Guidance on the Application of Human Factors to Consumer Products

ANNOTATED BIBLIOGRAPHY[1]

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A number of economic, legal, and technical factors provide the rationale for concern about product misuses. Legally, the term *product misuse* relates to the use of a product in a way not intended by the manufacturer, possibly resulting in personal injury or property damage. A second term, *foreseeability,* indicates that product misuses can be predicted and preventive actions taken. The article presents an objective method to predict, or foresee, potential product misuses and their potential for human injury or product damage so that product safety actions should be taken.

The article describes one such objective method. PROFORMIS (an acronym for "product foreseeable misuses") combines human cognitive prediction techniques and hazard analysis procedures into a method to predict (foresee) and evaluate product misuses. The method uses psychophysical scaling techniques to evaluate the likelihood of the occurrence and the severity (consequence) of foreseeable misuses. The manufacturer would review the list of potential misuses of the product and decide which misuses should be addressed by making safety changes to the product. Additionally, a manufacturer's use of an objective method to evaluate potential misuses can help protect the manufacturer during any legal actions resulting from misuse by providing the manufacturer with the legal position that a formal, systematic effort was used to foresee and address product misuses.

ASTM International, 2010: Standard practice for human systems integration program requirements for ships and marine systems, equipment, and facilities. *ASTM F1337-10*, ASTM, West Conshohocken, PA.

This Standard establishes and defines the processes and associated requirements for incorporating human systems integration (HSI) into all phases of government and commercial ship, offshore structure, and marine system and equipment acquisition life cycle. The goal is to fully integrate HSI with the engineering processes applied to the design, acquisition, and operations of marine systems. The intended audience for this Standard is individuals with HSI training and experience representing the procuring activity, contractor or vendor personnel with HSI experience, and engineers and management personnel familiar with HSI methods, processes, and objectives.

HSI takes a total system level view of design, acquisition, and operations. This system level view starts with the performance requirements of the total system that are translated into requirements for total system performance and total cost of ownership. The system performance and cost requirements then are integrated into the design by the application of HSI methods and processes to the design of the marine system. HSI continues as an integrated element of the operations and support activity as a mechanism to support training, maintenance, and identify system improvement opportunities. HSI relies on the individual technical HSI domains, but also the integration of these domains among themselves and with the other systems engineering and logistics requirements and processes. The domains of HSI must work in concert among themselves and with other systems engineering processes to address human design issues and trade-offs that optimize overall system performance and reduce life cycle costs.

Key objectives for HSI in the design of ships and marine systems are enhancement of human performance (the demonstrated capability of the intended user to operate, maintain, support, manage, and use the systems and equipment under all expected environmental and operational conditions), optimization of manpower (the determination of the number of personnel and skillsets required to perform the required missions, functions, or tasks successfully), reduction in training requirements (reduction of difficult to train skills through design), enhancement of safety and survivability (minimize the potential for mishaps causing death or injury to operators and maintainers or threaten the survival and/or operation of the system), and improvement in the quality of life

(living and working conditions which result in levels of personnel morale, safety, health and comfort, and fitness for duty adequate to sustain maximum personnel effectiveness). These key objectives are met through the application and integration of HSI within the systems engineering process throughout the life cycle of the system. This includes incorporating the feedback gained from lessons learned during design, development, build, and system operation into updates to HSI processes and requirements.

ASTM International, 2007: Standard guide for the integration of ergonomics/human factors into new occupational systems. *ASTM E2350-07*, ASTM, West Conshohocken, PA.

This Guide is intended to assist in the integration of ergonomic principles into the design and planning of new occupational systems from the earliest design stages through implementation. The proper integration of ergonomic principles may reduce or eliminate the necessity for later redesign that could have been foreseen and avoided. This Guide facilitates the integration of ergonomic principles into the design of occupational systems. The assumption is that there will be more than one iteration of the process, proceeding from the general and becoming more detailed with each iteration; the number of iterations will depend on the complexity of the process.

The evaluation begins by defining the essential qualities and quantities of the end product or service. After identifying the required physical and operational components, tasks are allocated to machines or workers. The jobs are then analyzed to determine if they exceed worker capabilities and limitations. Depending on the results of the analysis, the business outcome or jobs may be modified or action deferred to a later iteration. An operational audit evaluates the system as the design nears completion and identifies those issues either not considered or not apparent in previous stages. After the system is operational, periodic audits evaluate the effectiveness of the design.

Integrating ergonomic principles into new occupational systems may help organizations develop processes that do not exceed worker capabilities and limitations. Jobs and tasks that conform to worker capabilities and limitations may be performed more efficiently, safely, and consistently than those that do not. The integration of ergonomic principles at the earliest stages of process concept and design may facilitate appropriate design, layout, and allocation of resources and may reduce or eliminate the necessity for later redesign that could have been foreseen and avoided. Designing jobs that fit the capabilities of larger population segments may increase an organization's accessibility to the available labor pool. The integration of ergonomic principles into occupational systems may increase profit by lowering costs associated with preventable losses, injuries, and illnesses.

Australian Competition and Consumer Commission, 2010: Review of the Australian product safety recall system. *ACCC 05/10_41764*, Canberra, Australia.

This report is the culmination of a review conducted by the Australian Competition and Consumer Commission (ACCC) on the effectiveness of existing consumer product recall guidelines. Not only did the review examine the existing consumer product recalls system, but also looked at the regulators involved in the consumer product recall system oversight and the ways in which the risks associated with unsafe goods can be addressed by suppliers and regulators. While the review did not reveal significant problems with the system, it has enabled the ACCC to consider a number of product recall processes and practices which may improve the effectiveness of the system.

The overall average return rate of recalled goods, according to the ACCC, is just over 50 percent; however, the average return rates vary widely between different types of goods overseen by the different Commonwealth

regulators. This difference is attributed to a variety of factors such as the type of product being recalled, the communication methods used, the hazard posed by the product, and the level of intervention by regulators. The review found that some regulators encouraged industry to voluntarily address unsafe products and only intervened in the recall process if industry failed to adequately mitigate the risks, whereas others were more involved and actively managed the process from the outset. Analysis showed that the recall was more effective when the regulator actively managed and had a greater level of involvement in all aspects of the recall process.

The analysis of recall data also found that measuring recall effectiveness merely by the percentage of product returned does not provide a complete picture. Factors such as the communication method used to advertise the recall, the type of product being recalled, and the hazard posed by the product are also relevant considerations in evaluating recall effectiveness. The review identified four broad aspects of the recalls system that are influenced by differing levels of involvement; notification of the product recall to the relevant regulator(s), communication of the product recall to consumers, retrieval of the recalled product, and closure of the recall.

The report contains a number of findings and recommended actions which are targeted towards providing greater transparency and consistency in the actions taken by the ACCC and suppliers in relation to product recalls. Given that suppliers already have to comply with various forms of regulation, the recommendations are geared to be implemented through mechanisms that are already in place in order to ensure effective recalls with minimal costs to suppliers.

Baber, C. and Stanton, N. 2004: *Task analysis for error identification*, In The handbook of task analysis for human-computer interaction (edited by Diaper, D. and Stanton, N). Lawrence Erlbaum Associates Inc., Mahwah, NJ, 367-379.

Human error is a significant contributor to product failure. However, it is uncommon for designers to explicitly consider the potential for human error in the design of products. It is proposed that 'human error' arises as a consequence of the interaction between user and product, and that modeling this interaction can allow insight into possible error paths. Using a simple representation of product functioning, based on state-space diagrams, Task Analysis for Error Identification (TAFEI) indicates paths between states that are open to the user but which do not support the achievement of the user's goal; such paths are considered to be erroneous. From this perspective, one of the aims of product design is to minimize paths to error.

Product evaluation often involves user trials requiring a prototype to be available. While, the prototype need not be fully functioning, most of the major design decisions have already been made. This means that prototypes might already reflect significant design decisions and assumptions concerning *how* the user will interact with the product. The authors propose that an alternative approach is to perform an analytic evaluation of product concepts, i.e., to develop predictive models of user performance, and to use these models as a means of evaluating design ideas. In this manner, designs can be compared and evaluated prior to committing to a specific concept.

In any interaction, a product can be assumed to present a set of functions to the user, in the form of a system image. The user conceptualizes a representation of how the product works, possibly in terms of pairing features with functions. When there is a mismatch between the user's representation and the system image, then the user could make errors or become frustrated. The basis of TAFEI is the assumption that user-product interaction proceeds through a goal-oriented series of states, i.e., that each user action modifies that state of the product until the user has reached a specific goal. TAFEI has been designed to support designers in developing products with minimal potential for user error.

Baram, M. 2007: Liability and its influence on designing for product and process safety. *Safety Science*, 45 (1-2), 11-30.

The development of new products and industrial processes rely on various social controls to assure that technological advances do not pose unreasonable risks to health, safety, property, and the environment. These social controls can take the form of government regulation, private self-regulation, market forces, and tort liability doctrines. Social controls are expected to have preventive and corrective functions: to influence the design and preparation of new products and processes so they will not be harmful when they are used as intended; and if harmful after being put to use, to bring about corrective changes in order to reduce risks and prevent harm.

The article discusses four social controls for reducing risk. The first is the marketplace where industrial customers, household consumers, and other users choose among competing products which are similar in terms of function and cost and usually express preference for those products which can be used with less risk and regulatory burden. The second is self-regulation, but the credibility of self-regulation is diminished when harms occur, and is mistrusted by many because of its potential for bias, lack of transparency, and inadequate self-enforcement. The third is government regulation. The fourth is tort liability which empowers courts to impose liability on a company whose product caused harm.

Among the social controls, tort liability has gained prominence for several reasons. It can be applied to the broadest range of harm-causing products and processes; it can be quickly employed when new evidence emerges that a particular advance is injurious; it is capable of quickly causing economic loss for a company whose product or process is found to be harmful; and it is feared by companies and therefore has a preventive function that deters companies from disregarding risks when designing new products and processes.

The author challenges the common assumption that fear of tort liability causes companies to emphasize safety and minimize risk in the design and development of a new product or process. Given the unavailability of empirical data, the assumption comes from personal experience and case studies and holds that the fear is real but the influence is highly variable because tort liability is merely one of many factors considered in a company's business decision processes.

