Strategic accident prevention with applied human factors theories

Hidetake Sakuma
Japan Airlines

Introduction

Almost 100% of aviation accidents and incidents can be attributed to any human error by personnel working in the aviation system. This is because humans have incentives, capabilities and responsibility for safe and effective operation of the system. Human factors has, therefore, become a major concern for many operational and management personnel in all fields of aviation systems. Their attention is mainly focused on eliminating human error itself. (Error resistance)

It is recognized that human error would never be eliminated since it is a part of normal human behavior and an unfortunate result of the challenging activities which are inherent to human beings. If this is so, what should we do to achieve the goal of 'zero accidents'? As an attempt to answer this question, a new idea has unveiled itself, which intends not to eliminate but to control human error by intervening accidents. (Error tolerance)

It should be recalled that our true objective for enhancing flight safety is not necessarily to eliminate human error but to prevent the accident that is a result of human error. In this respect, error tolerance is considered the most reasonable and realistic approach to realizing our permanent goal of 'zero accidents', however, there still is a fear that tolerating human error might be a double-edged sword.

In this paper, the author will challenge the construction of an accident prevention strategy by integrating various human factors knowledge and skills including the human factors investigation process of using the 'Downhill model', which emphasizes the top-down (error tolerance) concept.

Air transport as a socio-technical system

Socio-technical system

A socio-technical system is a group in which the failure of risk control may directly lead to a disaster. The final decision to avoid an accident is entrusted to a small number of personnel who are working the front line. e.g. Nuclear power industry, Railway transport, Marine transport, Chemical plant, Space industry, Air transport, etc.

Mission of air transport

The ultimate goal of air transport is to fly passengers and freight from point A to point B safely and efficiently. 'Safely' means to protect the life and the property of passengers and employees. 'Efficiently' means to secure profit for shareholders, management's and employees by saving operational cost.

A conceptual model (Figure.1) represents the safety envelope as defined by four axis ; Indicated airspeed, Pressure altitude, Horizontal situation and Time (Time factor not shown in the model). Safe flight is defined as aircraft operation within this envelope, while efficient flight is aircraft operation within a narrower shaded region illustrated in the envelope.

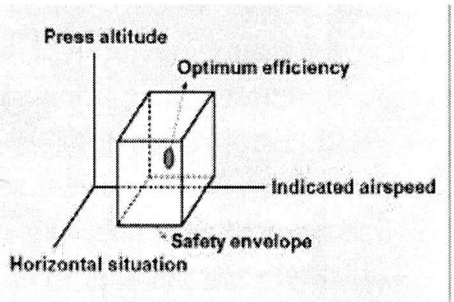

Figure.1 Safety envelope

The responsibility of a flightcrew is to accomplish their mission balancing these two objectives, safety and efficiency of flight. The boundaries of the safety envelope are often times hard for operational personnel to perceive in the aviation system as compared with in other transportation systems.

What is human error?

Why do humans make errors?

To better understand the characteristics of human error, it is suggested that we trace human history back to its origin. Humans had initiated, at some stage of their history, to walk on the ground and stand upright on their legs instead of residing in trees. (Erect bipedalism). This evolutional change enabled humans to use tools, speak languages and support their heads with an erect backbone, all of which contributed to the remarkable growth of the modern human brain.

The frontal lobe, as the latest addition to the cerebral cortex, functions to encourage the human brain to challenge difficult tasks that are beyond its capability, which sometimes causes human errors. To err is a unique characteristic inherent to humans. Human error may never be eliminated since humans are destined to never stop challenging.

Definition of human error

Human error is defined as a part of normal human behavior in which the expected level of performance cannot be achieved because (1) the performance of the human brain is lowered, or (2) the expected level of performance is too high.

Relationship between error, incident and accident

An accident is an occurrence in which the result of human error leads to fatal/serious injuries to persons or the damage/failure of an aircraft. An incident is an occurrence which is identical to an accident in nature but was detected and corrected before an accident occurred.

Strategy for accident prevention

Two different approaches for problem solving

Historically, there have been two primary approaches for problem solving. These are listed below.

