

The Use of Socio-Technical Probabilistic Risk Assessment at AHRQ and NASA

James B. Battles
Agency for Healthcare Research and Quality (AHRQ),
Rockville, Maryland, USA

Barbara G. Kanki
National Aeronautics and Space Administration (NASA) Ames Research Center
Moffett Field, California, USA

1 Government Agency Role

Government research agencies can play an important role in helping to shape a research agenda through the research methods and techniques that they fund through grants and contracts. While the use of Probabilistic Risk Assessment (PRA) has often been an accepted safety research tool in studying risk in technical systems, it has had limited use in predominately human systems in which human limitations and failure represent substantial risks. There is a need to apply PRA to more human based systems where the role of human behavior can represent a substantial portion of probable risk. Two U.S. federal governmental research agencies are now using socio-technical probabilistic risk assessment as an important research tool to meet program objectives as part of their overall safety research efforts. The Agency for Healthcare Research and Quality (AHRQ) is the federal agency designated to lead the research effort in the area of medical error and patient safety while the National Aeronautics and Space Administration has responsibility in research in aviation and space safety management. Both AHRQ and NASA are advancing the use of probabilistic safety assessment through active research programs which are described.

1.1 Activities at AHRQ

Patient safety and medical error has become a major international issue of in the past few years [1,2]. In the US there are over 98,000 deaths attributed to medical error or health care associated injury [1]. These shocking numbers are an indication that health care should be considered a high hazard industry. Health care associated injuries are those associated with the process or structure of care rather than to a patient's underlying or physiological, environmental or disease related antecedent conditions [3]. Patient safety is the *prevention* of harm to patients [4]. This can be accomplished by eliminating or minimizing unintended risks and hazards associated with the structure and process of care. AHRQ has been designated by the US Congress to take the lead in conducting research into the causes and prevention of medi-

cal error and health care associated injury or harm. AHRQ has established a multi stage research continuum as an organizing principle for its patient safety research initiative.

- *One - identify* the risks and hazards that cause or have the potential to cause health care associated injury or harm.
- *Two - design, implement, and evaluate patient safety practices* that eliminate known hazards, reduce the risk of injury to patients, and create a positive safety culture.
- *Three - maintain vigilance* to ensure that a safe environment continues and patient safety cultures remain in place.

Not surprisingly most of patient safety research to date has been devoted to stage one of the continuum with a focus on identification of risks and hazards to patients from health care associated injury or harm. Traditionally, patient safety systems have detected events through individual reports (e.g., a clinician reports an adverse event to a hospital risk manager), document review (e.g., retrospective review of patient records and death certificates), or monitoring patient progress retrospective in nature

However there is a growing awareness in health care that there is a critical need to move to more proactive or prospective process analysis as a necessary addition for improving safety approaches to risk assessment. The Joint Commission for Accreditation of Healthcare Organizations (JCAHO) which accredits US hospitals and other healthcare organizations now requires that accredited institutions incorporate the use of prospective risk analysis methods as a part of organizational patient safety plans and procedures [5]. The Institute of Medicine (IOM) in its recent report *Patient Safety: Advancing a New Standard of Care* recommends that AHRQ support the assessment of the validity and efficiency of integrating retrospective techniques (e.g., incident analysis) with prospective techniques [4]. In response to the shift toward more prospective safety assessment in health care, AHRQ has identified proactive risk assessment as an appropriate patient safety research methodology [6].

AHRQ launched a patient safety implementation challenge grant program designed to promote the use of various kinds of proactive risk assessment approaches to identify the critical risk and hazards within the health care process. The agency has encouraged health care organizations to partner with experts outside of health care to conduct comprehensive risk assessment research efforts. Table 1 is a listing of AHRQ funded probabilistic risk assessment projects. The application of probabilistic risk assessment approaches is a new concept in health care. The delivery of health care to patients has and continues to be a human based system where the actions or inaction of individual health care professionals pose a substantial risk to patients. The need to focus on human factors and behavior associated risk will continue to be a challenge in health care. We have much to learn about the application of PRA and its limits and constraints as a research tool. There is also a need to train health care professionals in the various methods and approaches to the application of proactive risk assessment as a new research paradigm. As the results of the current research efforts become more widely published, there should be a greater acceptance of proactive risk assessment. The application of socio-technical probabilistic risk assessment (ST-PRA) is having a positive impact in health care.

