively speaking, if not on an individual basis – is fairly significant. Resolving such problems in existing equipment may often be difficult and costly. However, DHS can proactively address environmentally related issues in new technologies by field-testing them in the environment of use before they are widely deployed (an approach actually recommended by some Phase 2 interviewees). This document covers testing in greater detail in **Sec. 4.1.2** and **Sec. 4.1.3**.

3.1.2 Software and Equipment Interfaces

Interviewees highlighted multiple issues related to software interfaces. ICE agents said that they must access multiple systems to enroll and/or check for detainee information (e.g., prior arrest records), and that it would be helpful to have a single, consolidated interface for this purpose instead. Similarly, Border Patrol agents said that they would prefer a more streamlined, easy-to-use interface for their software. Additionally, interviewees from both organizations said that more user-friendly software would help them minimize the time required to perform database

[1] This applies to other types of equipment as well, such as monitors and chemical detectors used by TSA agents.

queries and improve their task efficiency. It would also help them more rapidly identify potentially dangerous detainees, and thus reduce the risk to their safety.

Biometric interfaces were also a matter of concern for interviewees from the Coast Guard and CBP Air and Marine. End users from both organizations frequently collect biometric information from individuals with little or no proficiency in English, and the language barrier between the agents and these "secondary users" can delay or interfere with the biometrics collection process. Coast Guard interviewees suggested that symbol-driven or language-independent biometric devices could help address this issue.

DHS can build upon existing standards to improve its software interfaces, and could realize some significant benefits – gains in efficiency, reduction in errors, and (in some cases) improved user safety – by doing so. Developing more usable interfaces for biometric devices will be somewhat more difficult, since relevant standards do not yet exist. However, DHS has the potential to be a leader in this area: many of its end users are in a position to provide valuable input into a biometrics usability standards development effort.

3.1.3 Future Technology Needs

During interviews of DHS employees in Phase 2, interviewees discussed their needs for new technologies that they could use to help them perform their tasks more effectively. For example, users from USCIS and CPB Air and Marine said that they needed electronic options to replace largely paper-driven processes. Interviewees from CBP Air and Marine also said that they could use Biometrics on the Move technology to replace tasks that require them to direct passengers through the biometrics capture process, e.g., "stand here", "take off your hat", "move your hair" and so on.

Interviewees from other organizations saw considerable potential in advanced biometric technologies as well. Members of the Coast Guard said they wanted to use facial recognition technologies, which could help quickly identify dangerous individuals and reduce safety risks. ICE agents said that they need mobile technology and devices for processing detainees in the field (including biometric collection), which will facilitate rapid identification of repeat offenders and/or dangerous individuals.

As an organization, DHS has always been eager to embrace new technologies that can help it better carry out its mission. It may be beneficial to the organization to take a "bottom up" approach to technology acquisition – in other words, to adopt technologies that fulfill its users' most frequently expressed needs.

3.2 SYSTEMIC STANDARDS GAPS

The issues described in the previous section, along with the research team's observations, indicate certain critical systemic gaps in HSI technology and communications standards that DHS may wish to prioritize in its HSI standards development efforts. These are described in the following subsections.

3.2.1 DHS Software Applications and Interfaces

DHS application software packages are critical to many of the tasks performed by the end users interviewed in Phase 2. Some of the application types reported in that part of the study include real-time, client-server architectures, Web architectures, and mobile device applications.

The particular issues cited by interviewees from ICE and the Border Patrol point to a need for DHS to adopt interface and information presentation standards for real-time, non-local service applications. Some existing standards for websites, such as those found in ISO 9241, could be applied for this purpose. By employing interface standards to create apps that are more streamlined and customized for context of use, DHS could reduce the amount of time required to perform tasks and reduce the incidence of omissions and mistakes. Using these standards could also ensure the usability and utility of applications that might be used to replace largely paper-driven tasks (such as those performed by USCIS or CBP Air and Marine) in the future.

DHS has the opportunity to use cloud computing technologies to support an integrated data model for certain types of applications that are used by multiple directorates, e.g., those that collect or reference biometric identity data. Various views of the data could be provided to end users via applications that have been customized for their specific context of use – in other words, the computing platform they are using, their role, the task they are performing, and their access privileges. While this integrated data model would present clear advantages for DHS, implementing it would require significant effort.

