5.7 Integration

5.7.1 Introduction

Many systems, such as flight management systems, are integrated physically and functionally into the flight deck and may interact with other flight deck systems. It is important to consider a design not just in isolation, but in the context of the overall flight deck. Integration issues include where a display or control is installed, how it interacts with other systems, and whether there is internal consistency across functions within a multi-function display, as well as consistency with the rest of the flight deck's equipment.

CS 25.1302 requires that "…installed equipment must be shown, individually and in combination with other such equipment, to be designed so that qualified flight-crew members trained in its use can safely perform their tasks associated with its intended function …". To comply with this integration requirement, all flight deck equipment must be able to be used by the flight crew to perform their tasks, in any combination reasonably expected in service. Flight deck equipment includes interfaces to aeroplane systems the flight crew interacts with, such as controls, displays, indications, and annunciators.

Analyses, evaluations, tests and other data developed to establish compliance with each of the specific requirements in CS 25.1302 (a) through (d) should address integration of new or novel design features or equipment with previously approved features or equipment as well as with other new items. It should include consideration of the following integration factors:

— Consistency (see 5.7.2)

— Consistency trade-offs (see 5.7.3)

— Flight deck environment (see 5.7.4)

— Integration related workload and error (see 5.7.5)

5.7.2 Consistency

Consistency needs to be considered within a given system and across the flight deck. Inconsistencies may result in vulnerabilities, such as increased workload and errors, especially during stressful situations. For example, in some flight management systems, the format for entering latitude and longitude differs across the display pages. This may induce flight crew errors, or at least increase flight crew workload. Additionally, errors may result if latitude and longitude is displayed in a format that differs from formats on the most commonly used paper charts. Because of this, it is desirable to use formats that are consistent with other media whenever possible. Although trade-offs exist, as discussed in the next paragraph, the following are design attributes to consider for consistency within and across systems:

— Symbology, data entry conventions, formatting, colour philosophy, terminology, and labelling.

— Function and logic. For example, when two or more systems are active and performing the same function, they should operate consistently and use the same style interface.

— Information presented with other information of the same type that is used in the flight deck. For example, navigation symbology used on other flight deck systems or on commonly used paper charts should be considered when developing the symbology to be used on electronic map displays.

— The operational environment. It is important that a flight management system is consistent with the operational environment so that the order of the steps required to enter a clearance into the system is consistent with the order in which they are given by air traffic management.

Adherence to a flight deck design philosophy is one way to achieve consistency within a given system as well as within the overall flight deck. Another way is to standardise aspects of the design by using accepted, published industry standards such as the labels and abbreviations recommended in ICAO Annex 8400/5. The applicant might Standardise symbols used to depict navigation aids (the very high frequency omnidirectional ranges, VORs, for example), by following the conventions recommended in SAE ARP5289. However, inappropriate standardisation, rigidly applied, can be a barrier to innovation and product improvement. Additionally, standardisation may result in a standard to the lowest common denominator. Thus, guidance in this paragraph promotes consistency rather than rigid standardisation.

5.7.3 Consistency Trade-Offs

It is recognised that it is not always possible or desirable to provide a consistent flight crew interface. Despite conformance with the flight deck design philosophy, principles of consistency, etc, it is possible to negatively impact flight crew workload,. For example, all auditory alerts may adhere to a flight deck alerting philosophy, but the number of alerts may be unacceptable. Consistent format across the flight deck may not work when individual task requirements necessitate presentation of data in two significantly different formats. An example is a weather radar display formatted to show a sector of the environment, while a moving map display shows a 360 degree view. In such cases it should be demonstrated that the interface design is compatible with the requirements of the piloting task and can be used individually and in combination with other interfaces without interference to either system or function.

Additionally:

— The applicant should provide an analysis identifying each piece of information or data presented in multiple locations and show that the data is presented in a consistent manner or, where that is not true, justify why that is not appropriate.

— Where information is inconsistent, that inconsistency should be obvious or annunciated, and should not contribute to errors in information interpretation.

— There should be a rationale for instances where a system's design diverges from the flight deck design philosophy. Consider any impact on workload and errors as a result of this divergence.

— The applicant should describe what conclusion the flight crew is expected to draw and what action should be taken when information on the display conflicts with other information on the flight deck (either with or without a failure).