Berman, B. 1999: Planning for the inevitable product recall. *Business Horizons*, March-April 1999, 69-78.

A safety-related product recall which withdraws a product from the market is typically due to one of the following reasons: design flaw, production defect, new scientific information about the dangers from a product or material previously thought safe, accidental contamination, unforeseen misuse, or failure to comply with safety standards. Given the number of parts, processes, suppliers, types of consumers, and product uses encountered, the author notes that it is only a matter of time for any product manufacturer to be faced with a product recall. Both the direct and indirect costs associated with a product recall can be substantial, even crippling, for a company. The author provides recall examples to illustrate the reasons for recalls as well as the cost impacts.

In developing a product recall approach, the author suggests that companies need to incorporate strategies and activities before the recall, during the recall, and after a recall. Before a recall, companies must take an active approach to reduce the chances of having a recall and minimize the resultant negative impact. Appropriate activities for this period include designating responsibility for handling a product recall, instituting safety planning, developing effective communication channels, and designing effective product and customer databases. During a recall, certain strategies can be employed to enable a company to implement a product recall more effectively. These include conducting a comprehensive safety analysis, estimating the product recall budget, informing

intermediaries and final consumers, recovering the recalled product, and developing procedures to ensure that recalled products can be repaired or replaced in a timely manner. After a recall is completed, important activities include monitoring the effectiveness of the recall and restoring the company's reputation.

Chamorro-Koc, M., Popovic, V. and Emmison, M. 2008: Using visual representation of concepts to explore users and designers' concepts of everyday products. *Design Studies*, 29 (2), 142-159.

Enhancing the design of user-product interactions prompted the emergence of research that supports designers' engagement with users' experience as an essential component of the design process. One such study focuses on investigating the influence of human experience on users' and designers' differing concepts of products. The article introduces this study's methodological approach, which employs visual representations of concepts to uncover the experiential and contextual component of people's understanding of product use. Findings are presented in the form of design principles that aim to assist the design of product usability by informing designers about the specific aspects of human experience that trigger people's understanding of products and product usage.

The authors note that addressing the users' needs and designing to enhance the user-product interaction are core activities in product design. Product usability is the dimension of the user-product interaction that is affected by the user's experience and the product's context-of-use.

Chiang, W-C., Pennathur, A., and Mital, A. 2001: Designing and manufacturing consumer products for functionality: A literature review of current function definitions and design support tools. *Integrated Manufacturing Systems*, 12 (6), 430-448.

This article examines the product design and manufacturing literature to understand why consumer products of daily use often fail to provide the intended function to users' satisfaction. There are numerous products that are marketed as being sophisticated in terms of features they provide consumers, but routinely fail to perform the intended functions, or do so in a very unsatisfactory manner. The review shows that the bulk of published literature addressing functionality deals with mechanical systems design, and there are issues that directly affect the consumer that are yet to be accommodated in current research. The literature also reveals that very few of the product design support systems have been tested on real design cases, or have been developed and tested using real designers in manufacturing environments. There is relatively little that has been done to develop tools to evaluate alternative design solutions. It is apparent from this review that the main research focus has been on providing function, rather than on ensuring function in a product that is eventually manufactured.

Committee on Human-System Design Support for Changing Technology, 2007: Pew, R. W. and Mavor, A. S. (Eds.), *Human-system integration in the system development process: A new look*. Washington, DC: National Academies Press.

For years, people have had difficulties with many consumer products, such as cell phones and video recorders. At quite a different level of scale and consequence of the disconnect between people and technology are the major large-scale systems accidents for which human error was a major contributor (e.g., Three Mile Island and Chernobyl). The committee notes that a major, expensive console update to the nation's air traffic control operations was cancelled because the operational personnel concluded that it would be too complicated and difficult to operate. The pressures on industry and government rises as the complexity of the systems they seek to develop increase while at the same time they are challenged to shorten the development cycle for those systems. These problems are magnified by the increasing use of a systems of systems approach (when a collection of

different systems, originally designed for their own purposes, are combined to produce a very large system with new issues and challenges). These problems can be traced to a significant challenge—that human capabilities and limitations must be considered early and throughout system design and development.

To address these challenges, several U.S. Department of Defense laboratories asked the National Academies, through its Committee on Human Factors, to undertake a study of the current state of methods, tools, and approaches for analyzing human capabilities and needs and to develop a vision for creating an integrated, multidisciplinary, generalizable, human-system design methodology. The Committee on Human-System Design Support for Changing Technology was tasked to address this request. The Committee identified five principles that are critical to the success of human-intensive system development and evolution: (1) satisfying the requirements of the system stakeholders—the buyers, developers, and users; (2) incremental growth of system definition and stakeholder commitment; (3) iterative system definition and development; (4) concurrent system definition and development; and (5) management of project risk.

After analysis of several candidate system development models in terms of the five principles, the committee proposed the incremental commitment model as a useful systems engineering approach and as a framework for examining categories of methodologies and tools that provide information about the environment, the organization, the work, and the human at each stage of the design process. A central focus of the model is the progressive reduction of risk through the full life-cycle of system development in order to produce a cost-effective system that meets the needs of all the stakeholders. When trade-offs among cost, schedule, performance, and capabilities are not well understood, the model provides a framework to specify priorities and ranges of satisfactory performance. The incremental commitment model has five life-cycle development phases: exploration, valuation, architecting, development, and operation. In each phase, every activity must be considered. The specific level of the effort on each activity is risk-driven and thus varies across life-cycle phases and from project to project.

The committee concludes that a model such as the incremental commitment model that incorporates the five principles can provide a significant improvement in the design of major systems, particularly with regard to human-system integration. The committee also made five recommendations.

a. Organizations should refine and coordinate the definition and adoption of a system development process that incorporates the principles embodied in the incremental commitment model.

b. Organizations should revise current system acquisition policies and standards to enable incremental, evolutionary, capabilities-based system acquisition that includes human-systems integration (HSI) requirements and uses risk-driven levels of requirements detail.

c. Organizations should put the operational requirements of HSI on a par with traditional engineering requirements to determine which requirements have priority and provide an opportunity for negotiation.

d. When developing system acquisition programs, organizations should define potential means for verifying and validating HSI requirements in order to establish clearly specifiable HSI technical performance measures.

e. Organizations should account for HSI considerations in developing the technical, cost, and schedule parameters in the business offer.

Consumer Product Safety Commission, 2006: *Handbook for manufacturing safer consumer products*. CPSC, Bethesda, MD.

Manufacturers must assure the safety of consumer products. This is achieved through the design, production, and distribution of the products they manufacture. It is best accomplished by a comprehensive systems approach to

product safety, which includes every step from the creation of a product design to the ultimate use of the product by the consumer. This Handbook discusses the basic concepts for a comprehensive systems approach for the design, production, and distribution of consumer products. The underlying premise of the Handbook is that safety must be designed into and built into consumer products. The Handbook identifies the elements of a comprehensive system approach to manufacturing safe products.

The Handbook cites a Congressional report that found that (1) an unacceptable number of consumer products which present unreasonable risks of injury are distributed in commerce; (2) complexities of consumer products and the diverse nature and abilities of consumers using them frequently result in an inability of users to anticipate risks and to safeguard themselves adequately; and (3) the public should be protected against unreasonable risks of injury associated with consumer products. While there is ample data demonstrating the magnitude of the product safety problem, there is far less data for isolating the root causes of product-related safety hazards. Conventionally, the causes of product safety hazards are classified as man-related, environmental, and product-related. But irrespective of root causes, it can be said that manufacturers have the greatest potential for reducing hazards. Manufacturers' potential for reducing product defects that raise consumer safety concerns exists in their capability to design and fabricate products that take account of human and environmental factors.

The Handbook identifies the essential elements of industrial systems for manufacturing safe consumer products. It is concerned with "what" not "how." The practices identified in the Handbook are voluntary; however, they serve the interests of manufacturers as well as consumers. The substance of the Handbook reflects the premises that:

a. The safety of a product depends upon many factors, including building safety into the product design. The circumstances under which products are used or misused by consumers is another factor. The ability of manufacturers to recognize and anticipate these factors is central to the effective design and production of safe products.

b. There are basic principles for manufacturing safe consumer products applicable to industry generally, despite the scope and diversity of manufacturing. The application of these principles must be commensurate with the character of the product, which includes the product's complexity and intended use.

c. Systems already exist in industry to assure quality, reliability, and other product characteristics. Such systems ordinarily encompass many of the provisions of this Handbook. For many manufacturers, therefore, it is not necessary to create a new system to implement practices in this Handbook; existing systems can be readily augmented.

Department of Defense, 2011: Human engineering requirements for military systems, equipment, and facilities. *MIL-STD-46855A*. DoD, Washington, DC.

MIL-STD-46855 is the primary tasking document used by the services to specify human engineering efforts during system acquisition. It supports the human factors engineering discipline independently or as a part of Human System Integration initiatives. MIL-STD-46855 is also written to accommodate a wide range of products, including small equipment items as well as major systems. This standard intentionally provides reasonable latitude for performing organizations to apply technical and program judgment and innovation consistent with specific procurements.

This standard establishes and defines the requirements for applying human engineering to the design, development, and acquisition of military systems, equipment, and facilities. These requirements include the work to be accomplished in conducting a human engineering effort integrated with the total system engineering and

development effort. These requirements are the basis for including human engineering in proposals; user interfaces; system and facility analysis, design and test; and documentation and reporting.

In accordance with Department of Defense principles, directives and regulations governing the application and tailoring of specifications and standards to achieve cost effective acquisition and lifecycle ownership of defense materiel, this Standard should be tailored to specific programs and the milestone phase of the program within the overall lifecycle. This tailoring should selectively apply methods, tables, sections, individual paragraphs, or sentences, or a combination thereof, to be placed on contract in order to impose essential human engineering requirements, consistent with avoiding unnecessary program costs.

Department of Homeland Security, 2012: *DHS Human systems integration (HSI): The human systems integration (HSI) process for the S&T and acquisition program manager*. DHS, Washington, DC.

