Appendix 3. Top 33 Deficiencies Identified by the HF HWG

Topic Working Group Identifier	*Description of Deficiency*
HMI -1	Lack of information on and definition of feedback requirements
HMI –2	Design of the autopilot/autothrottle human-machine interface
HMI –5	Lack of criteria\guidance on understanding of automation behavior [pilot knowledge, skills, etc]
HMI –8	Standardization is not addressed in regulations/guidance.
HMI -9	Human Machine Interface – Lack of guidance on error resistance
Information 1	Information Required – Lack of guidance on what information is required and when it is needed.
Information 4	Information – Consistency of presented information
Displays 6	FAR25.703 Takeoff Warning Systems
Displays 13	FAR/JAR 25.777 Cockpit controls.
General 18	AR/JAR 25.1581 No regulation or AC guidance about distributing automation philosophy in users guides or pilot manuals
Extra General 3	AC 25-15Approval Of Flight Management Systems In Transport Category Aircraft 3
Pilot Characteristics 2	Pilot population characteristics that apply
Pilot Characteristics 4	Consistency with pilot expectations
Pilot Characteristics 5	Lack of guidance on the implication of the system design on the crew workload
Pilot Characteristics 7	Lack of guidance on the scenarios to use for testing design and no guidance on evaluators (pilots) background and training
Pilot Characteristics 9	Lack of criteria/guidance on “exceptional piloting skill or alertness” (e.g., how this is to be interpreted with respect to mode awareness issues with autoland systems)
Controls 1	Controls all aspects
Controls 2	Tasks that require controls
Controls 5	Accessibility and Operability
Controls 7	Consistency with other controls
Controls 8	Distinguishability from other controls

Topic Working Group Identifier	***Description of Deficiency***
Controls 10	Error tolerance
FAR- 1	The design of the system (i.e., intended function from the designer's perspective) may be inconsistent with the operational environment.
FAR- 2	FAR/JAR 25.1303 Flight and Navigation Instruments – inadequate guidance
FAR- 3	FAR/JAR 25.1305, Powerplant Instruments
FAR- 5	FAR/JAR 25.1309, Equipment, systems, and installations
FAR- 7	Warning, caution and advisory lights
FAR- 8	FAR/JAR 25.1323 Airspeed indicating system.
FAR -9	FAR/JAR 25.1329 Automatic Pilot system
FAR- 13	AC 20-73, Aircraft Ice Protection
FAR -14	AC 25-11 Transport Category Airplane Electronic Display Systems
Regulatory 1	Lack of guidance on the scenarios to use for testing design. No guidance on the test evaluator (pilots) background and training. This relates to testing.
Regulatory 6	Lack of guidance on non-essential systems

Appendix 4. Membership and Meetings

Since the launch of Human Factors HWG activity in October 1999, meetings have been held on a quarterly basis and lasted three to four days, as needed. Eighteen meetings were held, distributing the locations on both sides of the Atlantic Ocean so as to roughly balance the travel costs among participants.

Meeting Nr.	Period	Location	Hosted by
1	October 1999	Seattle	Boeing
2	January 2000	Toulouse	Airbus
3	April 2000	Phoenix	Honeywell
4	June 2000	Montreal	Bombardier
5	October 2000	Amsterdam	NLR
6	January 2001	Seattle	BF Goodrich
7	April 2001	Brighton	UK CAA
8	June 2001	Munich	Dornier
9	October 2001	Boston	FAA
10	January 2002	Long Beach	FAA
11	April 2002	Paris	DGAC
12	June 2002	Ispra	JRC
13	October 2002	Washington DC	FAA / ALPA
14	January 2003	West Palm Beach	Embraer
15	April 2003	Cheltenham	Smiths
16	June 2003	Ottawa	Transport Canada
17	October 2003	Linköping	Saab
18	February 2004	Paris	DGAC

Along the four years activity period, membership has evolved, maintaining an average of 30-32 members with a consistent core of about 20. The co-chairs were attentive to keep the group balanced in terms of expertise (HF specialist vs. certification specialists vs. designers vs. pilots), origin (North America, South America, and Europe) and organizations (authorities vs. industry) represented. This balance was crucial to get all the pertaining opinions and perspectives regarding the task related issues. The following list includes all persons having participated in the group activity together with the organization each represented.

