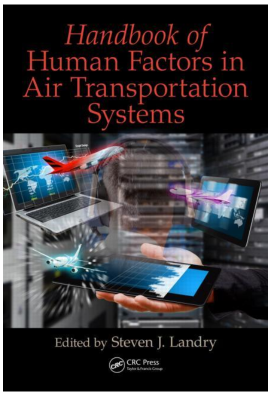

Handbook of Human Factors in Air Transportation Systems

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An Overview of Flight Deck Human Factors in the U.S. Aviation Regulatory System

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7 An Overview of Flight Deck Human Factors in the U.S. Aviation Regulatory System

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CONTENTS

INTRODUCTION

The current chapter presents a perspective of the U.S. regulatory system for aviation, administered by the Federal Aviation Administration (FAA). The chapter begins with a brief description of the underlying philosophy of aviation regulation as a form of risk management. It then described the history and philosophical basis of some of the key aviation regulations in the U.S. system.

The chapter will then focus on how and where flight-deck human factors (HF) are integrated in the regulations with an emphasis on flight deck–related applications. In particular, this chapter will discuss how HF applies within the regulatory structure for equipment design, flight-crew training, flight-crew procedures, and flight-crew operations.

AVIATION REGULATION—A BRIEF PRIMER

The legal origin for the FAA's regulatory activities is founded in the U.S. Constitution and is generally considered to have begun with the Air Commerce Act, enacted in 1926.* This act commissioned the Secretary of the Department of Commerce to be responsible for fostering air commerce, issuing and enforcing air traffic rules, certifying pilots and aircraft, and operating and maintaining air navigation aids (NAVAID). Birnbach and Longridge (1993) provided a historical perspective on the FAA and provide a more detailed history of the evolution of the legal structure.

* The material in this section is based on the regulatory primer perspective from the RTCA Task Force on Certification (RTCA 1999). In particular, the contributions of several members of RTCA Task Force 4 on Certification were instrumental in developing the material for the regulatory primer, including John Ackland, Tony Broderick, and Tom Imrich.

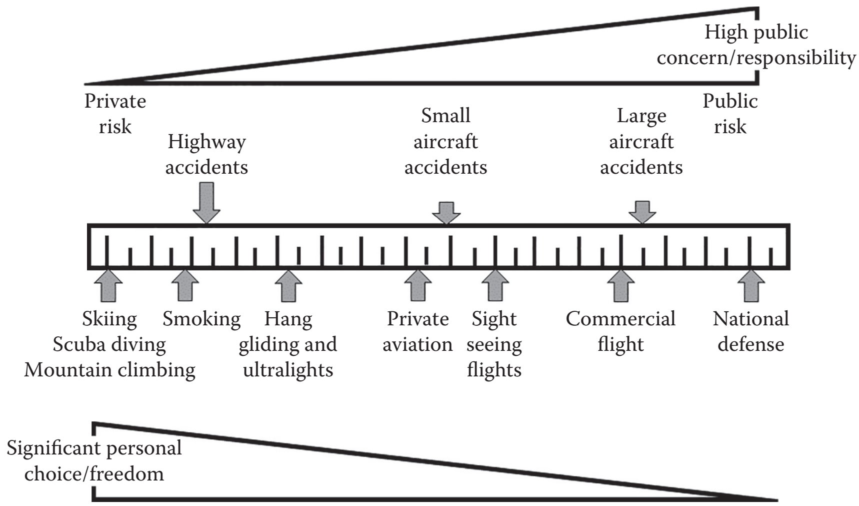

FIGURE 7.1 *Personal* versus *Public* risk assumption.

One way to look at regulation is to consider it as a form of safety risk management, and to consider where a society places certain activities on a notional continuum of safety risk. Figure 7.1 shows such a continuum, which describes private risk at one end and public risk at the other. It depicts different activities and where they may be placed by a society. In the continuum shown in the figure, the left end of the continuum represents private risk, with activities such as scuba diving, mountain climbing, and skiing as examples of items that a society might place on this end. These activities at this end correspond to significant personal choice and freedom, with low public concern and responsibility.

Activities considered to be of high public concern and responsibility are represented on the right end of the continuum, and examples include commercial flights and national defense. In the United States (and many other societies), large aircraft accidents are placed to the right end of the continuum, because they are considered to be of high public concern and responsibility. Highway accidents and small airplane accidents are further to the left on the scale, as this is the choice of the society.

Another society may choose to place these activities and safety-related events at different points on the continuum. For example, another society may choose to place private and commercial aviation at the same *risk* point (and therefore the same level of public concern).

