U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: MINIMUM FLIGHTCREW

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Initiated by: ANM-110 **Change:**

1. PURPOSE. This advisory circular (AC) sets forth a method of compliance with the requirements of § 25.1523 of the Federal Aviation Regulations (FAR), which contains the certification requirements for minimum flightcrew on transport category airplanes. As with all AC material, it is not mandatory and does not constitute a regulation. It is for guidance purposes only.

2. RELATED FAR SECTIONS. Section 25.1523 of the FAR, as amended through Amendment 25-3.

3. BACKGROUND. In early 1981, the President established a task force on aircraft crew complement which was directed to make "its recommendation whether operation of the new generation of commercial jet transport airplanes by two-person crews is safe and certification of such airplanes is consistent with the Secretary's duty under the certification provisions of the Federal Aviation Act of 1958 to promote flight safety." Several recommendations were made in the Report of the President's Task Force on Aircraft Crew Complement, dated July 2, 1981, including one that suggested that the agency complete and keep current Section 187 (Minimum Flightcrew) of FAA Order 8110.8, Engineering Flight Test Guide for Transport Category Airplanes. The agency agreed with the recommendation and took steps to complete these criteria for inclusion into the Order. However, in late 1982 the agency decided to upgrade the entire contents of the Order to advisory circulars to make such material formally available to the general public.

4. DISCUSSION.

a. Under § 25.1523, the minimum flightcrew for a transport category airplane must be established so that it is sufficient for safe operation considering:

(1) The workload on individual crewmembers;

(2) The accessibility and ease of operation of necessary controls by the appropriate crewmembers; and

(3) The kind of operation described in § 25.1525.

b. The criteria used in making the determinations required by § 25.1523 are set forth in Appendix D of Part 25.

c. The procedures for determining compliance with § 25.1523 and Appendix D may vary in complexity depending on whether the certification is:

(1) A new model;

(2) A follow-on model;

(3) A modification to reduce the original crew size of an already approved airplane; or

(4) A type design change or supplemental type certificate (STC) program expected to result in a substantial increase in the workload of any flight crewmember.

d. Although § 25.1523 addresses the accessibility and ease of operation of necessary controls in addition to individual workload, the methods of evaluating workload are far less straightforward, and usually dominate the determination of the minimum flightcrew. Further, Part 25 contains no rules specifically addressing the human factors issues encountered in workload evaluations, so that consideration of such issues tend to be viewed as falling into minimum crew evaluations. It is recognized that the size of the minimum flightcrew is usually fixed by the applicant's design from the outset. The purpose of the evaluations conducted under § 25.1523 is to corroborate by demonstration the predicted crew workload submitted by the applicant to substantiate compliance with § 25.1523, and to provide an independent and comprehensive assessment of individual crewmember workload in a realistic operating environment. Any problems encountered would probably be resolved by system redesign or procedural changes to redistribute workload more evenly.

e. Discussions on crew complement and the associated crew workload between the involved FAA Aircraft Certification Office and the manufacturer should take place early in the development cycle. These discussions should focus on identification of design features that are likely to impact crew workload. Subsequent analyses, demonstrations, and tests should be structured to verify that these design features do not place excessive workload demands on any crewmember. Crew duties and tasks for each crewmember should be appropriate to assure continuous involvement and awareness.

5. CERTIFICATION PROCEDURES.

a. General.

(1) A systematic evaluation and test plan is required for any new or modified airplane. Methods for substantiating compliance with § 25.1523 should include use of acceptable analyses, simulator demonstrations, and/or flight tests. Flight tests can confirm the analytical or simulator predictions. The minimum crew complement's workload should be studied through a logical process of analysis, measurement, and demonstration of the workload imposed by a particular flight deck design.

(2) Appropriate analysis should be conducted by the applicant early in the design process. The specific method(s) of analysis should be selected on the basis of its predictive validity, reliability, applicability to the particular flight deck configuration with emphasis on modification or new equipment, and availability of a suitable reference for comparison.

b. Analytical Approach.

(1) One acceptable analytical approach assesses workload as a percentage of the time available to perform tasks (Time Line Analysis). This process should be applied to an appropriate set of flight segments in which operationally important time constraints can be identified. This method is satisfactory for evaluation of flight deck changes relating to overt pilot tasks such as control movements and data inputs. The generally accepted practice involves careful selection of a limited set of flight scenarios and time segments that represent the range of operational requirements (including the range of selected normal, non-normal, and emergency procedures). Task-time line analysis yields useful data when tasks must be performed within operationally significant time constraints. An accurate determination of the time available is critical if this method is to have any value. Measurements of time that result from such analysis cannot be interpreted by any absolute standards, but such records can be used to identify increased workload demands for use in subsequent testing in a simulator or airplane, and comparison can be made with appropriate workload demands for in-service airplanes. The impact of flight deck changes on the tasks involved with planning and execution of emergency or non-normal procedures should receive particular evaluation.