- Bottom-up approach (Data-driven): is problem solving that begins with lower hierarchy like tactics, tools, details and procedures.
- Top-down approach (Conceptual-driven): is problem solving that begins with higher hierarchy like strategies, objectives, outlines and concepts.

Two different approaches for accident prevention

There are two different approaches for accident prevention, one is error resistance which is derived from the bottom-up approach and the other is error tolerance which is derived from the top-down approach. The process of the error tolerance approach requires in-depth knowledge and skills of human factors and related disciplines.

- Error resistance: is intended to intervene directly at the source of the error itself. (Bottom-up approach)
- Error tolerance: refers to the ability of a system to detect and correct the error before leading to serious consequences. (Top-down approach)

It is not recent that error tolerance has been recognized as an effective tool for accident prevention. Many people, however, are still reluctant to accept it because they are not comfortable leaving the conventional way of error resistance which has functioned well as a tool for maintaining satisfactory level of flight safety in current aviation systems.

The effectiveness of error tolerance, however, has been demonstrated in the automobile system. When driving a car, the driver roughly monitor the distances from road edges, other cars, pedestrians, etc. by time sharing their attention (Error tolerance) instead of exactly keeping within the center of lane (Error resistance). This implies that the human information process is better suited to a top-down approach rather than to a bottom-up one. This is the very reason why the author would propose accident prevention largely based upon the top-down (error tolerance) strategy.

More practically, boundaries of hazards which are hard to perceive should be clearly identified and displayed to operators. If operators were provided with sufficient information of the characteristics of probable hazards through the human factors investigation process, they could construct a proper mental image for associated risks in human factors training such as CRM (Crew resource management).

Concept of human factors

Definition of human factors

Human factors can be defined as an effort to harmonize and optimize the relationship between people and their living and working environments with the knowledge and skills related to human performance and limitations.

Conceptual model for human factors - SHEL model

The famous SHEL model (Hawkins, 1987) illustrates that humans are living and working in a system that consists of four fundamental elements; software-S, hardware-H, environment-E and liveware -L. (Figure.2) Information is exchanged through interfaces of each element. Human error may occur if the interface is not harmonized.

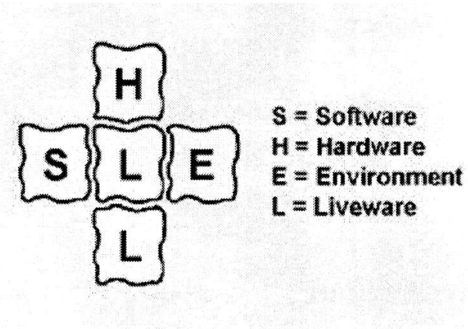

Figure.2 SHEL model

Modified SHEL model

Putting the SHEL model into more practical use, the author has proposed the following two modifications to the original model. (Sakuma, 1996)

SHEL molecular structure. This model illustrates that multiple livewares communicate with each other in the system where all elements but liveware are playing a role as media for information exchange. (Figure.3)

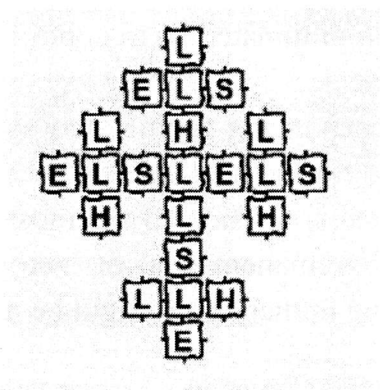

Figure.3
SHEL molecular structure

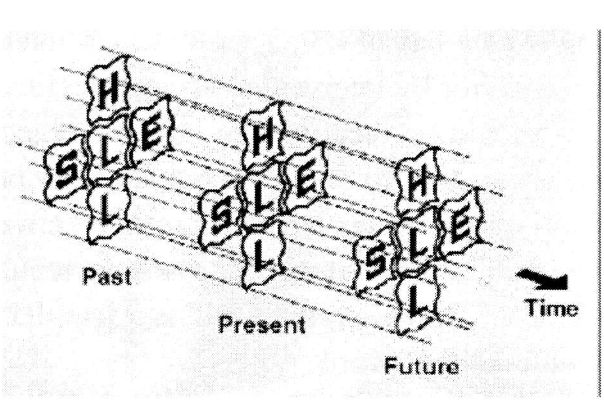

Figure.4
SHEL time tunnel

SHEL time tunnel. This model gives better insight into change in SHEL elements in terms of elapsed time, which helps clarify the relationship between error, incident and accident. (Figure.4)