Society also determines the role of the government in managing or mitigation of safety risk. Consider the continuum shown in Figure 7.2, which illustrates where the potential government role may be. The leftmost end is intended to represent activities or concerns that are primarily personal and commercial. At this end, the society chooses to limit the government's role—possibly in a role to simply enable the activity. At the rightmost end, one can find activities or concerns that are inherently governmental, such as national defense. At this end, the government actually conducts or controls the activity.

The location of any particular activity is driven by the will of the society for which the government works. In the United States, for example, private aviation is considered to be less of a public concern, and therefore less of a public responsibility by the government. Commercial aviation is much more a public concern and is expected to have the highest level of safety. Therefore, legislation requires that government oversight and standards are more stringent for commercial aviation than for private aviation.

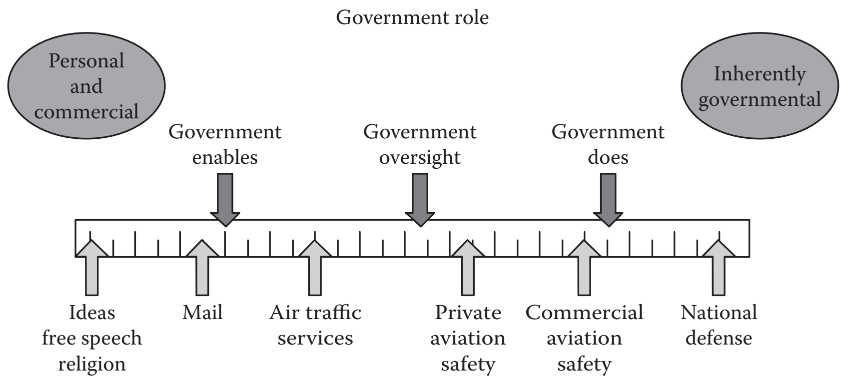

FIGURE 7.2 Continuum depicting potential governmental role.

The aviation regulations were initiated through the Air Commerce Act of 1926, which assigned responsibility and regulatory authority for aviation to the Aeronautics Branch of the Department of Commerce. This branch had the following objectives:

1. Establish airworthiness standards and associated system of aircraft registration.
2. Administer examination and licensing procedures for aviation personnel and facilities.
3. Establish uniform rules for air navigation.
4. Establish new airports.
5. Encourage the development of civil aviation.

Basically, the fundamental governmental responsibilities are to

1. Assure that aircraft do not fall on the public (assure the airworthiness of the aircraft);
2. Assure the *highest level of safety* for public transportation;
3. 3 Assure at least a basic level of safety for other *certificated aircraft* passengers;
4. Assure that aircraft can satisfy safety-related inter-aircraft responsibilities for mutual separation (e.g., the requirement for altitude-encoding transponders in certain airspace)

The means that are used to accomplish these responsibilities are as follows:

- Certifying air vehicles and supporting ground elements—if, and as necessary
- Establishing operating rules—*rules of the road*
- Providing or empowering certain capabilities (e.g., certain services, facilities, or capabilities agreed to by the aviation system users, or by the public)

In part, these functions are accomplished via some type of *certification*. Here, certification means the approval and authorization for aircraft; personnel (e.g., pilots), operations, procedures, facilities, and equipment.

The current regulations that the FAA administers are contained in the U.S. Code, specifically, Title 14—Code of Federal Regulations (CFR), Aeronautics and Space Chapter 1—FAA, Department of Transportation. Three subchapters of particular interest to this discussion are Subchapter C, Aircraft; Subchapter F—Air Traffic and General Operating Rules; and Subchapter G, Air Carriers and Operators for Compensation or Hire: Certification and Operations. Subchapter C includes the Airworthiness Standards for various categories of aircraft (including Part 25 for Transport Category Airplanes). Subchapter F contains the general operating and flight rules (Part 91) and Subchapter G contains Part 121 Operating Requirements: Domestic, Flag, and Supplemental Operations and

Part 135—Operating Requirements: Commuter and On-Demand Operations and Rules Governing Persons On Board Such Aircraft.

Part 25 and several other Parts in Subchapter C contain airworthiness standards for aircraft. These requirements are considered to be *point in time* regulations, because once compliance is found with one of these regulations (such as issuance of a Type Certificate for an airplane type design), it is not revisited unless the type design of the airplane changes (e.g., adding equipment or system not part of the original type design). Therefore, any change in any of the regulations in Part 25 does not result in the change of existing certificated aircraft type designs.