While standards and best practices exist for interface design, these are limited and do not address cloud-based services. DHS may want to partner with an accredited standards development organization to fill these gaps. The issue of interface design standards also applies to mobile technologies, which are discussed in more detail in the following subsection.

3.2.2 Mobile Devices and Touch Interfaces

During Phase 2, interviewees from various directorates identified mobile technology (such as smartphones and tablet computers) as being critical to mission success in the future. In particular, Border Patrol and ICE officers said they need mobile technology that will allow them to process detainees in the field. Hand-held or mobile devices are already used in many directorates throughout DHS, such as the wand metal detectors used by TSA or mobile fingerprinting devices. All of these devices have some component or components not covered by the HSI standards identified in Phase 1.

While there are a number of existing HSI standards that address generic mobile device components (such as displays, touch inputs, and operating systems), there are few if any standards that address specific mobile device interface features such as touch screen active area

and size; display controls; separation of buttons or touch adjacent active areas for use with/without gloves; and display lighting that accommodates night or limited lighting conditions.

Another consideration is environmental conditions such as sun, rain, wind, or other elements, which can potentially impact the functionality of a mobile device. In addition, connectivity and response times for mobile devices can be impacted by use in the field. Long response times for database queries and lag time can subject field officers to undue risk when dealing with detainees (a concern raised by interviewees from ICE). Adopting and adhering to a threshold for acceptable response and/or lag time would increase the safety of the field officers.

Authentication on mobile devices can also be challenging given the size of the interface and input device, and while there are a variety of authentication options that can work with desktop or laptop computers relatively easily (e.g., card reader, fingerprints, retina scan, voice recognition, or facial recognition systems) there are fewer options available to facilitate authentication on small mobile displays and keyboards.

3.2.3 Biometrics

Since collecting biometric information is a critical part of many DHS processes – USCIS, USCG, CBP, and ICE all collect biometric information – standards regarding biometric collection and devices should be of particular importance to DHS. A significant challenge in this area is that, while standards do exist regarding biometrics, they fall short of addressing some of the considerations of biometrics collection at DHS.

One general issue is the usability of biometrics collection processes. Some of the end users interviewed during Phase 2 of the study said they found it difficult to capture facial images with cameras due to environmental conditions such as ambient light levels. To help ensure better-quality facial image captures, DHS should adopt standards that specify required components, capabilities, and features for cameras and the characteristics of the environment in which they are to be used. These standards should be dependent upon the context (for example, taking pictures at a customs station versus taking pictures aboard a Coast Guard cutter). Other types of biometrics collection factors may also require usability standards; for example, labeling, height, and angle specifications for electronic fingerprint scanners.[2]

Another issue is the multi-cultural population from whom DHS collects biometric information. A sizeable fraction of that population has little or no proficiency in English, which can significantly hinder the biometric collection tasks performed by various DHS directorates. One way to alleviate this problem is to use language-independent icons and graphics to represent concepts that will help individuals go through the biometric collection process. Such icons can reduce the need for translation of text to explain those same concepts. However, use of icons can be problematic when used cross-culturally in this way, so developing icons that will adequately

[2] Standards for usability in biometrics are being developed by the NIST M1.6 working group.

serve a multi-cultural population is a challenge. The International Standards Organization (ISO) JTC1/SC37/WG 6 develops icons for biometrics.

3.2.4 Accessibility

On a related note, DHS agents interact with different populations that may include individuals with some type of disability. Disabilities may include physical, sensory, or cognitive impairments as well as various types of chronic disease. These disabilities can impact an individual's ability to carry out routine activities, which include reading Web pages, using applications, and understanding instructions. Individuals with disabilities may also experience difficulties undergoing biometric collection processes.

The World Wide Web Consortium (W3c) and Section 508.gov address accessibility standards for website design and applications. However, DHS also needs to consider accessibility for disabled individuals who interact with other technology and devices used by DHS agents, including those that involve biometric collection. There may be a need for additional accessibility standards addressing those technologies and devices.