5.7.4 Flight Deck Environment

The flight deck system is influenced by physical characteristics of the aeroplane into which a system is integrated, as well as by operational environment characteristics. The system is subject to such influences on the flight deck as turbulence, noise, ambient light, smoke, and vibrations (such as those that may result from ice or fan blade loss). System design should recognise the effect of such influences on usability, workload, and crew task performance. Turbulence and ambient light, for example, may affect readability of a display. Flight deck noise may affect audibility of aural alerts. The applicant should also consider the impact of the flight deck environment for non-normal situations, such as unusual attitude recovery or regaining control of the aeroplane or system.

The flight deck environment includes the layout, or physical arrangement of the controls and information displays. Layout should take into account crew requirements in terms of:

— Access and reach (to controls).

— Visibility and readability of displays and labels.

— Task-oriented location and grouping of human-machine interaction elements.

An example of poor physical integration would be a required traffic avoidance system obscured by thrust levers in the normal operating position.

5.7.5 Integration Related Workload and Error

When integrating functions and/or equipment, designers should be aware of potential effects, both positive and negative, that integration can have on crew workload and its subsequent impact on error management. Systems must be designed and evaluated, both in isolation and in combination with other flight deck systems, to ensure that the flight crew is able to detect, reverse, or recover from errors. This may be more challenging when integrating systems that employ higher levels of automation or have a high degree of interaction and dependency on other flight deck systems.

Applicants should show that the integrated design does not adversely impact workload or errors given the context of the entire flight regime. Examples of such impacts would be increased time to:

— Interpret a function,

— Make a decision,

— Take appropriate actions.

Controls, particularly multi-function controls and/or novel control types, may present the potential for misidentification and increased response times. Designs should generally avoid multi-function controls with hidden functions, because they increase both crew workload and the potential for error.

Two examples of integrated design features that may or may not impact error and workload are as follows:

— Presenting the same information in two different formats. This may increase workload, such as when altitude information is presented concurrently in tape and round-dial formats. Yet different formats may be suitable depending on the design and the flight crew task. For example, an analog display of engine revolutions-per-minute can facilitate a quick scan, whereas a digital numeric display can facilitate precise inputs. The applicant is responsible for demonstrating compliance with CS 25.1523 and showing that differences in the formats do not result in unacceptable workload levels.

— Presenting conflicting information. Increases in workload and error may result from two displays depicting conflicting altitude information on the flight deck concurrently, regardless of format. Systems may exhibit minor differences between each flight-crew member station, but all such differences should be evaluated specifically to ensure that potential for interpretation error is minimised, or that a method exists for the flight crew to detect incorrect information, or that the effects of these errors can be precluded.

The applicant should show that the proposed function will not inappropriately draw attention away from other flight deck information and tasks in a way that degrades flight crew performance and decreases the overall level of safety. There are some cases where it may be acceptable for system design to increase workload. For example, adding a display into the flight deck may increase workload by virtue of the additional time flight-crew members spend looking at it, but the safety benefit the additional information provides may make it an acceptable trade-off.

Because each new system integrated into the flight deck may have a positive or negative effect on workload, each must be evaluated in isolation and combination with the other systems for compliance with CS 25.1523. This is to ensure that the overall workload is acceptable, i.e., that performance of flight tasks is not adversely impacted and that the crew's detection and interpretation of information does not lead to unacceptable response times. Special attention should be paid to CS-25 Appendix D and specifically compliance for items that the appendix lists as workload factors. They include "accessibility, ease, and simplicity of operation of all necessary flight, power, and equipment controls."

6. MEANS OF COMPLIANCE

This paragraph discusses considerations in selecting means of compliance. It provides six general acceptable means to demonstrate compliance in addressing human performance issues. These means of compliance are generic and have been used in certification programmes. The acceptable means of compliance to be used on any given project should be determined on a case-by-case basis, driven by the specific compliance issues. They should be developed and proposed by the applicant, and then agreed to by the Agency. Uses and limitations of each type of compliance means are provided in paragraph 6.3.

6.1 Selecting Means of Compliance

— The means of compliance discussed in this paragraph include:

— Statements of similarity (See paragraph 6.3.1),

— Design description (See paragraph 6.3.2),

— Calculations/analyses (See paragraph 6.3.3),

— Evaluations (See paragraph 6.3.4),

— Tests ( See paragraph 6.3.5),

There is no generic method to determine appropriate compliance means for a specific project. The choice of an appropriate compliance means or combination of several different means depends on a number of factors specific to a project.