In contrast, the operating rules (Parts 91, 121, 135, etc.) are *continuous applicability* rules, and therefore, when a regulation is changed, the operators certificated under that operating rule must comply according to the date from when the rule is effective. Pilot training and qualification requirements fall under the operating regulations, allowing changes to be made continuously as needed.

The aforementioned discussion describes the underlying philosophy of the regulations, which represent requirements. Regulatory material can have one or more motivations, as discussed in the following:

- *Minimum standards*: The regulations might describe the minimum standards for a required characteristic, such as the performance of a system on an aircraft.
- *Protection, such as 14 CFR Part 193*: This part describes when and how the FAA protects from disclosure safety and security information that is submitted voluntarily to the FAA.
- *Incentives for equipage by giving operational credit*: For example, aircraft with autoland capability (and corresponding pilot qualification) have the potential to fly to lower visibilities than aircraft without such capability.

The FAA publishes several other types of documents, in addition to regulations. One such type of document is an advisory circular (AC), which provides guidance from the FAA to the external community. An AC may contain guidance on means of compliance with particular regulations or may provide other information of interest to the aviation community (e.g., one AC lists all the published ACs).

Advisory circulars are numbered using a system that corresponds to the regulations for which it provides information. For example, AC 25.1329 Approval of Flight Guidance Systems (FAA 2006b) provides a means of compliance with 14 CFR 25.1329 (FAA 2006a). Another example of an AC is AC 120-76A for Approval of Electronic Flight Bags (FAA 2003b). This includes both airworthiness and operational approval guidance for approving a technology or type of system, rather than a specific regulation.

The following material discusses both regulations and advisory circulars related to HF in airworthiness of equipment design, flight-crew training, and operational approval.

REGULATORY REQUIREMENTS AND GUIDANCE FOR FLIGHT DECK

> Congress recently directed the FAA to use the following definition of human factors: "human factors means a multidisciplinary field that generates and compiles information about human capabilities and limitations and applies it to design, development, and evaluation of equipment, systems, facilities, procedures, jobs, environments, staffing, organizations, and personnel management for safe, efficient, and effective human performance, including people's use of technology."* This is a very broad definition that is intended to cover all the ways that HF is applied by the FAA, whether air traffic applications, aircraft/flight-deck operations, maintenance, commercial space, or other.

* S.2658 Federal Aviation Administration Reauthorization Act of 2016. https://www.congress.gov/bill/114th-congress/senate-bill/2658/text

The current chapter will describe how HF is related to regulatory material for equipment design, flight-crew training, and flight-crew operations. In each area, regulatory material is discussed together with some illustrative HF aspects.

AIRWORTHINESS REQUIREMENTS FOR EQUIPMENT DESIGN—EXAMPLES

Chapter 9 of this book describes the certification of aircraft and aircraft systems.* HF is related to many of the airworthiness regulations. A thorough review of the HF considerations and where they can be found in aircraft certification standard and guidance material may be found in Yeh et al. (2016). A few of the Part 25 regulations will be discussed next to illustrate in more detail how HF considerations are incorporated into the airworthiness requirements for equipment design.

14 CFR Part 25 Section 25.1329 Flight Guidance Systems

This regulation describes the airworthiness requirements for Flight Guidance Systems (FGS), including autopilots, autothrust systems, flight directors, and associated flight-crew interfaces (FAA 2006a). Operational experience showed that flight-crew errors and confusion were occurring when operating the FGS and its subsystems (FAA 1996), including vulnerabilities that can be mitigated in the equipment design. Therefore, the airworthiness requirements were updated to address these issues, and to address changes in technology and capabilities of FGS.

As one example of how the equipment design requirements were updated to support crew coordination, paragraph (j) requires that the alert for autopilot disengagement must be done in a way to assure that the information is available to each pilot:

(j) Following disengagement of the autopilot, a warning (visual and auditory) must be provided to each pilot and be timely and distinct from all other cockpit warnings. (FAA 2006a)

The Advisory Circular for this regulation makes it clear that the intent is that the alert associated with disengagement of the autopilot(s) must be implemented in a way to support flight-crew coordination:

> "It should sound long enough to ensure that it is heard and recognized by the pilot and other flight-crew members, but not so long that it adversely affects communication between crew members or is a distraction." (FAA 2006b)

Paragraph (i) explicitly addresses the need to support error management through preventing errors, and through the equipment design providing feedback on current modes of operation:

(i) The flight guidance system functions, controls, indications, and alerts must be designed to minimize flight-crew errors and confusion concerning the behavior and operation of the flight guidance system. (FAA 2006a)

Paragraph (i) also says: "Means must be provided to indicate the current mode of operation, including any armed modes, transitions, and reversions. Selector switch position is not an acceptable means of indication. The controls and indications must be grouped and presented in a logical and consistent manner. The indications must be visible to each pilot under all expected lighting conditions." (FAA 2006a). This portion of the regulation supports the requirement for equipment design to support crew monitoring of the status of the FGS.