For the complex, high-impact, technology-based, manpower-limited homeland security systems of the 21st century, nothing more profoundly determines whether a mission will succeed than human performance. Human performance is the demonstrated capability of the human user to operate, control, maintain, support, manage, and use the system's components under all expected conditions, including operational, environmental, and tactical. Effective performance of these systems is usually a direct function of the capabilities of the human in making accurate decisions, understanding the situation, interacting with automation, and acting decisively in collaboration with other units to execute the mission. The discipline directed at addressing human performance in complex systems is human systems integration (HSI).

This document describes the process for applying HSI in each stage of the DHS acquisition process. It is intended for program management personnel who are not deeply familiar with HSI. HSI aims to influence how systems are designed by setting human performance requirements. To succeed in a meaningful way, HSI must be addressed as early as possible in the acquisition process. Typically, HSI begins in earnest at the very inception of the system need, in the pre-acquisition phase, when the capability requirements are being discussed. By embedding HSI into system development from the outset, developers can ensure that the human component and other system components are well integrated. But sometimes even that is not early enough. Increasingly, agencies look to technology to streamline acquisition and deploy systems more quickly. This means that addressing HSI must take on greater emphasis in technology development.

HSI must be emphasized early, when technology is being developed by the DHS Science and Technology Directorate (S&T). It also must be emphasized later, when a system is being developed and acquired by a DHS component. After all, the technology's ultimate purpose is to extend and expand on human performance capabilities. As the name suggests, HSI ensures that the human component of the system will be fully integrated with other system elements – with its hardware, software, firmware, webware, courseware, information, procedures, policy and doctrine, documentation, design features, technology, environments, organizations, and other humans. HSI is primarily concerned with designing the system or technology in a way that will ensure that the required levels of human performance will become part of the acquisition or development strategy. HSI looks at human performance across seven dimensions: human capability, proficiency, human utilization, accommodation, survivability, health, and personnel safety.

DHS S&T understands that its R&D efforts must add value to operating components by solving critical needs. The major way of accomplishing this is by making technology more efficient and more effective. The point of most technologies is to extend and augment people's capabilities. The need for HSI in systems acquisition is also evidenced by the constant need to reduce life cycle costs. The cost of selecting and training a system's operators, maintainers, and support personnel accounts for over 60 percent of life cycle costs. When HSI is applied to the

development of DHS technology and the acquisition of DHS systems, the deployed systems and technologies are more usable, affordable, supportable, reliable, and acceptable.

Department of Homeland Security, 2012: *DHS Human systems integration (HSI): The human systems integration (HSI) process for the HSI practitioner*. DHS, Washington, DC.

This document describes how to apply human systems integration (HSI) to each stage of the DHS acquisition process. Unlike the previous document which was intended for program managers, this document is intended for HSI practitioners who support DHS system acquisition, DHS components, and technology development in the DHS Science and Technology Directorate.

HSI is primarily concerned with design to ensure required levels of human performance are incorporated into the acquisition strategy. Addressing the various dimensions of human performance leads to the seven domains of HSI, which include: manpower (quantity and quality of personnel required); personnel (requirements for recruiting, retaining, assigning, and supporting personnel in career advancement); training (requirements and techniques for delivering needed knowledge, skills and abilities to the human); human factors engineering (requirements, concepts and criteria for design of user interfaces in accordance with the capabilities and limitations of the human); habitability (requirements for providing an adequate quality of life); personnel survivability (requirements for human protection and safeguards); and safety and health (requirements to reduce hazards to human safety and health). HSI is directed at improving the efficiency and effectiveness of systems by addressing human requirements in the design and use of the system. The dimensions of technologies or systems to be improved through the application of HSI include:

a. Usability – information is integrated, displays are understandable, controls and displays are integrated and compatible, labels are readable, decision aids are provided, awareness of the situation is maintained, automation interfaces are clear, procedures are consistent, and communications are intelligible.

b. Reliability – potential and consequences of human errors are identified, predicted and reduced; tolerance of errors is enhanced.

c. Supportability – human performance is addressed in the design for maintainability, and for supply and support.

d. Safety and survivability – hazards are eliminated or guarded (e.g., alarms, warning labels).

e. Affordability – costs associated with system/technology redesign, manpower, training, human support, errors and accidents are reduced.

f. Acceptability – the system or technology is accepted by users, by other persons affected by its use, and by the general public.

European Railway Agency, 2013: Application guide for the design and implementation of a Railway Safety Management System – Integrating human factors in SMS. *ERA/GUI/10-2013/SAF V1.0*. ERA, Valenciennes, France

There are other good reasons for implementing and delivering an effective safety management system (SMS). It has been recognized that structured management systems add value to business helping to improve overall performances, introduce operational efficiencies, enhance relations with customers and regulatory authorities, and build a positive safety culture. It should be clear that the SMS does not tend to harmonize the structures of the companies but their reference documents (mainly procedures) that illustrate how they are organized and how

they manage risks. The SMS should enable the company to 'write what they do' and doing so it should be possible to proactively revise their organization, reflect on their experience, and plan for the future.

This document is the first step in developing guidance to help railway companies systematically integrate human factors into their SMS and the overall risk management processes. The basic concept of this guidance is that the systematic integration of the human factors into the SMS should go beyond compliance with regulations and directives; it should be a conscious choice of the companies. Such an integrations of human factors and SMS yield the following benefits: improve staff well-being; improve staff effectiveness; ensure that staff can perform their tasks within the process of continuous improvement of the safety performance leading to fewer accidents; facilitate the appropriate allocation of human resources; contribute to establishing, maintaining, and improving the safety culture within the organization; improve the effectiveness of the training process; decrease costs from redesigning activities; and provide input to improve the safety performance and the resultant effectiveness of the SMS.

Federal Aviation Administration, 2009: Requirements for a human factors program. *HF-STD-004*. FAA, Washington, DC.

HF-STD-004 establishes and defines the requirements for applying human factors to systems, equipment (hardware and software), and facilities developed for, and acquired by, the Federal Aviation Administration (FAA). The Standard is written to accommodate a wide range of products, including commercial-off-the-shelf (COTS) and non-developmental items (NDI) as well as developmental systems. The Standard intentionally provides reasonable latitude to apply technical and programmatic judgment and innovation consistent with the nature, size, complexity, and level of human involvement associated with specific acquisitions.

The application of human factors should be viewed in the context of the total system concept in which the operator, maintainer, and operating environment are integral components of the system. When human factors is applied early in the acquisition lifecycle, it enhances the probability of increased performance, safety, and productivity; decreased lifecycle staffing and training costs; and becomes well-integrated into the program's strategy, planning, cost and schedule baselines, and technical trade-offs. Specifically, the application of human factors is intended to ensure that:

a. System requirements are achieved by appropriate consideration of the human component;

b. Through proper design of hardware, software, and environment, the personnel-hardware-software combination meets system performance goals;

c. Design features will not constitute a hazard to personnel, and will neither contribute to nor induce human error during system operations and maintenance;

d. Procedures for operating and maintaining systems are efficient, reliable, and safe; and

e. The layout of the facility and the arrangement of equipment provides efficient access by personnel and effective communication among team members.

Food and Drug Administration, 2016: *Applying human factors and usability engineering to medical devices*. FDA, Rockville, MD.

This guidance document was developed by the Food and Drug Administration (FDA) to assist industry in following appropriate human factors and usability engineering processes to maximize the likelihood that new medical devices will be safe and effective for the intended users, uses, and use environments. The recommendations in this

guidance document are intended to support manufacturers in improving the design of devices to minimize potential use errors and resulting harm. The recommendations contained in this document will enable manufacturers to assess and reduce risks associated with medical device use.

This guidance recommends that manufacturers follow human factors or usability engineering processes during the development of new medical devices, focusing specifically on the user interface, where the user interface includes all points of interaction between the product and the user(s) including elements such as displays, controls, packaging, product labels, and instructions for use. While following these processes can be beneficial for optimizing user interfaces in other respects, the FDA is primarily concerned that devices are safe and effective for the intended users, uses, and use environments. The goal is to ensure that the device user interface has been designed such that use errors that occur during use of the device that could cause harm or degrade medical treatment are either eliminated or reduced to the extent possible.

As part of their design controls, manufacturers typically conduct a risk analysis that includes the risks associated with device use and the measures implemented to reduce those risks. In this case, risk is the combination of the probability of occurrence of harm and the severity of the potential harm. However, because probability is very difficult to determine for use errors, and in fact many use errors cannot be anticipated until device use is simulated and observed, the severity of the potential harm is more meaningful for determining the need to eliminate (design out) or reduce resulting harm. If the results of risk analysis indicate that use errors could cause serious harm to the patient or the device user, then the manufacturer should apply appropriate human factors or usability engineering processes according to this guidance document.

Human factors testing is considered a valuable component of product development for medical devices. It is recommended that manufacturers consider human factors testing for medical devices as a part of a robust design control subsystem. For those devices where an analysis of risk indicates that users performing tasks incorrectly or failing to perform tasks could result in serious harm, it is recommended that manufacturers submit human factors data in their premarket submissions. The advantages of optimizing device design through application of human factors engineering extend beyond improved safety. Many device manufacturers have found that the application of human factors engineering during the development of their products reduces the need for design modifications and costly updates after market introduction and offers competitive advantages. With increased safety, the likelihood of incurring expenses associated with product recalls or liability is reduced; and when human factors engineering approaches are used during the design development process, particularly if the perspective of users is taken into account, the overall ease of use and appeal of a device can simultaneously be enhanced.

Furman, S., Theofanos, M. and Wald, H., 2012: *Human engineering design criteria standards, Part 1: Project introduction and existing standards*. National Institute of Standards and Technology, Gaithersburg, MD.

The Department of Homeland Security (DHS) was seeking 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 this project was to identify, develop, and apply a standard process to enhance technology and system design, system safety, and operational efficiency. The goal of this first phase was to identify and review the body of existing human factors and HSI standards, best practices, and guidelines. Future phases will map the standards to DHS needs, technology, and processes and identify where DHS may need to augment existing standards and/or create new HSI standards to meet organizational needs. DHS partnered with the National Institute of Standards and Technology (NIST) Visualization and Usability Group (VUG). 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, while remaining objective and vendor-neutral for

organizations and users in industry, academia, government, and other sectors. VUG, part of the NIST Information Technology Laboratory, conducts research in HSI and human-computer interaction technologies.