List of members:

1- Current Members

Name	**Organization**
Abbott, Kathy	FAA
Beaujard, Florence	Airbus
Bousquie, Jean-François	Airbus
Carr, Tom	Garmin
Crane, Jean	Boeing
Deharvengt, Stéphane	JAA Representative
Donovan, Colleen	FAA
Emmerson, Paul	BAE Systems
Gagnon, Pierre	Bombardier
Garloch, Julie	Rockwell-Collins
Graeber, Curt	Boeing
Harris, Don	Cranfield University
Hecht, Sharon	Research Integrations
Jorna, Peter	NLR
Kelly, Brian	Boeing
Lawrence, Simon	ALPA
Lyall, Beth	Research Integrations
McConnell, John	FAA Representative
Menini, Eduardo	Embraer
Newman, Pam	UK Small Industries
Reuzeau, Florence	Airbus
Ronceray, Didier	Airbus
Singer, Gideon	Saab
Starr, Alison	Smiths Industries
Stephen, Don	Transport Canada
Venn, Paula	IFALPA
Thiel, Guy	FAA
Walsh, Christine	Boeing

2- Former active members that left the group for various reasons:

Name	Organization
Armstrong, Don	FAA
Birowo, Imam	Dornier
Boyd, Stephen	FAA
Courteney, Hazel	CAA
Fiore, Eric (✞)	Bombardier
Hicks, Marck	SEA
Imrich, Tom	FAA
Kimball, Ken	Cessna
Leard, Tom	Honeywell
Landy, Michael	BF Goodrich
May, Doug	Bombardier
New, Michael	IFALPA
Newman, Terry	JAA/CAA
Nibbelke, Rene	BAE
Proust, Jean-Michel	Air France
Reinhold, Svenja	Dornier
Riley, Vic	Honeywell

3- Occasional attendees

Name	Organization
Berner, Ann	Aero Engineering
Bresley, Bill	Universal Avionics
Chappel, Sherry	Delta Technology
Dekker, Sidney	Linköping Inst of Tech
Delesalle, Eric	Sogerma
Fabre, François	JAA
Glover, Howard	Honeywell
Gurney, Dan	BAE
Julie, Marcel	Dassault
Price, Alan	Delta Airlines
Rebender Georges	JAA
Schwartz, Patricia	American Airlines
Shamo, Marcia	Avionitek
Sam Slentz	Universal Avionics
Vint, Rebekah	Research Integrations
Wilson, Jennifer	Research Integrations

Appendix 5. Description of Relevant Regulations

14 CFR 25:

14 CFR 25.671(a) Pilot compartment. (as amended 4/30/1965)
Each control and control system must operate with the ease, smoothness, and positiveness appropriate to its function.

14 CFR 25.771(a) Pilot compartment. (as amended 4/30/1965)
Each pilot compartment and its equipment must allow the minimum flight crew (established under Sec. 25.1523) to perform their duties without unreasonable concentration or fatigue.

14 CFR 25.771(c) Pilot compartment. (as amended 4/30/1965)
If provision is made for a second pilot, the airplane must be controllable with equal safety from either pilot seat.

14 CFR 25.771(e) Pilot compartment. (as amended 4/30/1965)
Vibration and noise characteristics of cockpit equipment may not interfere with safe operation of the airplane.

14 CFR 25.777 Cockpit controls. (as amended 12/1/1978)
(a) Each cockpit control must be located to provide convenient operation and to prevent confusion and inadvertent operation.
(b) The direction of movement of cockpit controls must meet the requirements of Sec. 25.779. Wherever practicable, the sense of motion involved in the operation of other controls must correspond to the sense of the effect of the operation upon the airplane or upon the part operated. Controls of a variable nature using a rotary motion must move clockwise from the off position, through an increasing range, to the full on position.
(c) The controls must be located and arranged, with respect to the pilots' seats, so that there is full and unrestricted movement of each control without interference from the cockpit structure or the clothing of the minimum flight crew (established under Sec. 25.1523) when any member of this flight crew, from 5'2" to 6'3" in height, is seated with the seat belt and shoulder harness (if provided) fastened.
(d) Identical powerplant controls for each engine must be located to prevent confusion as to the engines they control.
(e) Wing flap controls and other auxiliary lift device controls must be located on top of the pedestal, aft of the throttles, centrally or to the right of the pedestal centerline, and not less than 10 inches aft of the landing gear control.
(f) The landing gear control must be located forward of the throttles and must be operable by each pilot when seated with seat belt and shoulder harness (if provided) fastened.
(g) Control knobs must be shaped in accordance with Sec. 25.781. In addition, the knobs must be of the same color, and this color must contrast with the color of the control knobs for other purposes and the surrounding cockpit.
(h) If a flight engineer is required as part of the minimum flight crew (established under Sec. 25.1523), the airplane must have a flight engineer station located and arranged so that the flight crewmembers can perform their functions efficiently and without interfering with each other.