(2) The most frequently used basis for deciding that a new design is acceptable is a comparison of a new design with a previous design proven in operational service. By making specific evaluations using scenarios designed to exercise the new design features and comparing the results to a known baseline, it is possible to proceed with confidence that the changes incorporated in the new designs will accomplish the intended result. If the new design represents an evolutionary improvement of the reference flight deck without additions of major systems affecting crew workload, direct comparisons are possible. Service experience of the reference flight deck and airplanes having systems similar to the new design should be reviewed to assure that any existing problems are understood and not perpetuated or inappropriately increased by the new design.

(3) If preliminary analyses by the certification team identify potential problem areas, these areas should receive more extensive evaluation and data collection. These concerns should be adequately addressed in the manufacturers' test or certification plan when submitted to the FAA.

(4) If the new design represents a significant change in the level of automation or pilot duties, analytic comparison to a reference design may have a lesser value. Without firm data on the time required to accomplish both normal and contingency duties, realistic simulation and/or flight tests may be required for validation.

c. Testing.

(1) The final decision on minimum crew determination is to be reserved until the airplane has been flown by experienced and properly qualified pilots trained and current in the operation of the airplane. The pilots who perform these evaluations should not be limited to manufacturers' test pilots and FAA certification pilots. It is highly recommended that some evaluation be conducted by "line pilots" who routinely fly similar airplanes and who can base their judgment on operational experience. Appendix D of Part 25 contains the criteria for determining the minimum flightcrew under § 25.1523 (basic workload functions and workload factors).

(2) The test program should address all workload functions and factors listed in § 25.1523 and Appendix D. For example, an evaluation of workload should include the communications tasks required to properly operate the airplane in the environment for which approval is sought. The goal is to evaluate workload with the proposed crew complement during realistic operating conditions, including representative air traffic, weather, airline operational duties, and appropriate company and cabin communications.

(3) Evaluation pilots should assure that new systems and rearranged cockpit configurations will be evaluated using scenarios representative of the type of operation for which the airplane is intended. Although quantitative substantiating crew workload data will often be provided, the current state-of-the-art relies on structured subjective evaluations. These evaluations compare the ease of execution of crew tasks in the subject airplane with that experienced in the reference cockpits in identical or substantively similar scenarios.

(4) A proposed flight test program for showing compliance with § 25.1523 and Appendix D of Part 25 should be submitted by the applicant and should be structured to address the following factors:

(i) Route. The test program routes should be constructed to provide a representative mix of navigation aids, airports, instrument approaches and Air Traffic Control (ATC) services.

(ii) Weather. The routes should be selected to provide the likelihood of encountering types of adverse weather appropriate to the airplane's intended operation (IMC conditions, night, turbulence, icing, etc.).

(iii) Crew Work Schedule. The test crew should be assigned to a daily work schedule that is representative of the type of operations for which the airplane was developed. The program should include the duration of the work day and the maximum expected number of departures and arrivals, flights which begin at night, maximum allowable duty times, and minimum rest periods.

(iv) Minimum Equipment List. The applicant should incorporate representative dispatch configurations in the proposed flight test program. Combinations of these representative dispatch configurations with probable subsequent simulated malfunctions should form the basis of many of the evaluation scenarios.

(v) Traffic Density. The airplane should be operated on routes that would adequately sample high density areas in both IMC and VMC, but should also include precision and nonprecision approaches, holdings, missed approaches, and diversions to alternate airports.

(vi) Incapacitated Crewmember.

(A) The NTSB accident data indicates that there were 262 occurrences of pilot incapacitation in Part 91 operations from January 1980 through July 1989, that resulted in 180 fatalities. All these fatalities were attributed to single pilot operation. Similar NTSB data from the same time period reveals 32 occurrences of pilot incapacitation in Part 135 operations resulting in 32 fatalities. All fatalities were attributed to single pilot operation. Relative to Part 121 operations over the same time period, there were 51 pilot incapacitation occurrences which resulted in a normal recovery of the aircraft by the other pilot.