NIST's work on this project consisted of:

a. Identifying and reviewing the body of publicly available existing human factors and HSI standards, best practices, and guidelines for applicability to DHS.

b. Applying 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.

c. Determining where DHS may need to augment existing HSI standards and/or create new DHS HSI standards to meet organizational needs.

HSI design criteria, principles, and practices will benefit DHS by improving performance of personnel; reducing skill and personnel requirements; reducing training time; enhancing the usability, safety, acceptability, and affordability of technology and system; and achieving the required reliability and productivity of personnel-equipment combinations. More importantly for DHS, design criteria standards will foster design standardization and interoperability within and among DHS systems. Although numerous Federal standards exist that establish general HSI and human engineering criteria for design and development of systems, equipment, and facilities, 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.

Government Electronics and Information Technology Association, 2013: Human engineering – principles and practices. *HEB1-B*. GEIA, Arlington, VA.

This Engineering Bulletin and its annexes provide guidance on the application of human engineering principles and practices to the analysis, design, development, testing, fielding, support, accident investigation, and training for military and commercial products throughout their intended life cycles. Its purpose is to provide a human engineering best practices document in support of the Department of Defense's acquisition reform. Human engineering should be applied during pre-development, development, and acquisition of commercial and military systems, equipment, and facilities to integrate humans effectively into the design of the system in order to:

a. Develop or improve all human interfaces of the system;

b. Achieve required effectiveness of human performance during system operation, maintenance, support, control, and transport;

c. Make economical demands upon personnel resources, skills, training, and costs;

d. Improve human performance to maximize system performance; and

e. Effect safe, efficient life support, escape, and search and recovery of personnel.

Hale, A., Kirwan, B. and Kjellen, U. 2007: Safe by design – where are we now? *Safety Science*, 45 (1-2), 305-327.

This article reviews and discusses the findings of other papers in this special issue on safety and identifies lessons to be learned by designers, safety specialists and researchers. The article examines the questions posed in the editorial and groups them under design as an important contributor to operational safety, the general principles of the design process, the dilemmas facing designers, or the help which can assist them in their work. The article ends with a summary of the current gaps in the knowledge of the design process and its contribution to safety. These are prime areas for more research to study them.

Other papers in this special issue are written from the point of view of the safety and human factors experts working to increase the attention paid to safety issues in the design stage. Only a few are written from the point of view of the designer or design team, the people who ultimately have to carry out the task of achieving improvements. However, the authors believe that a clear picture emerges which can form the basis for designers to achieve a more systematic approach to inherently safe design.

An issue on which there was no clear agreement is what is covered by the design process – where does it start and when does it end? Does it include the initial choice of the high level concept for satisfying the system objectives, or does the design process only start once this has been specified and is being worked out? As an example, the authors uses the design of oil and gas installations, in which it makes no sense for the detailed design contractor to question the high level choices that led the customer (oil company) to the specified installation over that of another type of installation. The boundary question can also be reflected at the other end of the design process. In aviation, for example, the operating procedures for a plane are considered as part of the design. Errors in this aspect of design, related to procedures development, should therefore be considered design errors. There is no simple solution to this issue of defining the boundary of design. The definition depends on the context and the purpose for which it is being made.

Health and Safety Executive, 2009: Reducing error and influencing behaviour. *HSE Books ISBN 9780717624522*, HSE, Merseyside, United Kingdom.

The guidance provided in this document is aimed at managers with health and safety responsibilities, health and safety professionals, and employee safety representatives. The gist is that proper consideration of 'human factors' is a key ingredient of effective health and safety management. Human factors is a broad and diverse field which many organizations view as being too complex, too difficult, or too costly to do anything about. This guidance aims to overcome such notions by providing practical help on how to tackle some of the important issues. The guidance contained in this document explains how human error and behavior can impact on health and safety; shows how human behavior and other factors in the workplace can affect the physical and mental health of workers; provides practical ideas on what can be done to identify, assess and control risks arising from the human factor; and provides illustrative case studies to show how other organizations have tackled different human problems.

The individual chapters provide an introduction to human factors; look at types of human failures, their causes, and ways of reducing them; explore improvements to health and safety at work through better design of tasks, equipment, procedures, and warnings; look at some key operational issues; provide hints on how to get started; and present case studies which illustrate practical cost-effective solutions to real human factors problems. Some of the approaches shown in this guidance represent 'good practice' rather than what is strictly required by legislation. While the guidance cannot cover every aspect of human factors, it introduces some key influences on human behavior and work performance which need to be included in a health and safety management system.

International Organization for Standardization, 2016: The human-centred organisation – rationale and general principles. *ISO 27500: 2016*. ISO, Geneva, Switzerland.

This Standard describes the values and beliefs that make an organization human-centred, the significant business benefits that can be achieved, what policies are needed to put in place, and the risks for the organization of not being human-centred. The Standard sets out high-level human-centred principles, to optimize performance, minimize human-based risk, maximize well-being in their organization, and enhance relationships with customers.

Improving human well-being and total system performance through applying a human-centred approach is a key objective of ergonomics. There are a number of ergonomics and human factors standards that describe the general ergonomics approach and specifies basic ergonomics principles and concepts. These principles and concepts are applicable to the design and evaluation of tasks, jobs, products, tools, equipment, systems, organizations, services, facilities and environments. These principles and concepts can be used by organizations in selecting and designing systems and equipment to ensure that they are effective, efficient, and safe to use.

This Standard is aimed specifically at executive board members and explains the seven principles which characterize a human-centred organization:

a. Turn individual differences into an organizational strength;

b. Make usability and accessibility strategic business objectives;

c. Adopt a systems approach;

d. Ensure health, safety and well-being are business priorities;

e. Value employees and create a meaningful work environment;

f. Openness; and

g. Social responsibility.

International Organization for Standardization, 2015: Safety aspects – guidelines for child safety in standards and other specifications. *Guide 50*. ISO, Geneva, Switzerland.

Preventing injuries is a shared responsibility. The challenge is to develop products and manufactured articles which minimize the potential for causing deaths or serious injuries to children. A significant aspect of this challenge is to balance safety with the need of children to explore a stimulating environment and learn. Injury prevention can be addressed through design, engineering, manufacturing controls, legislation, education and raising awareness.

This Guide provides guidance to those developing standards, specifications and similar publications. It aims to address potential sources of bodily harm to children from products that they use, or with which they are likely to come into contact, even if not specifically intended for children. It contains important information that can be useful as background information for designers, architects, manufacturers, service providers, educators, communicators, and policy makers.

This Guide provides additional information to ISO/IEC Guide 51. Whereas ISO/IEC Guide 51 provides a structured approach to risk reduction within a general safety context, this Guide focuses on the relationships between child development and harm from unintentional injury, and provides advice on addressing hazards that children might encounter. This Guide describes a general approach to child safety, including the principles for a systematic way to address hazards; describes hazards to which children might be exposed during their use of, or interaction with, a

product, along with specific suggestions for addressing those hazards; and describes a structured means of considering the adequacy of safeguards. In addition, the Guide contains a checklist for assessing a standard. It provides an overview of hazards, potential injuries and structured approaches to solutions and lists some information on injury databases.

International Organization for Standardization, 2014: Safety aspects – guidelines for their inclusion in standards. *Guide 51*. ISO, Geneva, Switzerland.

This Guide provides requirements and recommendations for the drafters of standards for the inclusion of safety aspects in standards. It is applicable to any safety aspect related to people, property, or the environment, or to a combination of these. The underlying principles of this Guide can also be used wherever safety aspects require consideration, and as a useful reference for designers, manufacturers, service providers, policy makers, and regulators.

Work on standards deals with safety aspects in many different forms across a wide range of technologies and for most products, processes, services, and systems. The increasing complexity of products and systems entering the market makes it necessary to place a high priority on consideration of safety aspects. Hazards can pose different safety problems and can vary significantly depending on the end user of a product or system, including the environment in which a product or system is used. Whereas it is possible to control risks to a greater extent in the workplace, this might not be the situation in the home environment or when vulnerable consumers use the product or system. Consequently, this Guide might need to be supplemented by other publications for particular fields of interest.

This Guide aims to reduce the risk arising from the design, production, distribution, use, and disposal of products or systems. The complete life cycle of a product or system (including both the intended use and the reasonably foreseeable misuse) is considered, whether the product or system is intended to be used in the workplace, in the household environment, or for recreational activities. The goal is to achieve tolerable risk for people, property and the environment, and to minimize adverse effects on the environment.

International Organization for Standardization, 2013: Consumer product safety – Guidelines for suppliers. *ISO 10377: 2013*. ISO, Geneva, Switzerland.

This International Standard provides practical guidance to suppliers to assist them in assessing and managing the safety of the consumer products they supply throughout the products' life cycle; from the initial design, to production, to distribution, to retail, and to the final product end-user and disposal. This International Standard is also beneficial to many smaller and medium-sized companies and suppliers that do not design or produce products, but are still responsible for their safety. A number of governments have established laws and requirements for suppliers regarding the safety of the products they bring to the marketplace. However, many suppliers have limited experience and few resources, including practical documentation, to guide them through the process of assessing and managing risk.

The supply chain for consumer products is made up of a number of suppliers, often in different parts of the world, where products or components are being designed, produced, and sold in other countries. Therefore, it is important that the guidance provided is aligned with international best practice; easy to understand and applied consistently by suppliers.

The overall objective of this International Standard is to help produce safer consumer products thereby reducing the product safety risks to consumers, reducing the risks to suppliers of product recalls, providing consumers with

the needed information in order to make informed choices with respect to the safe use and disposal of consumer products, and assisting regulatory bodies by improving the safety of consumer products.

International Organization for Standardization, 2012: Instructions for use of products by consumers. *Guide 37*. ISO, Geneva, Switzerland.

Instructions for use are the means of conveying information to the user on how to use products and services in a correct and safe manner. The use of text; words; graphical symbols; diagrams; illustrations; and audible, visible, or tactile information are all means of communication. The instructions for use can be on the product itself or its packaging or in accompanying material.

This Guide offers guidance in the form of general principles and detailed recommendations on the design and formulation of all types of instructions necessary or helpful to the final user of consumer products. The Guide can be used in conjunction with the requirements of specific product standards or, where no such standards exist, with the relevant requirements for similar products.