14 CFR 25.779 Motion and effect of cockpit controls (as amended 8/20/1990).
Cockpit controls must be designed so that they operate in accordance with the following movement and actuation:
(a) Aerodynamic controls:
(1) Primary.

Controls	*Motion and effect*
Aileron	Right (clockwise) for right wing down.

Elevator	Rearward for nose up.
Rudder	Right pedal forward for nose right.

(2) Secondary.

Controls	*Motion and effect*
Flaps (or auxiliary lift devices).	Forward for flaps up; rearward for flaps down.
Trim tabs (or equivalent).	Rotate to produce similar rotation of the airplane about an axis parallel to the axis of the control.

(b) Powerplant and auxiliary controls:

(1) Powerplant.

Controls	*Motion and effect*
Power or thrust	Forward to increase forward thrust and rearward to increase rearward thrust.
Propellers	Forward to increase rpm.
Mixture	Forward or upward for rich.
Carburetor air heat	Forward or upward for cold.
Super-charger	Forward or upward for low blower. For turbosuperchargers, forward, upward, or clockwise, to increase pressure.

(2) Auxiliary.

Controls	*Motion and effect*
Landing gear	Down to extend.

14 CFR 25.1301 Function and installation. (10/3/1964)

Each item of installed equipment must--

(a) Be of a kind and design appropriate to its intended function;

(b) Be labeled as to its identification, function, or operating limitations, or any applicable combination of these factors;

(c) Be installed according to limitations specified for that equipment; and

(d) Function properly when installed.

14 CFR 25.1309(a) Equipment, systems, and installations.(as amended 9/1/1977)

The equipment, systems, and installations whose functioning is required by this subchapter, must be designed to ensure that they perform their intended functions under any foreseeable operating condition.

14 CFR 25.1309(c) Equipment, systems, and installations.(as amended 9/1/1977)

Warning information must be provided to alert the crew to unsafe system operating conditions, and to enable them to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors which could create additional hazards.

14 CFR 25.1523 Minimum flight crew. (as amended 5/28/1965)

The minimum flight crew must be established so that it is sufficient for safe operation, considering--

(a) The workload on individual crewmembers;
(b) The accessibility and ease of operation of necessary controls by the appropriate crewmember; and
(c) The kind of operation authorized under Sec. 25.1525.
The criteria used in making the determinations required by this section are set forth in Appendix D.
14 CFR 25 Appendix D Criteria for determining minimum flight crew. (as amended 5/28/1965)
The following are considered by the Agency in determining the minimum flight crew under Sec. 25.1523:

a. *Basic workload functions*. The following basic workload functions are considered:
(1) Flight path control.
(2) Collision avoidance.
(3) Navigation.
(4) Communications.
(5) Operation and monitoring of aircraft engines and systems.
(6) Command decisions.