4 RECOMMENDED INTERIM STEPS

It is reasonable to expect that identifying or developing and applying standards to address the current major HSI gaps described above would be a multi-year effort. In addition, DHS must consider emerging technologies its end users are likely to use in the near future, such as those mentioned by Phase 2 interviewees (e.g., mobile devices, emerging web applications, tools to support automation of tasks). As the technology and processes used within DHS change, new HSI standards will be needed – which means that iterative reviews of both standards and organizational processes will also be needed.

This section provides some recommendations on actions DHS can take while the organization addresses the identified systemic standards gaps. These actions will help DHS establish a more HSI-oriented organizational culture, so that it can effectively deal not only with existing HSI and usability issues but proactively address any similar issues that may come up in the future.

4.1 INTEGRATE HSI INTO THE TECHNOLOGY ACQUISITION PROCESS

One of the major findings that emerged from the Phase 2 study is that DHS needs to explicitly address HSI and usability considerations in its acquisition process. In particular, DHS needs to perform user acceptance and usability testing on new technologies before they are deployed in the field. Making such testing standard practice could help DHS proactively identify and address a number of usability issues like those described in **Sec. 3.1**.

In particular, DHS should add language to its procurement contracts to address:

- Definition of context of use
- Usability testing as defined in ISO/IEC 25062 (see **Sec. 4.1.1**)

- Usability requirements as defined in NIST IR 7432: *Common Industry Specification for Usability* (see **Sec. 4.1.2**)
- User acceptance testing as defined in the NIST Handbook *Usability and Biometrics: Ensuring Successful Biometric Systems* (see **Sec. 4.1.3**)

This section presents helpful standards and guidelines (including those in the list above) for UCD-oriented technology acquisition processes, including the user acceptance and usability testing described earlier.

4.1.1 ISO Standards for UCD

UCD is supported by three sets of formal standards: ISO 9241-210, ISO/IEC TR 25060, and ISO/IEC 25062.

ISO 9241-210 provides requirements and recommendations for user-centered design principles and activities throughout the life cycle of computer-based interactive systems.

ISO/IEC TR 25060 describes a potential family of International Standards, named the Common Industry Formats (CIF), that document the specification and evaluation of the usability of interactive systems. The Technical Report focuses on documenting design and development elements of usable systems. It does not prescribe a specific process and is intended for use with ISO 9241 standards.

ISO/IEC 25062 standardizes the types of information captured with user testing. The level of detail allows the same or another organization to replicate the test procedure. Major variables include: user demographics, task descriptions, test context (including the equipment used, the testing environment, and the participant and test administrator's interaction protocol), and the metrics chosen to code the study findings. Advantages of using standardized reporting format include: (1) a reduction in training time for usability staff since an individual only needs to learn to use one form regardless of how many companies he works for and (2) enhanced potential for increased communication between vendors and purchasing organizations since readers of CIF-compliant reports will share a common language and expectations.

4.1.2 NIST Common Industry Specification for Usability – Requirements

NIST IR 7432: *Common Industry Specification for Usability – Requirements* (CISU-R) sets standards for specifying usability requirements, which include three types of information [4]:

- **The context of use**: the intended users, their goals and tasks, associated equipment, and the physical and social environment in which the product can be used.
- **Performance and satisfaction criteria**: measures of usability for the product.
- **The test method and context of testing**: the method to be used to test whether the usability requirements have been met and the context in which the measurements will be made.

More specifically, the CISU-R provides guidance and structure to support the following activities related to gathering and articulating usability requirements during software development projects:

- Document the context of use for a product, including definitions of the expected technical, physical, and social environments, user groups, goals for use of the product and scenarios of use.
- Write usability requirements in sufficient detail to make an effective contribution to design and development.
- Relate usability requirements to stakeholder requirements (including user, customer, and business) for successful use of a product and increased productivity.
- Define usability criteria that can be empirically validated.
- Define the method for testing the product against the criteria.
- Create requirements that are useful throughout the product design and development process, providing input to the design process early in a project and adding more detailed information about criteria and methods, as it is available.

The CISU-R complements and expands upon the ISO standards for UCD described in **Sec. 4.1.1**, so it is possible (but not necessary) to use it in conjunction with those standards. In this and other respects, it is designed to be flexible and accommodate any type of development process. It supports different levels of compliance so that it can "match the level of detail and formality of the usability requirements to business needs" in a given project [4]. It can also be applied to contractual relationships between organizations – particularly useful for DHS, which works with private-sector organizations to develop most of its technological solutions.