The Guide takes into account the many research studies into the effectiveness of product instructions and warning labels, which vary a great deal in the degree to which consumers read, notice, and comply with them. The effectiveness of instructions in preventing harm can never be assumed to be as high as supervised training or designing the product to be fail-safe. The aim of this Guide is to help convey necessary knowledge to the end users of consumer products, and to facilitate understanding and use of instructions.

International Organization for Standardization, 2011: Ergonomics – general approach, principles and concepts. *ISO 26800: 2011*. ISO, Geneva, Switzerland.

This International Standard presents the general ergonomics approach and specifies basic ergonomics principles and concepts which are applicable to the design and evaluation of tasks, jobs, products, tools, equipment, systems, organizations, services, facilities and environments, in order to make them compatible with the characteristics, the needs and values, and the abilities and limitations of people.

The International Standard is intended to improve the safety, performance, effectiveness, efficiency, reliability, availability, and maintainability of the design throughout its life cycle, while safeguarding and enhancing the health, well-being, and satisfaction of those involved or affected.

Human, technological, economic, environmental and organizational factors all affect the behaviour, activities, and well-being of people in work, domestic, and leisure contexts. However, whatever the context, the underlying principles of ergonomics remain the same, although the relative emphasis placed on them will vary. These principles are fundamental to the design process wherever human involvement is expected, in order to ensure the optimum integration of human requirements and characteristics into a design. This International Standard considers systems, users, workers, tasks, activities, equipment, and the environment as the basis for optimizing the match between them. These principles and concepts serve to improve safety, performance and usability (effectiveness, efficiency and satisfaction), while safeguarding and enhancing human health and well-being, and improving accessibility.

Ergonomics covers a wide range of issues, including physical, cognitive, social, and organizational. These are ideally addressed within an integrated framework. A substantial number of ergonomics standards have been developed to cover specific issues and different application domains. All depend upon the basic principles and concepts that are fundamental to the ergonomics approach to design. This International Standard has been developed in order

to provide an integrated framework, bringing together the basic principles and concepts of ergonomics in one document, and thus providing a high-level view of the way in which ergonomics is applied.

International Organization for Standardization, 2010: Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems. *ISO 9241-210: 2010*. ISO, Geneva, Switzerland.

Human-centred design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors and usability knowledge and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability; and counteracts possible adverse effects of use on human health, safety, and performance. There is a substantial body of human factors and usability knowledge about how human-centred design can be organized and used effectively; this Standard aims to make this information available to help those responsible for managing hardware and software design and re-design processes to identify and plan effective and timely human-centred design activities.

The human-centred design described in this Standard complements existing systems design approaches. The Standard provides requirements and recommendations, in line with human-centred design principles, for activities throughout the life cycle of computer-based interactive systems. The Standard provides an overview of human-centred design activities; it does not provide detailed coverage of the methods and techniques required for human-centred design, nor does it address health or safety aspects in detail. Although the Standard addresses the planning and management of human-centred design, it does not address all aspects of project management.

The information in the Standard is intended for use by those responsible for planning and managing projects that design and develop interactive systems. It therefore addresses technical human factors and ergonomics issues only to the extent necessary to allow such individuals to understand their relevance and importance in the design process as a whole. It also provides a framework for human factors and usability professionals involved in human-centred design. The requirements and recommendations in this Standard can benefit all parties involved in human-centred design and development.

International Organization for Standardization, 2008: Ergonomics data and guidelines for the application of ISO/IEC Guide 71 to products and services to address the needs of older persons and persons with disabilities. *ISO TR 22411: 2008*. ISO, Geneva, Switzerland.

This Technical Report presents ergonomics data and guidelines for applying ISO Guide 71 in addressing the needs of older persons and persons with disabilities in standards development. It provides ergonomics data and knowledge about human abilities (sensory, physical, and cognitive) and guidance on the accessible design of products, services, and environments. Each of the design recommendations is based on ergonomic principles that are necessary for making products, services, and environments accessible to older persons and those with disabilities.

This Technical Report is intended to help standards developers understand the accessible design principles of ISO Guide 71 and implement them by providing design considerations and ergonomic data related to human abilities. In addition to its application by standards developers, this Technical Report may also be useful to manufacturers, designers, service providers, and educators. Guide 71 stresses the concept that taking care of the needs of older persons and persons with disabilities is important. The idea is that products, services, and environments

encountered in all aspects of everyday life should be designed to be accessible for all people, including those with special requirements.

For seven design fields, ISO Guide 71 provides structured tables of factors and human abilities that need to be considered in designing products and services. The tables are intended to focus the attention of standards developers. However, ISO Guide 71 does not describe how to consider those factors. What is missing are the design methods for implementing the concept of accessible design into individual standards. These methods demand a wider range of knowledge and ergonomic data on human abilities. Without such knowledge, design for persons with special requirements cannot be realized. This is the gap that is filled by this Technical Report.

This Technical Report broadens the range of users and is not limited to the 5^{th} to 95^{th} percentiles of the population. While not exhaustive, this Technical Report does present a starting point for technical information on accessible design. Social as well as economic benefits are expected from accessible design. From the social perspective, a greater number of individuals will be able to be involved in social activities without restrictions imposed by the product or service. From the economic perspective, products developed for accessible design can be purchased by a wider range of people. Older persons and persons with disabilities represent a significant portion of consumers with buying power.

International Organization for Standardization, 2007: Ease of operation of everyday products – Part 4: Test method for the installation of consumer products. *ISO PAS 20282-4: 2007*. ISO, Geneva, Switzerland.

This Standard specifies a test method that can be used to provide an operational evaluation of the ease of installation of consumer products. The test method is a summative method that gives performance-based measures that can be used for assessment against predetermined criteria or as the basis for comparisons between different products. Thus the test method can be used to measure ease of installation and establish whether quantitative usability requirements for ease of installation have been achieved. Manufacturers could communicate the test results to potential purchasers in product descriptions or advertising.

Many people find everyday products difficult to install. If the product is not easy to install, many users will find the product difficult, if not impossible, to use. This is clearly not desirable, either for the suppliers of such products or for the users. Information about the ease of installation of a product would therefore be of great value to both suppliers as part of their development process, and to potential purchasers making purchase decisions or comparing alternative products.

Usability is 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. Ease of installation provides a measure of the usability of an everyday product when used by the actual or intended users to achieve the goal of installing the product. When the installation process is relatively fast and of limited complexity, the most important measure of ease of installation is effectiveness. Effectiveness of installation is measured as the percentage of users who can successfully install the product. Efficiency of installation can be important if the time is extended. In addition, for some products to be identified as easy to install, it is important that users are satisfied with their experience of installation. This Standard was withdrawn by ISO in 2013.

International Organization for Standardization, 2006: Ease of operation of everyday products – Part 1: Design requirements for context of use and user characteristics. *ISO 20282-1: 2006*. ISO, Geneva, Switzerland.

This Standard provides requirements and recommendations for the design of easy-to-operate everyday products. It addresses the user interface by taking into account the relevant user characteristics and the context of use of

everyday products. This Standard is applicable to mechanical or electrical products with an interface that a user can operate directly or remotely.

An increasing number of everyday products include computer technology, making them more complex. Users need to understand how to operate products in order to benefit from the functionality offered. Hence, usability is a key factor in determining a product's success. As a product's complexity increases, so does the challenge for the user in understanding how to use the various functions of the product. For the manufacturer, it can be harder to design sufficiently usable products. Products with low usability often require the assistance of other people in order to be used. This can result in frustrated users as well as extra costs and the manufacturer. Many manufacturers have realized the importance of the usability of their products and now employ specialists in this area.

The focus on everyday products reflects the fact that many of the products we see around us on a regular basis still suffer from fundamental usability problems. The focus on user interfaces reflects the situation that while there are many factors that may have important effects on usability, all interactive products will have a user interface whose quality can have significant positive or negative effects that facilitate or hamper the usage of the product.

Everyday products are designed for an intended user population which includes people with a wide range of user characteristics. This Standard describes the user characteristics to be accommodated in the design of an everyday product, recognizing that the population of older persons is increasing, and takes into account the needs of these class of users. Everyday products include consumer products and walk-up-and-use products (e.g., a ticket booth at a train station). For everyday products, it is critical to ensure that the interface enables the user to achieve his or her objective.

International Organization for Standardization, 2004: Ergonomic principles in the design of work systems. *ISO 6385: 2004*. ISO, Geneva, Switzerland.

Technological, economic, organizational and human factors affect the work behavior and well-being of people as part of a work system. Applying ergonomic knowledge in the light of practical experience in the design of a work system is intended to satisfy human requirements. This International Standard provides a basic ergonomic framework for professionals and other people who deal with the issues of ergonomics, work systems and working situations. The provisions of this International Standard will also apply to the design of consumer products.

In the design of work systems in accordance with this International Standard, the body of knowledge in the field of ergonomics is taken into account. Ergonomic evaluations of existing or new work systems will show the need for, and encourage attention to, the role of the worker within those systems. This International Standard establishes the fundamental principles of ergonomics as basic guidelines for the design of work systems and defines relevant basic terms. It describes an integrated approach to the design of work systems, where ergonomists will cooperate with others involved in the design, with attention to the human, the social and the technical requirements in a balanced manner during the design process.

The intention is to improve, (re)design or change work systems. A work system involves a combination of people and equipment, within a given space and environment, and the interactions between these components within a work organization. Work systems vary in complexity and characteristics. Some examples of work systems are: a machine with a single person; a process plant including its operating and maintenance personnel; an airfield with users and personnel; an office with its workers; and computer-based interactive systems. The observance of ergonomic principles applies also to the installation, adjustment, maintenance, cleaning, repair, removal, and transport of work systems. The systems approach in this International Standard gives guidance to the users of this standard in existing and new situations. The definitions and ergonomic guiding principles specified in this International Standard apply to the design of optimal working conditions with regard to human well-being, safety

and health, including the development of existing skills and the acquisition of new ones, whilst taking into account technological and economic effectiveness and efficiency. While the principles in this International Standard are oriented to the design of work systems, they are applicable to any field of human activity, e.g. in the design of products for domestic and leisure activities.

International Organization for Standardization, 2004: Principles for selecting and using test persons for testing anthropometric aspects of industrial products and designs. *ISO 15537: 2004*. ISO, Geneva, Switzerland.