b. *Workload factors*. The following workload factors are considered significant when analyzing and demonstrating workload for minimum flight crew determination:
(1) The accessibility, ease, and simplicity of operation of all necessary flight, power, and equipment controls, including emergency fuel shutoff valves, electrical controls, electronic controls, pressurization system controls, and engine controls.
(2) The accessibility and conspicuity of all necessary instruments and failure warning devices such as fire warning, electrical system malfunction, and other failure or caution indicators. The extent to which such instruments or devices direct the proper corrective action is also considered.
(3) The number, urgency, and complexity of operating procedures with particular consideration given to the specific fuel management schedule imposed by center of gravity, structural or other considerations of an airworthiness nature, and to the ability of each engine to operate at all times from a single tank or source which is automatically replenished if fuel is also stored in other tanks.
(4) The degree and duration of concentrated mental and physical effort involved in normal operation and in diagnosing and coping with malfunctions and emergencies.
(5) The extent of required monitoring of the fuel, hydraulic, pressurization, electrical, electronic, deicing, and other systems while en route.
(6) The actions requiring a crewmember to be unavailable at his assigned duty station, including: observation of systems, emergency operation of any control, and emergencies in any compartment.
(7) The degree of automation provided in the aircraft systems to afford (after failures or malfunctions) automatic crossover or isolation of difficulties to minimize the need for flight crew action to guard against loss of hydraulic or electric power to flight controls or to other essential systems.
(8) The communications and navigation workload.
(9) The possibility of increased workload associated with any emergency that may lead to other emergencies.
(10) Incapacitation of a flight crewmember whenever the applicable operating rule requires a minimum flight crew of at least two pilots.

(c) *Kind of operation authorized*. The determination of the kind of operation authorized requires consideration of the operating rules under which the airplane will be operated. Unless an applicant desires approval for a more limited kind of operation, it is assumed that each airplane certificated under this Part will operate under IFR conditions.

EASA CS 25:

Aircraft, including any installed product, part and appliance shall comply with the EASA Essential Requirements (ER) for Airworthiness. ER for airworthiness states that “Information needed for the safe conduct of the flight and information concerning unsafe conditions must be provided to the crew, or maintenance personnel, as appropriate, in a clear, consistent and unambiguous manner. Systems, equipment and controls, including signs and announcements must be designed and located to minimize errors which could contribute to the creation of hazards”.

Certification Specifications 25 (CS-25), which is the applicable airworthiness code for ensuring compliance with the ER, only address those issues by equipment specific rules and AMC or by general applicability rules that lack adequate guidance. The EASA rules corresponding to those listed for 14 CFR 25 above are completely harmonized with the exception of CS 25.1301, CS 25.1309(a) and 25.1309(c). The full text of CS 25.1301 and CS 25.1309 is as follows:

CS 25.1301 Function and installation

(See AMC 25.1301)

Each item of installed equipment must –

(a) Be of a kind and design appropriate to its intended function;

(b) Be labeled as to its identification, function, or operating limitations, or any applicable combination of these factors. (See AMC 25.1301(b).)

(c) Be installed according to limitations specified for that equipment;

25.1309 Equipment, systems, and installations

(See AMC 25.1309)

The requirements of this paragraph, except as identified below, are applicable, in addition to specific design requirements of CS-25, to any equipment or system as installed in the airplane. Although this paragraph does not apply to the performance and flight characteristic requirements of Subpart B and the structural requirements of Subparts C and D, it does apply to any system on which compliance with any of those requirements is dependent. Certain single failures or jams covered by CS 25.671(c)(1) and CS 25.671(c)(3) are excepted from the requirements of CS 25.1309(b)(1)(ii).

Certain single failures covered by CS 25.735(b) are excepted from the requirements of CS 25.1309(b).

The failure effects covered by CS 25.810(a)(1)(v) and CSCS 25.812 are excepted from the requirements of CS 25.1309(b). The requirements of CS 25.1309(b) apply to powerplant installations as specified in CS 25.901(c).

(a) The airplane equipment and systems must be designed and installed so that:

(1) Those required for type certification or by operating rules, or whose improper functioning would reduce safety, perform as intended under the aeroplane operating and environmental conditions.

(2) Other equipment and systems are not a source of danger in themselves and do not adversely affect the proper functioning of those covered by sub-paragraph (a)(1) of this paragraph.

(b) The airplane systems and associated components, considered separately and in relation to other systems, must be designed so that -

(1) Any catastrophic failure condition

(i) is extremely improbable; and

(ii) does not result from a single failure; and

(2) Any hazardous failure condition is extremely remote; and

(3) Any major failure condition is remote.

(c) Information concerning unsafe system operating conditions must be provided to the crew to enable them to take appropriate corrective action. A warning indication must be provided if immediate corrective action is required. Systems and controls, including indications and annunciations must be designed to minimize crew errors, which could create additional hazards.