How to harmonize SHEL interfaces

The theory of communication process as illustrated in Figure.5 can be applied in harmonizing the SHEL interfaces since the elements communicate with each other in the SHEL model. Both livewares process and exchange information based upon their own knowledge, objective and situation at hand. Differences in knowledge, objective and situation may lead to communication errors. The effort by responsible livewares to harmonize the interface is categorized as follows.

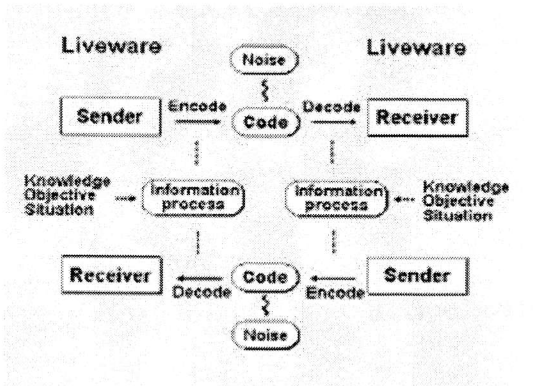

Figure.5 Communication process

- Training: is the effort by the liveware located inside the SHEL model to fit with surrounding four elements. e.g. CRM/LOFT
- Management: is the effort by the liveware peripherally located outside the SHEL model to tailor the working environments. e.g. Ergonomics, Human-centered design

CRM is a kind of human factors training which aims to activating all functions of the human information process in an integrated manner, which consists of training for situational awareness, problem solving, decision making, communication and stress management. CRM is definitely training which conforms to error tolerance concept.

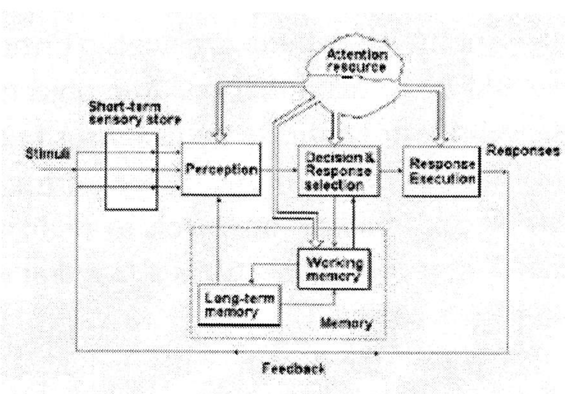

Figure.6 Human information process

Human information process

Figure.6 is a conceptual model of the human information process drafted by Wickens (1984).

Three types of human information process

The function of human information process is classified into three types as indicated in Table.1. Associated errors are also included.

Table.1 Three types of human information process

	Knowledge-base	Rule-base	Skill-base
Information	Never experienced	Ever experienced	Frequently experienced
Problem solving	Heuristics	Automatic (Rules)	Automatic (Schema)
Attention	High	Moderate	Low
Connection of nerve & cell	Developing	Tentatively multiple	Stabilized
Type of error	Random	Systematic	Sporadic
Error prediction	Easy	Moderate	Difficult
Error detection	Difficult	Moderate	Easy
Causal factor	Lack of knowledge, skill	Defect of design, procedure	Characteristics of brain
Countermeasure	Education, Training	Improvement of design, procedure	HF training, CRM/LOFT

Various human limitations

Various limitations reside in the human information processes as below.

- Capabilities of human information process remains unchanged from ancient times that only fit with natural surroundings in which the human is destined to reside.
- Humans can respond only to moving or changing quantities because the nervous system is essentially an analogue detector.
- Resources of the human information process, like attention resource, memory capacity and informatio n channels are not infinite.
- Humans are prone to mistakes in the forming, selecting and storing of a

group of memories (schema).