Project Title	Institution
Risk Modelling in Transitions of Care	Abt Associates
Risk and Recovery in complex Environments – Labor & Delivery as a Model	Beth Israel Deaconess Medical Center
Re-Engineering the Hospital Discharge for Patient Safety	Boston Medical Center
Risk Modelling to Improve Long-Term Care Medication Safety	Oregon Department of Human Services
Risk Analysis of Pediatric Chemotherapy Process	St. Jude Children’s Research Hospital
PRA Chicago Transplant Insight	University of Chicago
Real-Time Assessment of Risk Factors- Medication Errors	Veterans Medical Research Foundation

Table 1. AHRQ Funded Probabilistic Risk

1.2 Activities at NASA

PRA is not a new concept in aerospace but it has been primarily applied to engineering objects (e.g., vehicles, systems, subsystems, components) as a tool for making decisions in the design process [7]. For example, loss-of-vehicle risk for the Space Shuttle can be assessed and “averaged” over mission phases and described by the relative contributions of principal vehicle elements such as orbiter, space shuttle main engines (SSME), solid rocket boosters, external tank, etc. These elements, in turn, are described by the relative contributions of their main risk drivers, such as turbo machinery and combustion devices which are the main risk drivers of SSME [8, 9]. But aerospace accidents and incidents have taught us that risk assessments that focus only on hardware elements fail to account for the considerable risks inherent in the operational environment in which aerospace vehicles are maintained and flown. Furthermore, many of these risks are virtually undocumented except in the collective memory of the people operating the equipment themselves. The study of human factors in aviation and space and more recent innovations in Socio-Technical PRA (ST-PRA) give us tools for analyzing risks associated with human error, non-standard practices, procedural noncompliance, etc.--any of which can degrade safety and performance quite apart from limitations of the hardware or system as designed.

1.2.1 ST-PRA in the NASA Aviation Safety Program (AvSP).

One of the elements of the NASA Aviation Safety Program focuses on Maintenance Human Factors (MHF). The primary goal of the MHF tasks is to understand and mitigate potential root causes of incidents and accidents intrinsic to aircraft maintenance and inspection operations. Specific objectives include: increased understanding of human error and human reliability associated with maintenance and inspection tasks, and the development of interventions and task aids that reduce human error and enhance safety and effectiveness. Similar to AHRQ, this program follows a phased approach including: 1) identification of safety needs, 2) application of methods and tools, 3) development of interventions and 4) validation of products (see Figure 1).

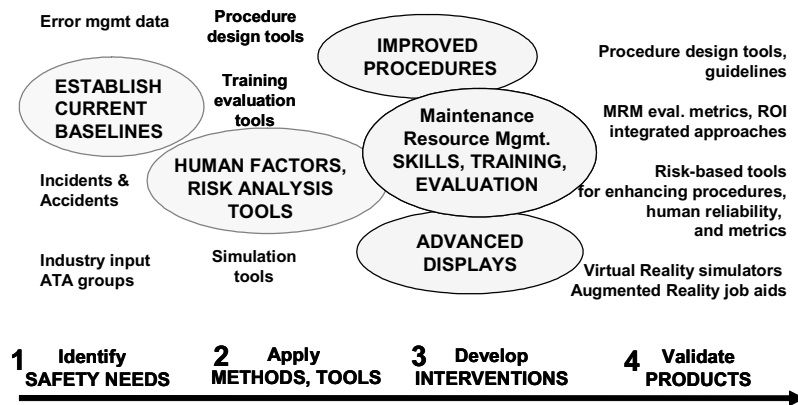


Figure 1. Maintenance Human Factors Program Elements and Approach: Risk analysis plays a key role as both product and tool for the NASA Aviation Safety Program

Central to this research approach and critical for its success is the continuous involvement of operational partners through all phases of the research. While we use a variety of methods to establish current maintenance error baselines and to develop and validate interventions, ST-PRA has emerged as a useful multi-purpose tool. When applied within a maintenance organization, ST-PRA can help to identify high priority safety needs; its associated fault tree indicates paths of process improvement opportunities, and outcome probabilities provide error rates upon which metrics can be tracked. In maintenance and inspection operations where there is a general lack of human error data, this tool can provide organizations a way to begin systematic data collection. Such a database helps to establish a performance-based rationale for making maintenance and inspection management decisions. Our eventual goal within the AvSP MHF program is to develop a generic, public-domain version of the ST-PRA tool suitable for use in any maintenance and repair station. In addition, such a tool can be applied to a wide range of high risk operations even when users may not have formal risk modelling experience.

1.2.2 ST-PRA in the NASA Engineering Complex Systems (ECS) program

The NASA ECS program is primarily directed toward NASA operations (e.g., space shuttle, space station, unmanned launch initiatives, etc.) and its overall goal is to achieve ultra-high levels of safety and mission success through the infusion of advanced information technologies and knowledge engineering. One task focuses on the development of a Digital Shuttle Ontology which lays the foundation for a shared, user-centric information system that incorporates risk priorities in its knowledge base. This task was developed to address three major challenges: 1) the need for a shared information system that crosses organizational boundaries and works effectively for diverse information requirements, 2) the need for an inter-organizational process model that examines knowledge acquisition, usage and in-

formation priorities, and 3) the need to develop risk-informed knowledge management techniques that can be consistently used across the lifecycle of the vehicle (e.g., design, manufacture, test, operate, maintain, etc.).