As an interim solution to comply with the above-mentioned ER referring to human performance for flight deck design, the assessment of human factors aspects of flight deck design is done with JAA Interim Policy 25-14 published on 15 March 2001.

Appendix 6. List of Typical Flight Crew Errors

When performing the experience related review of safety records and accident reports, the group developed a matrix which listed, to the best of the HWG's knowledge, all relevant issues regarding human performance or error on the flight deck. The matrix remained an internal working document from which to extract events focused on actual crew error with actual safety consequences. The intent was to have an as extensive as possible list of typical dangerous crew errors and to understand where design was involved or could help mitigate the error class.

We believe that the proposed rule and AC/AMC describe as much as can reasonably be expected from the design viewpoint to address these safety issues. However the matrix included many issues which cannot be treated or mitigated by this new material focused on design. Therefore, we decided that it would be beneficial to share this information with other organizations involved in aircraft safety so that they may use it in their own field of activity and possibly take relevant actions to address some of the issues.

The following is the list of those issues with some associated examples organized in terms of operational behavior. All these examples have resulted in serious safety consequences, eventually airplane losses. They are therefore valuable situations to be considered by all for the sake of aircraft safety.

1. Absence of reaction:
   The crew does not react when they are supposed to, following a stimulus (alert, airplane behavior,...)
   - No reaction to an engine failure
   - No reaction to failure warning
2. Procedural deviations:
   The crew doesn't act or react as they are supposed to, intentionally or unintentionally, according to basic airmanship behavior or type-specific procedures.
   - Engine start with lever not at idle
   - Take off abort after V1
   - Landing gear or aural warning C/B pulled because of permanent warning
   - Incorrect fuel balancing procedure leading to engine loss.
   - Reset of an active computer leading to upset
   - Procedure incomplete
3. Limitations transgressions:
   The crew performs an action out of the allowed envelope, therefore exceeding the limits of the airplane. Although these are most frequently violations, in some cases, these actions may be simple unintentional errors.
   - Surface or landing gear extension out of certified envelope
   - Inappropriate use of autoland (mainly exceeding autoland limitations on X-wind and contaminated runway)
   - Flight above maximum altitude
4. Pilot fighting against automation:
   This happens when the crew is surprised or not satisfied by the performance of an automatic system (in general, autopilot or autothrust) and reacts to override it instead of disconnecting the active system and then recovering manually. This pilot action may induce abnormal behavior of the systems that may lead to hazard or catastrophe.
   - Overriding AP without disconnecting, leading to deep out-of-trim condition
   - Overriding AT without disconnecting during flare, leading to inadvertent high thrust setting after landing

5. Incorrect data entry

   The crew fails to enter and correctly crosscheck safety critical values. Usually due to unchecked wrong key entries but may also arise from the wrong reading of correct information.
   - Wrong IRS alignment position
   - Wrong FLEX temperature
   - Wrong take-off speed

6. Energy management

   The crew fails to manage the speed of the airplane so as:
   - to keep the speed within the normal envelope, while having the ability to do so
   - to bring the airplane at the correct location with the correct speed, because of incorrect estimation of the acceleration/deceleration capabilities of the airplane, or unexpected requests from ATC (route shortening, "expedite FL")

   This generally results in undesired speeds such as excessively high speeds at landing, or excessively slow speeds in climb, but the contrary may also happen:
   - Inadvertent stalls (especially with one engine inoperative during circling or final turns)
   - Speed too high at threshold leading to runway overrun (especially when braking is poor and/or reversers are inoperative)
   - Use of AP modes that exceed the capability of the airplane (V/S, VNAV)
   - No use of available extra thrust when drastically under performing
   - Airbrakes not retracted during go around

7. Poor mastery of novel systems

   When novel and/or complex systems (e.g., TCAS, FMSs) are introduced, the associated training is insufficient to enable crew members to feel comfortable using the system without significant adverse issues which may result in crews feeling weak and dominated by the system (e.g., "How should I do this?"," What is it doing now ?"," Oops !", etc...)..