One point worth of note is that this regulatory material addresses systems but does not use the term *automation*. The FAA does not apply aircraft certification requirements any differently for so-called automation as a separate type of system than for other complex systems. Instead, the systems are evaluated for compliance with the regulations based on their function.

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* Chapter 9 Certification of Aircraft and Aircraft Systems, this book.

14 CFR 25.1302 Installed Systems and Equipment for Use by the Flight Crew and European Aviation Safety Agency Certification Specification CS 25.1302

Another airworthiness regulation was developed jointly by the FAA, the Joint Aviation Authorities (JAA), the European Aviation Safety Agency (EASA), North and South American industry, and European industry to address the need for the equipment design to support error management by the pilots (EASA 2007b). This regulation was written to require the equipment design to have characteristics that are known to avoid error. Specifically, the equipment must provide the information and controls necessary for the pilots to do the tasks associated with the intended function of the equipment, and the controls and information must be in a usable form.

In addition, the regulation was written on the basis of the understanding that even well-qualified pilots using well-designed systems will make errors. Therefore, the equipment design must support detection and recovery aspects of error management. The first sentence of paragraph (d) explicitly addresses this:

(d) To the extent practicable, installed equipment must enable the flight crew to manage errors resulting from the kinds of flight crew interactions with the equipment that can be reasonably expected in service, assuming the flight crew is acting in good faith (EASA 2007; FAA 2013).[*,†]

This regulation requires that the equipment design provide the information needed to perform the tasks associated with the intended function of the equipment—and this includes monitoring of the equipment—and that the equipment provide information about its operationally relevant behavior. The FAA and EASA regulations are harmonized, which results in the United States and Europe having consistent requirements for this aspect of equipment design.

The airworthiness regulations described earlier are *point in time* regulations, as discussed earlier. Therefore, any new airplane type must meet the requirements, but existing airplanes do not. As there are many aircraft that received their aircraft certification approval before these regulations were implemented, such aircraft do not necessarily meet the requirements for the equipment design to support crew coordination, error management, and crew monitoring. Thus, the mitigations required in the flight-crew training and procedures are especially important for such aircraft.

OTHER AIRCRAFT CERTIFICATION STANDARDS

Many other aircraft certification requirements have HF-related aspects. Examples include 14 CFR 25.1322 Aircraft Alerting Systems;

Flight-Crew Training and Operational Requirements

Flight-crew training and qualification requirements include many aspects that affect pilot performance and, therefore, involve the application of human factors. One major area (but by no means the only one) is that of Crew Resource Management (CRM). The U.S. regulations include a requirement for training of CRM principles and topics for pilots and dispatchers. These requirements for CRM are codified into 14 CFR Part 121 Section 121.404, Compliance dates: Crew and dispatcher resource management training, which states

> After March 19, 1998, no certificate holder may use a person as a flight crewmember, and after March 19, 1999, no certificate holder may use a person as a flight attendant or aircraft dispatcher unless that person has completed approved crew resource management (CRM) or dispatcher resource management (DRM) initial training, as applicable, with that certificate holder or with another certificate holder. (FAA 1996)

[*] 14 CFR 25.1302 Installed Systems and Equipment for Use by the Flightcrew. http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgFAR.nsf/0/FE0119F0EBD3BAC086257B9C0051C97C?OpenDocument&Highlight=25.1302

[†] As with all regulations, the regulatory material should be read and considered in its entirety, together with other applicable regulations.

The requirement extends beyond air carriers operating under Part 121. On December 20, 1995, the FAA published Air Carrier and Commercial Operator Training Programs. This final rule required CRM training for crew members in their training programs by certificate holders conducting operations under part 135 that are required to comply with part 121 training and qualification requirements, such as those certificate holders that conduct commuter operations with airplanes for which two pilots are required by aircraft certification rules, and those that conduct commuter operations with airplanes having a passenger seating configuration of 10 seats or more.