A determination that ergonomic requirements have been considered with regard to industrial products and designs is often performed using test equipment. In cases where no technical test procedures have been established, one or several people are often designated as test persons and are observed and/or surveyed while or after using the product under test. The validity of findings captured in this manner is very much dependent on the extent to which the test persons actually represent the intended user population in various aspects. One means to verify that a product or design fulfils the desired end result is to establish a group of test persons and let them use the product in different ways. This International Standard deals with adjusting the product or design based on the anthropometrics of the intended user population.

This International Standard establishes methods for determining the composition of groups of persons whose anthropometric characteristics are to be representative of the intended user population of any specific object under test. The Standard is applicable to the testing of anthropometric aspects of industrial products and designs having direct contact with the human body or dependent on human body measurements, e.g. machinery, work equipment, personal protective equipment, consumer goods, working spaces, architectural details or transportation equipment. The Standard is also applicable to the testing of such safety aspects of products that are dependent on human body measurements. It does not deal with other aspects of the task or other requirements, such as perception of information and the use of controls.

International Organization for Standardization, 2001: Guidelines for standards developers to address the needs of older persons and persons with disabilities. *Guide 71*. ISO, Geneva, Switzerland.

It is an important goal for the whole of society that all people have access to products, services, workplaces, and environments. The issue of accessibility to and usability of products and services has become more critical with the increasing percentage of older persons in the world's population. While not all older persons have disabilities, the prevalence of disability or limitations is highest among this demographic group. The needs and abilities of people change as they advance from childhood to old age and the abilities of individuals in any particular age group vary substantially. It is important to recognize that functional and cognitive limitations vary from comparatively minor, such as mild hearing loss or use of spectacles only to read, to blindness, deafness or the inability to move part or all of one's body.

This Guide is intended to be part of the overall framework that standards bodies can use in their efforts to support the need for more accessible products and services. This Guide applies to products, services and environments encountered in all aspects of daily life and intended for the consumer market and the workplace. Of necessity, guidance provided in this Guide is general. It is recognized that additional guides need to be developed for specific product or service sectors.

This Guide aims to inform, increase understanding, and raise awareness about how human abilities impact on the usability of products, services and environments; to outline the relationship between the requirements in

standards and the accessibility and usability of products and services; and to raise awareness about the benefits of adopting accessible design principles in terms of a wider market.

This Guide describes a process by which the needs of older persons and persons with disabilities may be considered in the development of standards, provides tables to enable standards developers to relate the relevant clauses of a standard to the factors which should be considered to ensure that all abilities are addressed, offers descriptions of body functions or human abilities and the practical implications of impairment, and offers a list of sources that standards developers can use to investigate more detailed and specific guidance materials.

International Organization for Standardization, 2000: Ergonomic design of control centres – Part 1: Principles for the design of control centres. *ISO 11064-1: 2000*. ISO, Geneva, Switzerland.

Driven by demands for safer, more reliable, and more efficient operations, advances in information technology have led to the increased use of automation and centralized supervisory control. Notwithstanding these advances, the human operator still retains a critical role in monitoring and supervising the behavior of these complex, automated systems. As the magnitude of automated solutions has grown, so have the consequences of equipment and human failures. The consequences resulting from inappropriate operator action in control rooms, such as omissions, errors in commissions, poor timing, and out of sequence steps can be potentially disastrous.

This Standard sets up a generic framework for applying human factors requirements and design guidance in designing and evaluating control centers with the goal of eliminating or minimizing the potential for human errors. The Standard discusses nine principles that should be considered in the human factors design of control centers.

a. Application of a human-centered design approach: In a human-centered design approach, the combination of humans and machines, in its organizational and environmental context, is considered as an overall system to be optimized, developing solutions that maximize the strengths, features, and capabilities of both humans and machines in a complementary fashion.

b. Integrate human factors in engineering practice: Human factors and its associated tools should be integrated into the project's guidelines to allow the role of human factors to be taken into account by all involved in the planning, design, implementation, and operation of a control center.

c. Improve design through iteration: Design and evaluation processes should be repeated until the interactions between the humans and designed objects achieve the desired functional requirements and objectives.

d. Conduct a situational analysis: A situational analysis of existing or similar situations allows the functions of the future system to be understood and anticipated beforehand.

e. Conduct a task analysis: The tasks delegated to individual control room personnel need to be fully understood. The task analysis should consider all modes of system operation including start-up, normal operation, shut-down, and anticipated emergency scenarios.

f. Design error-tolerant systems: Human error cannot be totally eliminated. It is therefore necessary to strive for error-tolerant design.

g. Ensure user participation: User participation is a structured approach where future users are involved in the design. User participation instills a sense of ownership in the design. Also, experienced users can offer valuable empirical contributions to the design; their practical experience is not always documented or well known by designers.

h. Form an interdisciplinary design team: An interdisciplinary design team should be formed to oversee and influence all phases of the design project.

i. Document the human factors design basis: Internal documents that reflect the basis for the human factors design should be generated, including significant findings and rationale for decisions made.

Lastly, the Standard outlines a framework for the control center design process which consists of five design phases; clarification, analysis and definition, conceptual design, detailed design, and operational feedback. The complexities of a design project can often be accommodated by implementing a methodical sequence of procedures that focus attention on particular topics, design activities, and iterative reviews.

Jacobs, R. M. 1996: Product recall – a vendor/vendee nightmare. *Microelectronics Reliability*. 36 (1), 101-103.

This article presents guidance on how a portion of the recall headaches can be minimized by planning. Costs can escalate quickly, not only for parts and technician labor but also for recordkeeping and communication with vendors. The author notes that any time after a product has left the manufacturer's control and a hazard (mechanical, electrical, thermal, chemical, instructional) is discovered, the product may be subject to recall. The recall may be for replacement, repair, or even removal of the product from the market. Resolution of a product recall is often a business decision, not a technical one.

The author points out that user friendly product identification is only the initial step to be considered in all situations that may ultimately involve a product recall. The identification needed involves knowing where the product will ultimately be used, sold, warehoused, and transported; that is, how will the customer or ultimate owner readily identify the product. The product identifier must be recognizable and be permanently affixed to the product. Whether model numbers, serial numbers, or date codes are used is not as important as to where it appears on the product. In the example given in the article, the identification information was inside the assembly, requiring first removal, then disassembly before the inspector knew if it was the assembly in question.

The author concludes that a product recall can be a vendor's nightmare, from both a financial as well as an organizational viewpoint. The costs associated with a recall can be astronomical and escalate dramatically. In order to control these potential future costs, planning and decisions must be made at the beginning, in the design phase, when the pressure of a defect is not driving the decision process. It is suggested that manufacturers protect their interests by establishing full traceability of their products both by identifying the product in an unambiguous and clear manner, and by maintaining a method of locating their product once in the field.

Kreifeldt, J. G. and Hill, P. H. 1976: The integration of human factors and industrial design for consumer products. *Proceedings of the Human Factors and Ergonomics Society – 20th Annual Meeting*, 20 (5), 108-112.

The successful integration of human factors and industrial design will produce an aesthetically pleasing and functionally superior product. A case study in the design of a new manual toothbrush is used to illustrate techniques and studies developed over four years to produce a consumer product along rational human factors lines in conjunction with innovative industrial design. The primary functional requirement was that the final product be significantly better in plaque removal than other leading manual toothbrushes as well as eliciting strong consumer appeal.

The authors note that the user must be treated as a continuing integral part of the design from product inception to product promotion. The product design solution which is directed toward specific human factors, consumer desires, and aesthetic requirements will result in a superior product with the best chances for commercialization. The industrial designer and the human factors engineer, by combining their separate areas of expertise and refined sensibilities for the different design aspects form a natural working team since they are both directed to the same end – customer satisfaction and thereby a successful product.

Kumar, S. and Schmitz, S. 2011: Managing recalls in a consumer product supply chain – root cause analysis and measures to mitigate risks. *International Journal of Product Research*, 49 (1), 235-253.

The article describes a study designed to analyze the management of recalls in a consumer products supply chain, as well as the reasons, costs, and measures to prevent recalls. Companies in the consumer products industry need to consider not only the cost to their financials in an event of a product recall, but also the loss in terms of goodwill and consumer risk. Product recalls can present a major crisis for manufacturers, especially those involving adverse media publicity, and a negative effect on the stock price for publicly held companies. The authors note that companies are often disinclined to state why failures happen or how defects occurred; there is a tendency to keep this information under wraps.

In today's global market, the supply chain presents significant risk management challenges. Having an appropriate traceability and recall plan in place is critical to managing supply chain risks. The ability to track products through all stages of the supply chain has always been important for companies, but in the event of a product recall, having an efficient system in place is critical. Testing and inspection procedures for materials or subcomponents received from suppliers will help detect if the material is adversely affected and will help prevent its introduction into the consumer product.

The direct and indirect costs of a recall are discussed. The article discusses several major recalls and how the various direct and indirect costs have impacted the company's costs as well as damage to the company's image with the public. The authors discuss several lessons learned including the importance to ensure that manufacturers are in a position to implement corrective measures as quickly and effectively as possible, companies need to have quick access to product information to have efficient recalls, speed is key to removing defective products effectively from the marketplace, companies need to understand the risk and be prepared to defend their decision whether or not to recall the product, and companies need to adopt a proactive approach for preventing recalls.

Lidwell, W., Holden, K. and Butler, J. 2010: *Universal principles of design*. Rockport Publishers, Inc., Beverly, MA.

Convenient access to cross-disciplinary knowledge has not previously been available. A designer interested in learning about other areas of specialization would have to study texts from many different design disciplines. Determining which texts in each discipline arte worthy of study would be the first challenge, deciphering the specialized terminology of the texts the second, and enduring the depth of detail the third. The effort is significant, and rarely expanded beyond brief excursions into unfamiliar areas to research scientific problems. The goal of this book is to assist designers with these challenges, and reduce the effort required to learn about the key principles of design across disciplines.

The concepts in this book, broadly referred to as "principles" consist of laws, guidelines, human biases, and general design considerations. The principles were selected from a variety of design disciplines based on several factors, including utility, degree of misuse or misunderstanding, and strength of supporting evidence. The selection of 125 concepts should not be interpreted to mean that there are only 125 relevant principles of design; there are obviously many more.