8. Fuel management

   The crew fails to manage the remaining fuel in the airplane so that fuel reserves at landing are abnormally low or so that, eventually, all engines flame out.
   - Poor check of remaining fuel or assessment of fuel leaks
   - Poor decision making on management of fuel reserves during diversion
   - Confusion on units (lbs versus kg)

9. Ice and consequences of icing awareness

   The crew failed to identify and/or react to prevailing icing conditions.
   - No recognition of icing
   - No application of procedure for flight in icing conditions

10. Information integrity

    The crew fails to sort between erroneous and correct data.
    - No detection of erroneous data (wrong database, navigation data, or anemometric information)
    - No reaction to actual failures when frequent erroneous warnings occur

11. Language

    The crew's mastery of English is insufficient for flying in occidental airplanes or airspaces.
    - Lack of or late understanding of presented information (displays, aural alerts, manuals, ATC clearances) for crew whose native language is not English.

12. Minimum altitude violation (even more critical in approach)

    When flying in instrument meteorological conditions, where visual ground contact is not present, the crew has to fly above declared minimum altitudes that insure proper ground clearances. When flying below these altitudes, the clearance is decreased and eventually zeroed, leading to CFIT.

13. Misuse of adjacent controls

    For some reason, the crew moves a control adjacent to the one that is supposed to be used. It should be noted that a chain of several elementary actions that are usually performed in sequence may be considered in this context as a single action.

    - Acting on hydraulics pumps P/Bs when thinking to perform the fuel balancing procedure, because of similar shape and close placement, despite not on the same panel.
    - Confusion between speed, heading, altitude knobs on AP interface
    - Shutdown of wrong engine
    - Feathering of the wrong propeller

14. Standardization issues

    Accustomed to equipment with given characteristics, crew members may be faced with other equipment whose characteristics are different, eventually reversed, thus favoring the probability of error.

    - "Inside-Out" versus "Outside-In" ADI
    - Data entry formats

15. Take-off configuration

    The crew takes off with a configuration that deeply penalizes performance. This may result in a considerably unsafe take-off, or in a rejected take-off, possibly ending in a runway overrun if the crew decision is late.

    - Take-off with Parking brake set
    - Take-off with bleeds ON, when they're supposed to be OFF due to performance requirements
    - Take-off with wrong T/O flaps configuration

16. Incorrect take-off data

    The parameters computed by the crew for take-off are wrong for some reason. Performance limited take-offs may be considerably unsafe.

    - Erroneous speeds
    - Erroneous weight
    - Erroneous flex temperature or derate
    - Late change of runway with no change of speeds
    - Use of wrong performance data (wrong a/c type, engine type, bleed, dry/wet...)

17. Wrong approach path

    - Flying across final approach course due to approach mode not properly armed (terrain may be on the opposite side)
    - Flying across Glideslope from above (with high vertical speed...) due to approach mode not properly armed
    - Wrong course selected with small offset (automatic roll out may be hazardous)
    - Wrong course selected with big offset (capture may be hazardous)
    - Wrong position at final descent initiation
    - Wrong execution of a clearance when vectored (wrong turn)

Appendix 7 – FAA Position Paper.

FAA Position Statement
for Submission in the Final Report of the
ARAC Human Factors Harmonization Working Group

The FAA concurs with and supports the proposed rule drafted by the Human Factors Harmonization Working Group (HFHWG). In addition, we have no specific disagreements with the general scope, structure or substantive content of the draft advisory circular. We believe, however, that this AC requires some additional guidance with respect to acceptable ways to show compliance to the proposed rule and to some of the other rules the draft document addresses. Upon formal receipt of the HFHWG recommendations, and as part of our normal process of using an ARAC Fast Track recommendation in the development of an NPRM and proposed AC, the FAA will develop this additional guidance material where needed.

The FAA considers both harmonization and consistency with the consensus of the HFHWG to be important. Therefore, during this development, we will work with the representatives from EASA/JAA and Transport Canada, and with other members of the HFHWG, to maintain harmonization of both the regulatory and guidance material and to maximize the consistency of this additional guidance with the consensus intent of the Working Group. Finally, we are in full support of the anticipated request by the HFHWG for a Phase 4 review of the draft NPRM package and proposed AC prior to publication.

Note: this Position Statement reflects the views of the FAA and is not intended to represent the position of the HFHWG or of any other member(s) of the HF HWG.