4.1.3 NIST Handbook on Usability and Biometrics

The NIST Handbook *Usability and Biometrics: Ensuring Successful Biometric Systems* details a UCD design methodology specifically for the development of biometric technologies [5]. It incorporates the ISO standards described in the previous section. The design process consists of four steps:

- Define the Context of Use
- Determine User and Organizational Requirements
- Develop the Design Solution
- Conduct the Evaluation

As **Fig. 1** below demonstrates, the latter three steps in the Handbook are best treated as a cycle. Evaluation should generate feedback that helps define new requirements and/or further elaborate existing ones. Changes to requirements spur changes in system design, and the modified system must be tested again.

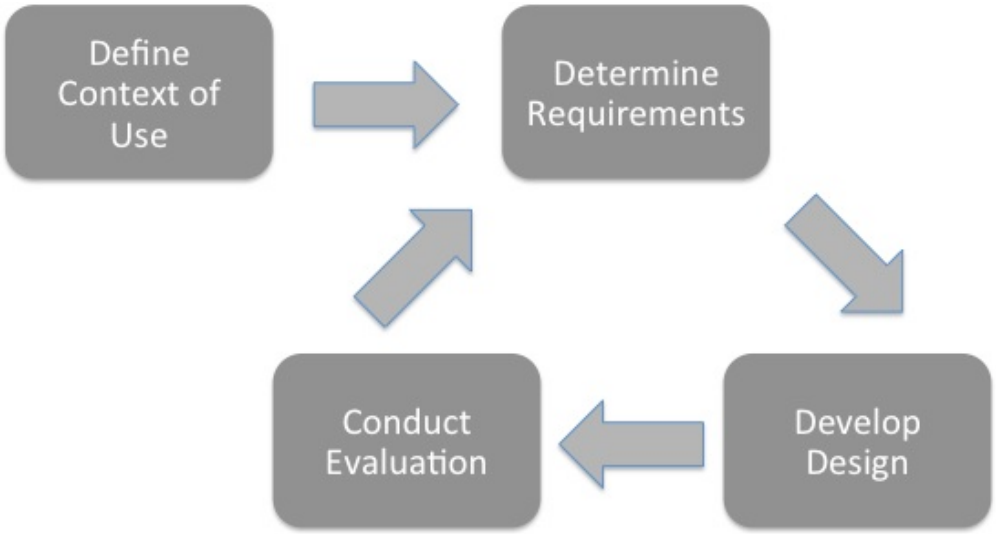

Figure 1: The NIST Usability and Biometrics Development Process

Step 1 is to Define the Context of Use. The *Usability and Biometrics* handbook provides guidance on how to conduct research with users in order to:

- Identify user populations (both primary and secondary)
- Capture user demographics
- Capture characteristics of the environment of use
- Explicitly define user goals and tasks

The output from Step 1 informs the two subsequent steps. In Step 2, Determine the User and Organizational Requirements (i.e., requirements analysis), information about context of use should form the basis of user, environmental/physical, and functional requirements. An example of each type of requirement is described in the list below:

- **User requirement:** Foreign nationals who have little or no English proficiency need a fingerprint scanner with a language-independent, symbol-driven interface to help guide them through the process.
- **Environmental/physical requirement:** Cameras used by members of the Coast Guard to capture facial photos of illegal aliens at sea must automatically adapt to ambient light levels, so that picture quality will not be impacted by low-light conditions or glare.
- **Functional Requirement:** Black lights used by TSA agents to check IDs should have a long battery life, be easily rechargeable, or both.

Step 3 is to Develop the Design Solution. For DHS this may mean *selecting* an available technology that best fills the requirements elaborated in Step 2. Regardless of whether the technological solution is designed or acquired, however, user demographics and goals captured in Step 1 should be used as the basis for interaction design, interface design, and any associated training materials. Also, DHS should not neglect secondary users, i.e., non-DHS employees who participate in DHS processes.