The book is organized alphabetically so that principles can be easily and quickly referenced by name. For those interested in addressing a specific problem of design, the principles have also been indexed by questions commonly confronting designers. Each principle is presented in a two-page format. The left-hand page contains a succinct definition, a full description of the principle, examples of its use, and guidelines for use. Side notes appear to the right of the text and provide elaborations and references. The right-hand page contains visual examples and

related graphics to support a deeper understanding of the principle. The use of well-established design principles increases the probability that a design will be successful.

Miaskiewicz, T. and Kozar, K. A. 2011: Personas and user-centered design: How can personas benefit product design processes? *Design Studies*, 32 (5), 417-430.

This article investigates personas, an alternative method for representing and communicating customer needs. Personas are fictitious representations of target users; abstractions of groups of real consumers who share common characteristics and needs. By using a narrative, picture, and name, a persona provides product designers with a vivid representation of the design target. The authors note that the acceptance of user-centered principles has not eliminated frustration with the design of modern products. Many organizations simply fail to consider the consumer needs as the focal point of their design processes. As a result, many design processes are still not reaching their target consumers or users of the product.

Numerous benefits of incorporating personas into product design approaches have been suggested, but the present literature fails to reach consensus on the benefits of incorporating personas into the design process. The authors suggest that by incorporating expert opinion through the use of Delphi methodology, the benefits of incorporating personas into the design process will become more evident. After gaining consensus on the perceived importance of the individual benefits, the article then elaborates on the most significant benefits of persona use and needed future research on the personas method. As a result of this study, the authors conclude that the most significant benefit of personas is their ability to focus product design teams on the actual goals of the target customers; personas facilitate a clear focus on who the product or service is designed for, who it is not, and what the goals are.

Ministry of Defence (United Kingdom), 2016: Human factors integration for defence systems, Part 0: Contracting for human factors integration in defence systems. *DEF-STAN 00-251 Part 0*. Glasgow, Scotland.

Human Factors Integration (HFI) is a systematic process within Defence acquisition that supports the successful integration of people, processes, and technology. Failing to consider the human user, their characteristics and limitations, early and throughout the lifecycle, and as an integral part of the system is likely to lead to sub-optimal capability. HFI ensures that system design fully considers the role of the human in the system. Although many Defence acquisition projects are concerned with the acquisition of technology, such tangible items must be operated, maintained, and supported by people. Thus whatever their nature, degree of complexity or technological sophistication, systems that provide Defence capability and comprise:

a. Equipment, infrastructure, hardware, software, information and material necessary to deliver the required capability;

b. People (MOD Service personnel and civilian support staff) who operate, manage, maintain, and support the capability; and

c. Processes that link the Equipment with People to achieve the required capability with all three aspects working in harmony.

The purpose this Standard is to create a contractual relationship between the Ministry of Defence (MOD) and the industry Solution Provider. It details what MOD requires industry to do with respect to HFI, but does not mandate the details of how it should be done. DEF-STAN 00-251 contains four parts:

a. Part 0 (this document) provides an introduction to HFI and a description of the method for MOD to contract with the Solution Provider;

b. Part 1 (Early Lifecycle Human Factors Integration Process Requirements) provides the human factors process requirements to be applied to all MOD projects that contain a human element. It focuses on those activities to be conducted early in the lifecycle, either by MOD or industry;

c. Part 2 (Human Factors Integration Process Requirements for the Solution Provider): provides the human factors process requirements to be applied to all MOD projects that contain a human element. It focuses on those activities to be conducted by the Solution Provider from the assessment phase of the concept, assessment demonstration, manufacture, in-service, and disposal lifecycle onwards; and

d. Part 3 (Human Factors System Requirements) provides the human factors user and system requirements that can be used by the MOD to facilitate the integration of human factors within the system design and assure the integration of human factors from requirements to acceptance.

The intent of DEF-STAN 00-251 as a whole is to make it easier for MOD to contract for HFI and remove ambiguity for both MOD and industry in ensuring that the system design reflects the requirement for human factors. This will support the definition of appropriate statements of work and the verification and validation process.

The requirements are expressed in terms of an assumed mutual contractual arrangement between the MOD and the Defence industry for the supply of a system that is to be handled, transported, used, maintained, or otherwise supported by MOD Service personnel or MOD civilian employees.

Ministry of Defence (United Kingdom), 2010: Joint services publication: Human factors integration for defence systems. *JSP 912*, MOD, London, England.

This document defines MOD policy with respect to the process of human factors integration (HFI) in defence systems, together with requirements for the HFI process and its constituent activities. This document should be used in conjunction with DEF-STAN 00-251 which provides guidance to MOD on the execution of HFI within contracts. HFI is the MOD process by which the people component of is considered during delivery of the desired capability. It is a systematic process for identifying, tracking, and resolving human-related considerations ensuring a balanced development of both technologies and human aspects.

It is recognized that a failure to consider the people component of a system can result in increased accidents and incidents; greater training costs; reduced performance and mission effectiveness; breaches in duty of care; a scarcity of appropriately skilled personnel; and substantial increases in design and redesign costs. The process specified in this document is both goal-based and risk-based. Overarching HFI goals that must be satisfied in every project are identified. The extent and depth of HFI activities should be tailored to the degree of project risk presented by people-related considerations.

The process reflects agreed systems engineering practice and follows accepted HF good practice in the management and mitigation of people-related issues and risks in projects. It provides a consistent framework within which projects can systematically address people-related considerations. Process steps are associated with typical project phases, so providing a mechanism for monitoring performance.

Although many acquisition projects are concerned with the acquisition of technology, even unmanned systems must be operated, maintained, and supported by people. Thus whatever their nature, degree of complexity, or technological sophistication, systems that provide a needed capability comprise infrastructure, equipment, hardware, software, information, and materiel necessary to deliver the required capability; and people. HFI is the process by which the equipment and people components are brought together and made to work. Of critical importance is that the two components be considered as having equal 'weight', and so must be integrated (i.e., human-centered design). To achieve the required capability, both of these components must work in close

combination and harmony. The effectiveness and efficiency of the resulting system may depend on the people component and the adequacy of this combination.

National Aeronautics and Space Administration, 2011: NASA space flight human-system standard, Volume 2: Human factors, habitability, and environmental health. *NASA-STD-3001, Vol 2*. NASA, Washington, DC.

The purpose of this Standard is to provide uniform technical requirements for the design, selection, and application of hardware, software, processes, procedures, practices, and methods for human-rated systems. NASA-STD-3001, Space Flight Human-System Standard, is a two-volume set aimed at minimizing health and performance risks for flight crews in human space flight programs. Volume 1 of NASA-STD-3001, Crew Health, sets standards for fitness for duty, space flight permissible exposure limits, permissible outcome limits, levels of medical care, medical diagnosis, intervention, treatment and care, and countermeasures.

This Standard, Volume 2 of NASA-STD-3001, focuses on human physical and cognitive capabilities and limitations and defines standards for spacecraft, internal environments, facilities, payloads, and related equipment with which the crew interfaces during space operations. This Standard focuses on human-system integration where the context is about how the human crew interacts with other systems, including the habitat and the environment. The focus is on performance issues during a mission — whether the human and the system can function together and accomplish the tasks necessary for mission success.

This Standard addresses the equipment and operational interfaces that are common to both flight crew and ground personnel. System requirements fall into one of two categories: requirements for the design of systems that directly interface with only the flight crew during a mission (such as environmental support systems, architecture, controls and displays, and operations), and requirements for the design of systems that are common between the flight crew and ground personnel (such as hatches, passageways, inspection points, and emergency equipment). Requirements for these “common” systems consider the unique characteristics between the two user populations.

Newell, A.F. and Cairns, A.Y. 1993: Designing for extraordinary users. *Ergonomics in Design*, 1 (4), 10-16.

This article deals with designing, or failing to design, for persons with disabilities. Many systems are designed for physically and mentally active young people; in essence, average users with average abilities. Few systems take into account individual differences among the user population and the wide range of abilities, particularly those with disabilities. Quite often research subjects are chosen because they are easy to obtain rather than representative of the true user population. Including users with disabilities broadens the range of individual differences that exist in most user groups.

The authors note that every human has a set of abilities, some of which are ordinary and some that are extraordinary. Even people with disabilities have abilities that are different from ordinary users; they merely lie on a different point on the continuum of human ability. A person with a mental impairment is not without abilities, but merely has lower abilities. The author’s also note that the environment in which one has to operate can have a severe impact on a person’s capabilities. A hostile environment can turn a perfectly fit user into one whose performance is similar to that of a person with disabilities.

A user with functional impairments can present very difficult problems, which can then stimulate the designer to develop new and more effective interfaces. Using people with disabilities to evaluate interfaces can highlight problems that would not be obvious to those without such disabilities.

Nuclear Regulatory Commission, 2012: Human factors engineering program review model. *NUREG-0711, Rev 3*. NRC, Upton, NY.

The human factors engineering (HFE) staff of the Nuclear Regulatory Commission (NRC) evaluates the HFE programs of applicants for construction permits (CPs), operating licenses (OLs), standard design certifications (DCs), and combined licenses (COLs). The purpose of these reviews is to verify that the HFE aspects of the plant are developed, designed, and evaluated via a structured analysis founded on HFE principles that are acceptable to the NRC staff. The HFE review covers the HFE design process, the HFE final design, its implementation, and ongoing performance monitoring. Therefore, these reviews support public health and safety by verifying that the plants' designs incorporate HFE practices and guidelines.