- The human brain can solve a new problem in a relatively short time without any program (Heuristics) but easily makes mistakes because of its ambiguous working process.

Errors associated with expectation of performance

Human error is classified into five categories in accordance with the relationship between performance and expectation in terms of level and time as illustrated by Figure.7. (Kantowitz and Sorkin, 1983)

- Omission error: is skipping a part of a task.
- Commission error: is performing a task incorrectly.
- Extraneous act: is a task that should not have been performed.
- Sequence error: is a task that was performed out of sequence.
- Time error: is performing a task too early, too late or not within the time allowed.

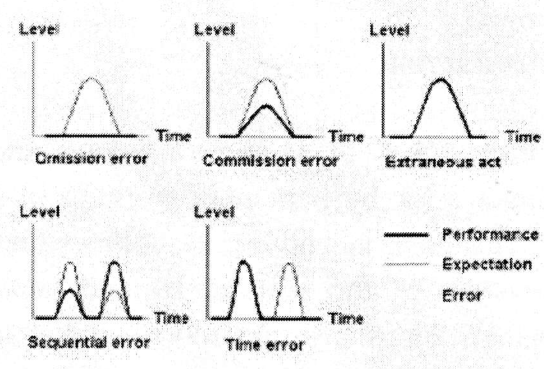

Figure.7
Errors associated with expectation

Error tolerant feedback system

Figure.8 shows the framework of an error tolerant feedback system in which any major failure in human performance is properly analyzed to identify hazards with the information of 'what', 'where', 'how' and 'why' of human error involved. Corrective actions planned are to be timely and reflected in the CRM training and in the process of corporate safety management. The effectiveness of corrective actions should also be carefully evaluated.

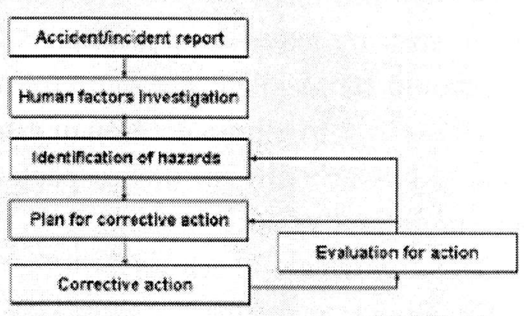

Figure.8
Error tolerant feedback system

Integrated process for human factors investigation

Conceptual model for human factors investigation - Downhill model

The author would like to present a conceptual model as shown in Figure.9 that is tailored to help in understanding and investigating human factors issues. In this model, the mission of air transport is simulated by a man or a woman skiing down a hill along the prescribed route on the slope. The skier represents an operator (flightcrew) and the prescribed route stands for the standard operating procedure (SOP).

During the journey from the start to the goal, there may be a number of possibilities for operator to intentionally or unintentionally deviate from the route. An unintentional deviation from the route symbolizes the operator's procedural error. Once deviation from the route occurs for any reason, he or she might encounter a number of hazards which are indicated by holes widely dispersed on the slope.

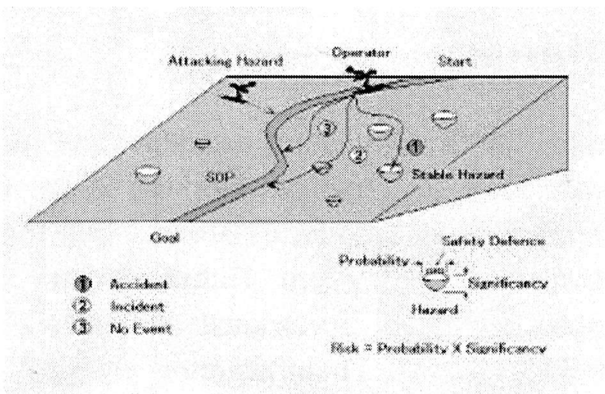

Figure.9 Downhill model

The type of encounter the operator has with the hole is grouped into three categories. The first case is dropping into a deep hole with no recovery, which stands for an accident. The second is a recovery from a shallow hole, which represents an incident. The last one is returning to the original route with no event.