Some certification projects may necessitate more than one means of demonstrating compliance with a particular requirement. For example, when flight testing in a conforming aeroplane is not possible, a combination of design review and part-task simulation evaluation may be proposed.

Answering the following questions will aid in selecting means of compliance.

— With which means of compliance will it possible to gather the required certification data?

— Will a single means of compliance provide all of the data or will several means of compliance be used in series or in parallel?

— What level of fidelity of the facility is required to collect the required data?

— Who will be the participants?

— What level of training is required prior to acting as a participant?

— How will the data from an evaluation be presented to show compliance?

— Will results of a demonstration be submitted for credit?

— If a test is required, what conformed facility will be used?

6.2 Discussion and Agreement with the Agency on Compliance Demonstrations

The applicant's proposal for means of compliance must be coordinated with the Agency to ensure that all aspects necessary for desired credit towards certification are achieved. These could include the planned scenarios, the necessary types of human performance issues to be explored, or the conditions under which the test will be conducted to provide a realistic environment for the evaluation.

6.3 Description of Means of Compliance

The six general means of compliance found to be acceptable for use in demonstrating compliance related to flight deck design are described in the following sub-paragraphs.

6.3.1 Statement of Similarity

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| **Description** |
| A statement of similarity is a description of the system to be approved and a description of a previously approved system detailing the physical, logical, and operational similarities with respect to compliance with requirements. |
| **Deliverable** |
| A statement of similarity could be part of a certification report, containing references to existing certification data/documents. |
| **Participants** |
| Not applicable. |
| **Conformity** |
| Not applicable. |

| Uses |
|---|
| It may be possible to substantiate the adequacy of a design by comparing it to previously certificated systems shown to be robust with respect to lack of contribution to crew error and/or capability of the flight crew to manage the situation should an error occur. This avoids repetition of unnecessary effort to justify the safety of such systems. |
| **Limitations** |
| A statement of similarity to show compliance must be used with care. The flight deck should be evaluated as a whole, not as merely a set of individual functions or systems. Two functions or features previously approved on separate programmes may be incompatible when combined on a single flight deck. Also, changing one feature in a flight deck may necessitate corresponding changes in other features, to maintain consistency and prevent confusion. |
| **Example** |
| If the window design in a new aeroplane is identical to that in an existing aeroplane, a statement of similarity may be an acceptable means of compliance to meet CS 25.773. |

6.3.2 Design Description

The applicant may elect to substantiate that the design meets the requirements of a specific paragraph by describing the design. Applicants have traditionally used drawings, configuration descriptions, and/or design philosophy to show compliance. Selection of participants and conformity are not relevant to this means of compliance.

a. Drawings

| Description |
|---|
| Layout drawings or engineering drawings, or both, depicting the geometric arrangement of hardware or display graphics. |
| **Deliverable** |
| The drawing, which can be part of a certification report. |
| **Uses** |
| Applicants can use drawings for very simple certification programmes when the change to the flight deck is very simple and straightforward. Drawings can also be used to support compliance findings for more complex interfaces. |
| **Limitations** |
| The use of drawings is limited to physical arrangements and graphical concerns. |

b. Configuration Description

| Description |
|---|
| A configuration description is a description of the layout, general arrangement, direction of movement, etc., of regulated item. It can also be a reference to documentation, giving such a description (for example from a different project with similar layout) . It could be used to show the relative locations of flight instruments, groupings of control functions, allocation of colour codes to displays and alerts, etc. |
| **Deliverable** |
| Explanation of functional aspects of crew interface: text description of certification item and/or functional aspects of the crew interface with the system (with visuals as appropriate). |
| **Uses** |
| Configuration descriptions are generally less formalised than engineering drawings. They are developed to point out features of the design that support a finding of compliance. In some cases, such configuration descriptions may provide sufficient information for a finding of compliance. More often, however, they provide important background information, while |