The HFE program review model consists of 12 review elements as follows: HFE Program Management (to verify that the applicant has an HFE design team with the responsibility, authority, placement within the organization, and composition to reasonably assure that the plant design meets the commitment to HFE), Operating Experience Review (to identify HFE-related safety issues), Functional Requirements Analysis and Function Allocation (to verify that the applicant defined those functions that must be carried out to satisfy the plant's safety goals and that the assignment of responsibilities for those functions to personnel and automation in a way that takes advantage of human strengths and avoids human limitations), Task Analysis (to verify that the applicant undertook analyses identifying the specific tasks needed to accomplish personnel functions), Staffing and Qualifications (to verify that the applicant has systematically analyzed the requirements for the number of personnel), Treatment of Important Human Actions (to identify those human actions most important to safety for a particular plant design), Human-System Interface Design (to evaluate the process used by applicants to translate the functional- and task-requirements to human-system interface design requirements), Procedure Development (to confirm that the applicant's procedure development program incorporates HFE principles and criteria), Training Program Development (to verify that the applicant has employed a systems approach for developing personnel training), Human Factors Verification and Validation (to determine that the final HFE design conforms to accepted design principles), Design Implementation (to verify that the applicant's as-built design conforms to the verified and validated design resulting from the HFE design process), and Human Performance Monitoring (to verify that the applicant prepared a program to adequately assure that the conclusions drawn from the integrated system validation remain valid with time, and to ensure that no significant safety degradation occurs because of any changes made in the plant).

Privitera, M. B. and Murray, D. L. 2009: Applied ergonomics: Determining user needs in medical device design. *Proceedings of the 31st Annual International Conference of the IEEE EMBS*, September 2009, 5606-5608.

This article describes a methodology for determining user needs within the design process currently being used by the University of Cincinnati's Medical Device Innovation and Entrepreneurship Program. Topics such as user observation and interviews, task analysis, and human factors for product embodiment are discussed. Specific tools for data gathering, analysis, and synthesis towards determining design considerations, requirements, and specifications are defined.

Applied ergonomics allows designers and engineers to develop solid information about user wants and needs, minimizing the frustrations of providing solutions to the wrong problems. Through applied ergonomics, it is possible to identify problems which may not yet be known by patients, physicians, or other stakeholders. Through the optimization of the entire system, one should be able to produce results that decrease operational time, minimize unintended device effects, and make it easier for the physician to do the 'right thing' while, at the same time, make it harder for the physician to do the 'wrong thing.'

Rausand, M. and Utne, I. B. 2009: Product safety – principles and practices in a life cycle perspective. *Safety Science*, 47 (7), 939-947.

This article describes a new product life cycle model that can be used by producers to improve safety and to prevent defective products, both consumer and industrial, from being placed on the market. The proposed model has eight phases and the article describes and discusses the required safety-related issues in each phase. Analytical methods that should be used in the various phases are identified. The article outlines the main product safety requirements with a focus on European product safety legislation. The concept of "adequate safety" is introduced as an acceptance criterion for the producer during the product development process, and factors that should be taken into account when deciding whether or not a product has adequate safety are discussed.

The authors note that the lack of safety is often explained by the increasing complexity of many products, the time and cost pressures during product development, new technology being brought to market before all characteristics and risks are known, designers and producers who cut corners to save time or money, and products being used in other ways and for other purposes than anticipated. The article concludes that meeting product safety is a trade-off decision within the constraints of cost, schedule, and performance. The ultimate goal, from the producer's perspective, is to ensure that consumer products do not present any unacceptable risk under normal use or reasonably foreseen conditions of use. Most producers are striving to increase the safety of their products in order to enhance their competitive edge, reduce warranty cost, and prevent liability claims and product recalls. This can be achieved by applying product safety principles early and throughout the product life cycle.

Ryan, J. P. 1987: Consumer behavior considerations in product design. *Proceedings of the Human Factors and Ergonomics Society – 31st Annual Meeting*, 27 (9), 1236-1240.

The article discusses human factors guidelines which can be a valuable source of information for designers to support a safe consumer product design. These human factors guidelines will assist the designer to recognize the user's behavior in the reasonable and foreseeable use, and mis-use, of consumer products. The article concludes that safe product design can be planned and designed into products that will reduce the risk of injury in product use.

The occurrence of user injury, and even death, is often the result of product mis-use; that is, the product was used in a way the designer did not intend. The author notes that accident causation is the result of many factors. These factors are present during product use, and are dependent upon the product design, the environment in which the product is being used, and the behavior of the product user. In the absence of a product defect, accident causation is directly or indirectly the result of user behavior. Thus, a safe product can be defined as a product, when used in a reasonable and foreseeable way, will present a low risk of injury to the user. It should be noted that products which have been declared as reasonably safe can, and do, cause injuries to users.

Savage, P. and Pearsall, S. 1998: A case study in iterative design. *Ergonomics in Design*, 6 (1), 18-25.

The article describes an iterative design process that was used in the development of a graphical user interface for a multimedia messaging application. Feedback was alternately obtained from human factors experts and from end users. Application of the methodologies, representative output from each design activity, and significant findings are discussed. Specific examples of redesign based on customer feedback and needs are also discussed.

There is no single design technique or process that ensures easy-to-use products and services. And while the designer is faced with differing characteristics, needs, tasks, goals, and environments, there is general consensus

that end users should be included in the design process. The authors note that an important aspect of an interactive design process is to validate previous design changes. This is especially important when design decisions are based on perceptions of use rather than actual use.

Recommendations include using a variety of design activities during the design process, draw on human factors expertise to identify design issues and explore alternate feature designs, obtain expert and user feedback, use low-fidelity paper scoreboards to ensure scenario events are executable, collapse usability inspection techniques within a single expert review session, and continue to document use of techniques and share findings with the design community.

Singer, J. P., Balliro, G. M. and Lerner, N. D., 2003: *Manufacturer's guide to developing consumer product instructions*. Consumer Product Safety Commission, Washington, DC.

The U.S. Consumer Product Safety Commission (CPSC) provided this guide to help manufacturers develop the wide range of instructional materials typically associated with consumer products. These materials include:

a. Owner's manuals,
b. Assembly instructions,
c. Training materials,
d. Product repair or recall information
e. Maintenance and troubleshooting guides,
f. Quick reference guides, and
g. Storage or disposal information.

Each of these materials serves a different purpose, and the design issues for each will differ. One needs to consider the product for which instructional materials are being developed. This guide helps customize the manufacturer's approach to best meet the needs of the particular application. It will help identify the right questions to ask and will help answer those questions.

Many books, manuals, research papers, industry standards, and regulations deal with some aspect of consumer product instructions. Other sources may offer greater detail or more topics. Unfortunately, much of this information is scattered, hard to find, overly technical, or narrow in perspective. This guide integrates information from many sources and provides it in a convenient form. This guide does not provide a detailed "how-to" for each type of instructional material or product. Instead, it shows those principles of good design that are generally applicable to all instructions associated with consumer products. This guide does not prescribe requirements, and it is not a CPSC rule.

Strawderman, L. and Huang, Y. 2012: Designing product feature upgrades: The role of user processing and design change. *International Journal of Industrial Ergonomics*, 42 (5), 435-442.

This article examines user performance changes based on user processing and changes made to a task during a product upgrade. User processing is the type of cognitive processing a user employs to complete a task and is identified as either controlled or automated. Changes to a product task are categorized into three types: omission (removal of a step), commission (addition of a step), and sequence (new order of steps). Participants completed

tasks designed to represent the three types of design changes and two levels of user processing. The study examined the ease in transitioning between old and new versions of the same device is required, i.e., when different tasks are introduced within a device, how easy is it for the users to adapt to the design change; is performance dependent on the way a task is changed or the type of cognitive processing the user employs?

The results indicate a difference in user performance based on processing type. Participants adapted to changes in the product more readily when using controlled processing as opposed to automated processing the variance of user performance was greater for tasks that required controlled processing. Design changes were most readily adapted to with a change of sequence. Tasks that were altered using omission and commission caused a greater negative effect on the participants' performance. When using automated processing, users can more readily adapt to design changes of sequence when compared to other types of design changes.

The authors note that the introduction of new product versions requires additional consideration of how a user's existing knowledge impacts acceptance of the upgraded product. When upgrading consumer products, designers should be mindful of the way tasks are changed, particularly for common automated tasks, which will allow users to more easily adapt to upgraded products.

Weinberger, M. and Romeo, J. B. 1998: The impact of negative product news. *Business Horizons*, 32 (1), 44-50.

Marketing managers are continually concerned with improving and fine-tuning their marketing mix. They are also aware, however, that their best marketing efforts can be drastically altered by forces beyond their control. Today, with emerging technologies and vast distribution systems involved in business, the possibility of something going wrong before or after the product is distributed to consumers is more than remote. In this article, the authors try and gain some insight about negative product incidents from four case studies.

Mass media have made it possible to spread negative information quickly to large audiences. Negative product news typically has a higher profile in both print and broadcast media. The authors conclude that the short-term effects of intense negative publicity were severely detrimental in each case study. The longer-term effects appear to depend upon demographic group, persistence of negative publicity, and the ability and willingness of companies to act positively and promptly.

Zitkus, E., Langdon, P. and Clarkson, P. J. 2013: Inclusive design advisor: Understanding the design practice before developing inclusivity tools. *Journal of Usability Studies*, 8 (4), 127-143.

This article describes an exploratory study investigating ways to accommodate inclusive design techniques and tools within industrial design practices. The approach of the research is that by making only small changes in design features, designers end up with more inclusive products. The research team examined how to enable designers to make design decisions toward more accessible products by observing and interviewing 20 experienced industrial designers. The team designed an inclusive design advisor tool that provided suggestions that designers could use to make more inclusively designed products. Designers were asked about their opinions of available inclusive design techniques and tools and their tendency to use those techniques and tools. Designers were then presented with the interactive design advisor tool. Although the tool was in the very early stages of development, it exemplified an interactive way to supply designers with information about inclusivity. Through using the tool, designers were encouraged to talk about pros and cons of the tool. Designers were asked to provide more detailed information about their current practices. The results confirm that tools, such as guidelines, user testing, and physical simulations, all have limitations that restrict their adoption by designers. Inclusive design

advisors could be accepted by the design community if the tool is tailored for each design domain and the tools that they use.

The study concluded that incorporating inclusive design advisors into computer programs already used in the design industry could be a viable way to integrate inclusivity and accessibility concepts and practices into the design process. The design process is often a trade-off between different client-driven priorities and requirements and the practicalities and costs of designing and manufacturing a product. Understanding the clients' motivations and requirements could clarify how an inclusive design advisor tool should and could work to inform clients and designers of inclusive design practices. The study examined the current industry design practices with the intention of developing or implementing an inclusive design tool. Based on interviews and observations, it was discovered that it is not common for clients to include accessibility requirements into their product requirements. It was also discovered that designers often do not evaluate accessibility or usability unless they are required to by the client.