The regulation itself does not specify the content of the training, but Advisory Circular (AC) 120-51E (FAA 2004) provides guidance for the content of U.S. operator training programs to address CRM. Subjects such as crew coordination and communication, error management, and flight-crew monitoring are specifically described in the AC. This AC also discusses the importance of pre- and post-training session briefings, and ways to evaluate the pilots' performance as a result of the training, among other topics. As an example of related guidance outside the United States, CAA UK (2006) provides guidance for the content of CRM training.

Moreover, as with all the operating regulations, the requirement for CRM training for flight crews is a continuous applicability requirement. Thus, improvements to the guidance can be made and applied as more is learned about effective implementation of training for CRM.

The FAA also recognizes that human factors is an important element of effective flight-crew procedures. The design of procedures should embody that coordination. Degani and Weiner (1994) describe that there are several aspects to design of the procedures that can promote crew coordination:

1. *Reduced variance*: The procedure triggers a predetermined and expected set of actions.
2. *Feedback*: Procedures specify expected feedback to other crew members (e.g., callouts). This feedback can detail (1) the current, and/or expected system state; (2) the actions that are currently being conducted; (3) the system outcome; and (4) an indication of task completion. There are several ways in which this feedback is provided: (1) verbally (callouts, callback, etc.); (2) nonverbally (gestures, manual operation—such as pulling down the gear lever); (3) via the interface (when the configuration of the system is significantly changed, for example, all displays are momentarily blank when power is switched from APU to engine-driven generators, this provides clear feedback to the other pilot); and (4) via the operating environment (when slats/flaps are extended during approach, there is a clear aerodynamic feedback—pitch change).
3. *Information transfer*: Procedures convey, or transfer, information from one agent to others (e.g., *the after takeoff checklist is complete).*

Another area that is important to consider for crew coordination is the delineation of duties among the Pilot Flying (PF), the Pilot Not Flying (PNF)/Pilot Monitoring (PM), and the Flight Engineer (if present). This includes the identification of who does which tasks, which pilot calls for particular procedures, which pilot reads them and which one responds.

The FAA has published an advisory circular that provides guidance for implementation of Standard Operating Procedures (SOPs) that address these areas,* each task, and that mental model is founded on SOPs. The procedures templates included in the AC provide recommended steps for crew coordination and communication tasks.

This AC specifically highlights the need for pilots to perform monitoring tasks, based on recognition of the role that inadequate monitoring played in previous accidents. For example, the National

* AC 120-71B Standard Operating Procedures and Pilot Monitoring Duties for Flight Deck Crewmembers. http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/CF313985D7C52500862580A500692715?OpenDocument&Highlight=120-71b

Transportation Safety Board has identified that inadequate crew monitoring or challenging was involved in 84% of crew-involved accidents (NTSB 1994, Sumwalt 2004).

The AC also reflects the conversion of the term *Pilot Not Flying* to *Pilot Monitoring* to reflect what the pilot *is* doing, rather than what the pilot is not doing. In addition, it helps one to emphasize the importance of the monitoring task. This emphasis must be part of the philosophy that forms the foundation of the SOPs.

Another area that can involve application of HF is the evaluation of operational approvals. The general process of approval or acceptance of certain operations, programs, documents, procedures, methods, or systems is an orderly method used by FAA inspectors to ensure that such items meet regulatory standards in the operating rules and provide for safe operating practices.* This can vary from evaluation of a single system (such as an Electronic Flight Bag) or operations that involve equipment, flight crew training, and flight-crew procedures (such as Performance-Based Navigation operations [Barhydt and Adams 2006]).

CONCLUDING REMARKS

The current chapter has presented a regulatory perspective on HF, given primarily from a U.S. point of view. It is not comprehensive, as HF considerations can be found throughout the regulatory material related to flight-deck airworthiness, flight-crew training, and flight-crew operations and procedures—among other application areas.

The FAA and other regulatory authorities around the world recognize the importance of HF as an important contributor to aviation safety. Although most of this chapter has focused on the pilots and flight decks, the regulatory system is recognizing the importance of resource management for other personnel in the aviation system, including dispatchers (as evidenced by the requirement for dispatcher resource management training), stated earlier, and guidance for training of maintenance personnel (FAA 2000).

This propagation of resource management considerations throughout the regulatory material reflects the growing understanding of the importance of this area—but it needs to be even more widespread. Application of CRM concepts to air traffic personnel, to the communication and coordination between pilots and ATS, among pilots, maintenance, dispatchers, cabin crew, and others remain important and can be improved even further.

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