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| final confirmation of compliance is found through other means, such as demonstrations or tests. The background information provided by configuration descriptions may significantly reduce the complexity and/or risk associated with demonstrations or tests. The applicant will have already communicated how a system works with the configuration description and any discussions or assumptions may have already been coordinated. |
| **Limitations** |
| Configuration descriptions may provide sufficient information for a finding of compliance with a specific requirement. More often, though, they provide important background information, while final confirmation of compliance is found by other means, such as demonstrations or tests. Background information provided by configuration descriptions may significantly reduce the complexity and/or risk associated with the demonstrations or tests. |

c. Design philosophy

| **Description** |
|---|
| A design philosophy approach can be used to demonstrate that an overall safety-centred philosophy, as detailed in the design specifications for the product/system or flight deck, has been applied. |
| **Deliverable** |
| Text description of certification item and/or functional aspects of the crew interface with the system (with figures and drawings as appropriate) and its relationship to overall design philosophy. |
| **Uses** |
| Documents the ability of a design to meet requirements of a specific paragraph. |
| **Limitations** |
| In most cases, this means of compliance will be insufficient as the sole means to demonstrate compliance. |
| **Example** |
| Design philosophy may be used as a means of compliance when a new alert is added to the flight deck, if the new alert is consistent with the acceptable existing alerting philosophy. |

### 6.3.3 Calculation/analysis

| **Description** |
|---|
| Calculations or engineering analyses ("paper and pencil" assessments) that do not require direct participant interaction with a physical representation of the equipment. |
| **Deliverable** |
| Report detailing the analysis, its components, evaluation assumptions, and basis for decision making. The report details results and conclusions. |
| **Participants** |
| Conducted by the applicant. |
| **Conformity** |
| Not applicable. |
| **Uses** |
| Provides a systematic evaluation of specific or overall aspects of the human interface part of the product/system/flight deck. May be specified by guidance material. |
| **Limitations** |
| Carefully consider the validity of the assessment technique for analyses not based on advisory material or accepted industry standard methods. Applicants may be asked to validate any computational tools used in such analyses. If analysis involves comparing measured |

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| characteristics to recommendations derived from pre-existing research (internal or public domain), the applicant may be asked to justify the applicability of data to the project. |
| **Example** |
| An applicant may conduct a vision analysis to demonstrate that the flight crew has a clear and undistorted view out the windows. Similarly, an analysis may also demonstrate that flight, navigation and powerplant instruments are plainly visible from the flight-crew member station. The applicant may need to validate results of the analysis in ground or flight test. |

### 6.3.4 Evaluations

The applicant may use a wide variety of part-task to full-installation representations of the product/system or flight deck for evaluations. These all have two characteristics in common: (1) the representation of the human interface and the system interface do not necessarily conform to the final documentation, and (2) the certification Agency is generally not present. The paragraphs below address mock-ups, part-task simulations, full simulations, and in-flight evaluations that typically make up this group of means of compliance. A mock-up is a full-scale, static representation of the physical configuration (form and fit). It does not include functional aspects of the flight deck and its installed equipment.

| **Description** |
|---|
| Evaluations are assessments of the design conducted by the applicant, who then provides a report of the results to the Agency. |
| **Deliverable** |
| A report, delivered to the Agency. |
| **Participants** |
| Applicant and possibly Agency |
| **Facilities** |
| An evaluation can be conducted in a mock-up, on a bench, or in a laboratory, simulator or aeroplane. |
| **Conformity** |
| Conformity is not required. |
| **Mock-up evaluation** |
| Mock-ups can be used as representations of the design, allowing participants to physically interact with the design. Three-dimensional representations of the design in a CAD system, in conjunction with three-dimensional models of the flight deck occupants, have also been used as “virtual” mock-ups for certain limited types of evaluations. Reach assessments, for example, can use either type of mock-up. |
| **Example of a mock-up evaluation** |
| An analysis to demonstrate that controls are arranged so that flight-crew members from 1.58 m (5ft 2 inches) to 1.91 m (6ft 3 inches) in height can reach all controls. This analysis may use computer-generated data based on engineering drawings. The applicant may demonstrate results of the analysis in the actual aeroplane. |
| **Bench or laboratory evaluation** |
| The applicant can conduct an evaluation using devices emulating crew interfaces for a single system or a related group of systems. The applicant can use flight hardware, simulated systems, or combinations of these. |
| **Example of a bench or laboratory evaluation** |
| A bench evaluation for an integrated system could be an avionics suite installed in a mock-up of a flight deck, with the main displays and autopilot controls included. Such a tool may be |