The types of hazards are classified into two kinds. One is a stable hazard in which the operator tends to approach by mistake. The other is an attacking hazard which may attack the operator traveling along the prescribed route. The stable hazard represents, for example, stall, high speed buffet, pilot involved oscillation, terrain, turbulent weather, etc., while the attacking hazard represents aircraft malfunctions, attacking aircraft, fire, misloading, etc.

Investigation process

Figure.10 and Figure.11 illustrate a process that provides a step-by-step systematic approach for use in the investigation of human factors. The process is an integration and adaptation of a number of human factors theories and conceptual models referenced in this paper. A unique feature of this process resides in the capability of identifying a hazard as in depth as possible by the use of available concepts and theories of applied human factors. Figure.11 shows the reverse process of Figure.10.

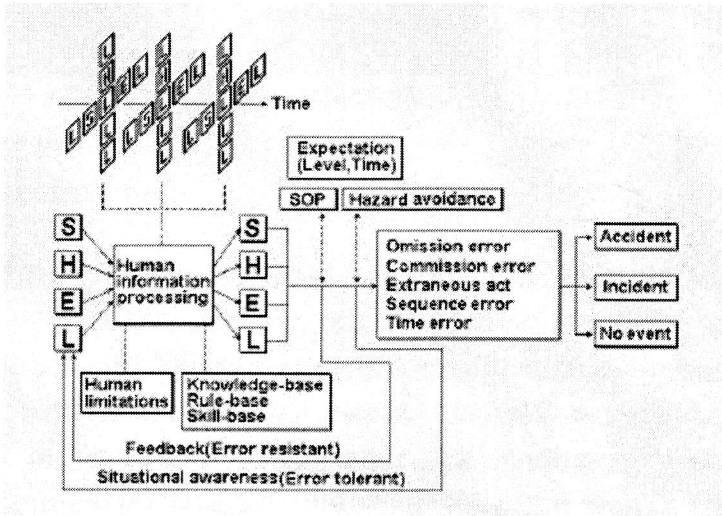

Figure.10 Human factors investigation process (1)

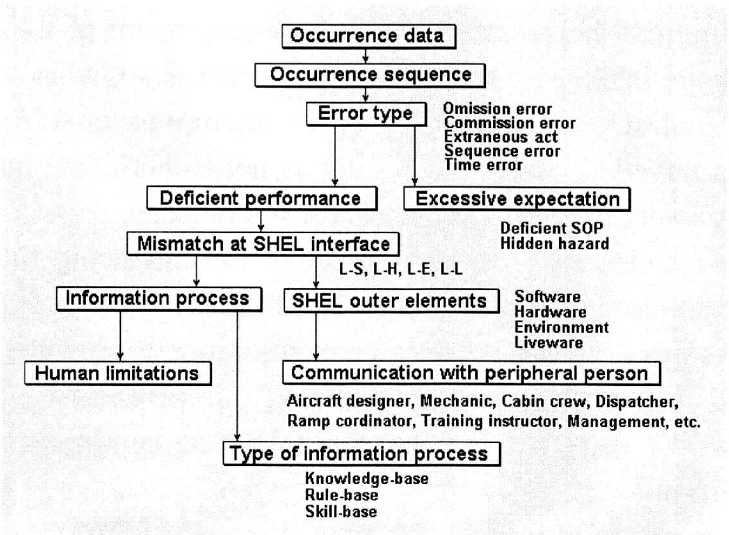

Figure.11 Human factors investigation process (2)

Conclusion

The process of human factors investigation presented in this paper has proved to be effective by the author's demonstrations which were applied in several cases of actual aviation occurrences involving the failure of human behavior. There, however, exist some problems that a sufficient level of proficiency is required in human factors and other related disciplines to carry out the process. The author believes that the most urgent issue in achieving the goal of 'zero accidents' is at this time to provide as many operational and management personnel as possible with sufficient skills and knowledge of human factors that will enable them to carry out an integrated process for investigation.

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