Step 4, Conduct the Evaluation, is where usability and user acceptance testing occurs. According to the handbook:

> *"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 at a much earlier stage." [5]*

There are two types of evaluation: qualitative and quantitative. Qualitative evaluation involves:

- Asking users about their expectation 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

Quantitative evaluation involves measuring the following:

- **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

A balanced approach combines both qualitative and quantitative evaluation. Generally, qualitative evaluation is appropriate for earlier stages of the design process, while quantitative evaluation is best applied during later stages. As indicated in **Fig. 1**, the cycle of evaluation, feedback, and modification should be repeated as many times as is practical.

In addition to outlining this four-step UCD process, the handbook contains detailed guidance on how to carry out the activities associated with each step.

4.2 EMPHASIZE HSI WITHIN THE ORGANIZATION

To effectively address its HSI and usability issues, DHS, like any organization, must first understand the context of use for the technologies it deploys in the field. The best way to do this is to use the study described in Part 2 as an "exemplar methodology": in other words, to use its approach and associated questionnaire as the basis for longer-term, more intensive UCD field studies. In particular, these studies should focus capturing any problems that end users have with the equipment they use to perform their tasks and the environment in which they do so.

Performing such UCD-based field studies is an excellent way to gather data on, and understand, the context of use for particular technologies, whether they are fingerprint scanners at U.S. ports of entry or cameras used on Coast Guard cutters. The context of use for a particular product (which can be a technology, system, device, piece of equipment, or process), as defined in **Sec. 2.2.3**, includes: the intended users, their goals and tasks, associated equipment, and the physical and social environment in which the product can be used.

For an organization like DHS, context of use is an important consideration. It is clear from the data collected during Phase 2 that end users in different directorates may perform broadly similar tasks. For example, five of the directorates' (i.e., USCIS, USCG, CBP, ICE, FEMA) end users use some type of camera as well as a fingerprint capture device. However, the context of use in which these tasks are performed may be very different. There is a significant difference between fingerprinting an applicant at a USCIS center and a (potentially dangerous) illegal alien at the border or at sea.

Also, many of the issues highlighted by interviewees in Phase 2 concerned ways in which tasks or equipment were compromised by the conditions of the working environment, i.e., the context of use. One example is fingerprint scanners: in certain environments, sun glare, moisture, or dust often affected the quality of captured fingerprints. A number of interviewees said that they encountered similar problems when using cameras to take photographs: certain environmental characteristics affected device functionality and/or picture quality. These kinds of problems result from mismatches between the equipment being used for a certain task and the context of use for that task. Thus, while theoretically it makes sense to use the same type of equipment (e.g., fingerprint scanner, camera) across the organization for similar or identical tasks performed by end users in different directorates, the reality is that different environments of use necessitate at least some degree of equipment customization.

Field studies like the one conducted in Part 2 should also include asking end users about the technology they currently use – in essence, whether it meets their requirements – and also about technology they would like to have, or anticipate having, in the near future (e.g., mobile devices, biometrics on the move). The subsequent findings can be used as the basis for a variety of HSI-related organizational efforts, including user requirements gathering and acceptance testing (as described in **Sec. 4.1.3**). DHS can also use such findings to more accurately predict, and proactively address, emerging technology- and usability-related needs.

5 CONCLUSION

DHS is very forward-thinking with respect to technology: the organization is always looking for new technology solutions to help it carry out its mission. But if DHS wants to maximize its return on investment in new technologies, it needs to expand its focus to include the people who use those technologies – both department agents and the populations they work with. In the end, technology is only as useful as it is usable.

As previously described, DHS can significantly improve the usability of its technologies by studying and understanding context of use; integrating UCD practices into its technology acquisition processes; and performing usability and user acceptance testing of new technologies before they are deployed. DHS can take these actions while applying existing HSI standards (detailed in Phase 1) to its currently deployed technologies and addressing the issues described by DHS end users. Making HSI and usability important considerations in the acquisition process will allow DHS to identify and mitigate potential usability issues before they create significant difficulties for end users out in the field.

By following UCD standards and best practices during the technology acquisition process, DHS can help its users complete their tasks more efficiently and effectively, with fewer adverse effects to their health and safety. Integrating HSI and usability into technology acquisition will also help DHS realize a greater return on its investments in new technologies, while pursuing new standards to address gaps identified in Phase 2.

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