Developing a shuttle ontology for a system of organizations that have evolved, merged, split, and disappeared is not easy to achieve, and there is an inherent limitation to this task due to corporate and technical knowledge already lost over the 30-year history of the Space Shuttle Program (SSP). Nevertheless, the flip-side of this challenge is that there exists a 30-year history of flight and test data, lessons learned, research engineering, and a large body of experiential knowledge in the form of a highly skilled and dedicated workforce.

Socio-technical risk modeling has proven to be a useful process for capturing knowledge from a variety of information sources. For example, in the shuttle processing work environment, a partial risk model of ground-processing-induced in-flight anomaly (GPI-IFA) risk has been built [10]. In this model, 9 top-level classes of mechanical, electrical and tile processing events are identified and the selection of the top-level events are based on documented in-flight anomaly events (e.g., incomplete installations, processing-induced damage). Although this partial model focuses on only one part of the shuttle process (orbiter processing between flights), these results represent a significant contribution to risk in the shuttle lifecycle, and address the need to identify and understand human error risks.

In short, the socio-technical risk modeling process provides critical risk information. It identifies vulnerabilities in the system design and high-impact strategies to reduce risk. Furthermore, it provides a system for building a risk/data driven approach to managing error. Finally, in relation to the ECS program, the partial risk model developed for shuttle ground processing provides an important knowledge capture tool for populating the shuttle ontology with risk priorities. In both AvSP and ECS programs, we find that the socio-technical approach to risk modeling provides an appropriate way to integrate equipment/design risk assessment (for which aerospace is data-rich) with knowledge about human operator error. Human factors research applications in maintenance and inspection are not new, nor are safety management concepts and tools, but the “socio” elements of a socio-technical system have often been sidelined as if they were independent of the “technical” context in which they reside. While NASA is known for its ability to overcome operational barriers through creative technology solutions, NASA also acknowledges the unique capabilities and limitations of the human operator interacting with technology in high-risk operations. ST-PRA is an approach that brings us one step closer to understanding these complex relationships so that the most effective operations and highest level of safety can be achieved.

2 Summary

Socio-Technical Probabilistic Risk Assessment is a powerful tool for safety assessment, and federal agencies can play a critical role in supporting the application of this research method for achieving their strategic goals. Both AHRQ and NASA have launched important programs utilizing these methods and are finding benefits that support their overall research missions.

References

1. Kohn LT, Corrigan JM, Donaldson MS, eds. To err is human; building a safer health system. National Academy Press, Washington, D.C.: 1999.
2. Department of Health, United Kingdom (DOH/UK). An organization with a memory: a report of an expert group on learning from adverse events in the NHS. National Health Service, London, 2000.
3. Battles JB, Lilford RJ. Organizing patient safety research to identify risks and hazards. *Qual Safe Health Care* 2003; 12 (Suppl II): ii2-ii7.
4. Aspden P, Corrigan JM, Wolcutt J, Ericksen SM, eds.. Patient safety: advancing a new standard of care. National Academy Press Washington, D.C., 2003.
5. Joint Commission on Accreditation of Healthcare Organization: Medical errors, sentinel events, and accreditation. A report to the to the Association of Anaesthesia Program directors: October 28, 2000.
6. Marx DA, Slonim AD. Assessing patient safety risk before the injury occurs: an introduction to sociotechnical probabilistic risk modelling in health care. *Qual Safe Health Care* 2003; 12 (Suppl II): ii33-ii38.
7. Kanki, BG. Current Approaches to Assessing Risk in Maintenance and Inspection. In *Proceedings of the 16th Symposium on Human Factors in Aviation Maintenance and Inspection*. San Francisco, CA, 2002.
8. Science Applications International Corporation. *Probabilistic Risk Assessment of the Space Shuttle*, NASA/HQ Code M. Washington DC 20546, 28 February 1995, CASI Record No. 95N26398.
9. Fragola, J. Space Shuttle Probabilistic Risk Assessment. In *1996 Proceedings Annual Reliability and Maintainability Symposium.*, 1996.
10. Kanki, BG, Marx D, Hale MJ. Socio-Technical Probabilistic Risk Assessment: Its Capabilities and Limitations. In *Proceedings of International Conference on Probabilistic Safety Assessment and Management*. Berlin, Germany, 2004.