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| valuable during development and for providing system familiarisation to the Agency. However, in a highly integrated architecture, it may be difficult or impossible to assess how well the avionics system will fit into the overall flight deck without more complete simulation or use of the actual aeroplane. |
| **Simulator evaluation** |
| A simulator evaluation uses devices that present an integrated emulation (using flight hardware, simulated systems, or combinations of these) of the flight deck and the operational environment. These devices can also be "flown" with response characteristics that replicate, to some extent, responses of the aeroplane. Simulation functional and physical fidelity (or degree of realism) requirements will typically depend on the configurations, functions, tasks, and equipment. |
| **Aeroplane evaluation** |
| This is an evaluation conducted in the actual aeroplane. |
| **Uses** |
| Traditionally, these types of activities have been used as part of the design process without formal certification credit. However, these activities can result in better designs that are more likely to be compliant with applicable requirements. |
| **Limitations** |
| Evaluations are limited by the extent to which the facilities actually represent the flight deck configuration and realistically represent flight crew tasks. As flight deck systems become more integrated, part-task evaluations may become less useful as a means of compliance, even though their utility as engineering tools may increase. |

### 6.3.5 Tests

Tests are means of compliance conducted in a manner very similar to evaluations (described above in paragraph 6.3.4). There is, however, a significant difference. Tests require a conforming product/system and system interface. A test can be conducted on a bench, in a laboratory, in a simulator, or on an aeroplane.

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|---|
| **Description** |
| Tests are assessments of the design conducted with the Agency present. |
| **Deliverable** |
| A report, delivered to the Agency. |
| **Participants** |
| Applicant and possibly Agency |
| **Facilities** |
| A test can be conducted on a bench or in a laboratory, simulator or an aeroplane. |
| **Conformity** |
| The facility must be conforming. |
| **Bench or laboratory test** |
| This type of testing is usually confined to showing that components perform as designed. Bench tests are usually not enough to stand alone as a means of compliance. They can, however, provide useful supporting data in combination with other means. |
| **Example of a bench or laboratory test** |
| The applicant might show visibility of a display under the brightest of expected lighting conditions with a bench test, provided there is supporting analysis to define the expected lighting conditions. Such supporting information might include a geometric analysis to show potential directions from which the sun could shine on the display, with calculations of expected viewing angles. These conditions might then be reproduced in the laboratory. |

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| **Conformity related to a bench or laboratory test** |
| The part or system would need to be conforming to show compliance. |
| **Simulator test** |
| A simulator test uses devices that present an integrated emulation (using flight hardware, simulated systems, or combinations of these) of the flight deck and the operational environment. They can also be "flown" with response characteristics that replicate the responses of the aeroplane. The applicant should determine the physical and functional fidelity requirements of the simulation as a function of the issue under evaluation. |
| **Simulator test conformity and fidelity issues** |
| Only conforming parts of the flight deck may be used for simulator tests. Applicants may use a flight crew training simulator to validate most of the normal and emergency procedures for the design, and any workload effects of the equipment on the flight crew. If the flight deck is fully conforming and the avionics are driven by conforming hardware and software, then the applicant may conduct and use integrated avionics testing for showing compliance. Note that not all aspects of the simulation must have a high level of fidelity for any given compliance issue. Rather, assess fidelity requirements in view of the issue being evaluated. |
| **Aeroplane test** |
| Aeroplane tests can be conducted either on the ground or in flight. |
| **Example of an aeroplane test** |
| An example of a ground test is an evaluation for the potential of reflections on displays. Such a test usually involves covering the flight deck windows to simulate darkness and setting the flight deck lighting to desired levels. This particular test may not be possible in a simulator, because of differences in the light sources, display hardware, and/or window construction. Flight testing during certification is the final demonstration of the design. These are tests conducted in a conforming aeroplane during flight. The aeroplane and its components (flight deck) are the most representative of the type design to be certified and will be the closest to real operations of the equipment. In-flight testing is the most realistic testing environment, although it is limited to those evaluations that can be conducted safely. Flight testing can be used to validate and verify other tests previously conducted during the development and certification programme. It is often best to use flight testing as final confirmation of data collected using other means of compliance, including analyses and evaluations. |
| **Limitations of flight tests** |
| Flight tests may be limited by the extent to which flight conditions of particular interest (for example, weather, failure, unusual attitudes) can be found/produced and then safely evaluated in flight. Also note that flight testing on the aeroplane provides the least control over conditions of any of the means of compliance. The Agency and the applicant should thoroughly discuss how and when flight tests and their results will be used to show compliance. |

[Amdt 25/3]