(B) Whenever the applicable operating rule requires a minimum flightcrew of at least two pilots, the certification program should include a demonstration of operations during the total incapacitation of a crewmember at any point in a given flight. It must be shown that the airplane can be operated safely and landed safely with the remaining crew at a planned or unplanned destination. Incapacitated crewmember tests need not be additive to all other "dispatch plus subsequent failure" scenarios. Incapacitation should be viewed as another example of "subsequent failure" to be included within one or more scenarios beginning with a dispatch configuration which includes selected items from the proposed Minimum Equipment List. Although Part 25 does not specifically disallow certification of single piloted transport category airplanes, the FAA has been reluctant to approve this operation when all aspects of the intended use of the airplane and the consequences of pilot incapacitation are considered, as well as the historical accident record noted in Paragraph (A) above.

(vii) System Failures. The consequences of changes from normal to failed modes of operation should be included in the program. Both primary and secondary systems should be considered and representative combinations of failures should be included. (See note in Paragraph 5c(4)(viii).)

(viii) Emergency and Non-normal Situations. A sampling of various emergencies and non-normal conditions should be established in the test program to show their effect on the crew workload. Note: Prior to selecting the system failures that will be evaluated in the flight test program, it is necessary to conduct simulation or analytical studies. The crew workload distribution during the execution of emergency or non-normal situations should be understood to assure selection of appropriate failure cases.

(5) Guidelines concerning the implementation of a selected number of subjective, physiological, and performance workload measurement techniques, is contained in the FAA report "Assessment of Crew Workload Measurement Methods, Techniques, and Procedures" Vol. II (Report No. WRDC-TR-89-7006).

d. Recording Flight Test Data.

(1) The members of the type certification team who serve as pilots and observers should be supplied with subjective workload assessment questionnaires tailored to match the extent of the evaluation. If the flight deck is altered from a previously approved and fully satisfactory configuration by the addition of a single new system, for example, the evaluation can be limited and specific as to scenarios and questionnaires. For a complete new flight deck and a reduction in previously approved minimum crew, a complete workload assessment covering all phases of flight should be conducted, with correspondingly complete evaluation questionnaires. In addition there should be in-flight observer forms that provide means to record crew performance, crew errors, missed communications, and problems with checklists, flight management or flight guidance systems, or a structured debrief questionnaire and interview after the flight designed to identify operational situations experienced in flight. For the purposes of this data gathering, the airplane should be configured to allow the team evaluators to observe all crew activities from the cockpit and to hear both external and internal communications.

(2) The regulatory criteria as well as individual flightcrew ability, differences with the reference airplane, and variations in the test environment, are not conducive to analyses that use precise measurements. Instead, coarse rankings of the perceived workload factors listed in Part 25, Appendix D, should be sought, and compared to either a baseline model or the evaluator's impressions of a typical workload in similar current design airplanes. Areas of increased workload due to external elements, system failures, individual differences in ratings, and quantity and impact of crew errors must be understood and resolved. Increase workload does not necessarily make the airplane under evaluation unacceptable. However, to be acceptable, it must be a consensus of the certification team members that all of the workload elements specified in Part 25, Appendix D, can be accomplished by appropriately rated and trained pilots.

e. Additional Workload Test Methods.

(1) If a new airplane design incorporates changes not assessable by traditional test methods, alternative methods should be proposed by the manufacturer with sufficient substantiating data to assess the validity, reliability and applicability of the method.

(2) Comparisons may be required between the speed and accuracy of problem resolution or workload in a conventional versus a modified flight deck design or with conventional versus modified handling qualities. In any case, it should not be presumed that traditional test methods are appropriate for all new designs.

f. Involvement of Third Parties. Responsibility for the preparation of the data collection and analysis plan rests with the applicant. The FAA is responsible for assuring that the plan incorporates valid and reliable measures of crew workload that are viewed by experts as representative of current knowledge and developments. The FAA will, and applicants are encouraged to, consult with other government and industry specialists to achieve this objective.

6. CHECKLIST OF EVENTS. Summarized in chart form (see APPENDIX 1) are the sequential stages of implementation of § 25.1523. For each briefly described action, it is indicated when the procedures should be initiated and completed, and who has the primary responsibility for planning and executing the step.

Ronald T. Wojnar

RONALD T. WOJNAR
Manager, Transport Airplane Directorate,
Aircraft Certification Service, ANM-100

9.	Preparation of detailed test plan for demonstration of compliance with § 25.1523.	Prior to flight test for § 25.1523.	Manufacturer (FAA)
10.	Decisions on flight test plan requirements for flight test.	Upon completion of ground studies.	FAA
11.	Conduct flight tests.	From flight test plan.	Manufacturer/FAA

* Customer participation in all phases of flight deck evaluation is implicit in the manufacturer's responsibilities. Consultation between the manufacturer and customers is continuous from inception through the phase of airplane delivery, and until completion of airplane service life.

( ) Indicates secondary responsibility