Federal Aviation Administration
Aviation Rulemaking Advisory Committee

Transport Airplane and Engine Issue Area
Powerplant Installation Harmonization Working Group

Task 4 – Thrust Reversing Systems

Task Assignment

Aviation Rulemaking Advisory Committee; Transport Airplane and Engine Subcommittee; Installation Harmonization Working Group

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of establishment of installation harmonization working group.

SUMMARY: Notice is given of the establishment of the Installation Harmonization Working Group of the Transport Airplane and Engine Subcommittee. This notice informs the public of the activities of the Transport Airplane and Engine Subcommittee of the Aviation Rulemaking Advisory Committee.

FOR FURTHER INFORMATION CONTACT: Mr. William J. (Joe) Sullivan, Executive Director, Transport Airplane and Engine Subcommittee, Aircraft Certification Service (AIR-3), 800 Independence Avenue SW., Washington, DC 20591, Telephone: (202) 267-9554; FAX: (202) 267-5364.

SUPPLEMENTARY INFORMATION: The Federal Aviation Administration (FAA) established an Aviation Rulemaking Advisory Committee (56 FR 2190, January 22, 1991) which held its first meeting on May 23, 1991 (56 FR 20492, May 3, 1991). The Transport Airplane and Engine Subcommittee was established at that meeting to provide advice and recommendations to the Director, Aircraft Certification Service, FAA regarding the airworthiness standards for transport airplanes, engines and propellers in parts 25, 33, and 35 of the Federal Aviation Regulations (14 CFR parts 25, 23 and 35).

The FAA announced at the Joint Aviation Authorities (JAA)-Federal Aviation Administration (FAA) Harmonization Conference in Toronto, Ontario, Canada, (June 2–5, 1992) that it would consolidate within the Aviation Rulemaking Advisory Committee structure an ongoing objective to "harmonize" the Joint Aviation Requirements (JAR) and the Federal Aviation Regulations (FAR). Coincident with that announcement, the FAA assigned to the Transport Airplane and Engine Subcommittee those projects related to JAR/FAR 25, 33 and 35 harmonization which were then in the process of being coordinated between the JAA and the FAA. The harmonization process included the intention to present the results of JAA/FAA coordination to the public in the form of either a Notice of Proposed Rulemaking or an advisory circular—an objective comparable to and compatible with the assigned to the Aviation Rulemaking Advisory Committee. The Transport Airplane and Engine Subcommittee, consequently, established the Installation Harmonization Working Group.

Specifically, the Working Group's tasks are the following:

The Installation Harmonization Working Group is charged with making recommendations to the Transport Airplane and Engine Subcommittee concerning the FAA disposition of the following subjects recently coordinated between the JAA and FAA:

Task 1—Installations (Engines): Develop recommendations concerning new or revised requirements for the installation of engines on transport category airplanes and determine the relationship, if any, of the requirements of FAR 25.1309 to these engine installations (FAR 25.901).

Task 2—Windmilling Without Oil: Determine the need for requirements for turbine engine windmilling without oil (FAR 25.903).

Task 3—Non-contained Failures: Revise advisory material on non-contained engine failure requirements (FAR 25.903 and related provisions of FAR Parts 23, 27, 29, 33, and 35, as appropriate; AC 20–128). The working group should draw members for this task from the interests represented by the General Aviation and Business Airplane, and Rotorcraft Subcommittees.

Task 4—Thrust Reversing Systems: Develop recommendations concerning new or revised requirements and guidance material for turbojet engine thrust reversing systems (FAR 25.933).

Reports:

A. Recommend time line(s) for completion of each task, including rationale, for Subcommittee consideration at the meeting of the subcommittee held following publication of this notice.

B. Give a detailed conceptual presentation on each task to the Subcommittee before proceeding with the work stated under items C and D, below. If tasks 1, 2, and 4 require the development of more than one Notice of Proposed Rulemaking, identify what proposed amendments will be included in each notice.

C. Draft a Notice of Proposed Rulemaking for tasks 1, 2 and 4 proposing new or revised requirements, a supporting economic analysis, and other required analysis, with any other collateral documents (such as Advisory Circulars) the Working Group determines to be needed.

D. Draft a change to Advisory Circular 120–128 for task 3 providing appropriate advisory material for each task. When the detailed briefing under item B, above, and this report are presented to the subcommittee, the Subcommittee and Working Group Chairs should arrange for a joint meeting with the General Aviation and Business Airplane and Rotorcraft Subcommittees to consider and join in the consensus on the results of those reports.

E. Give a status report on each task at each meeting of the Subcommittee.

The Installation Harmonization Working Group will be comprised of experts from those organizations having an interest in the tasks assigned. A Working Group member need not necessarily be a representative of one of the organizations of the parent Transport Airplane and Engine Subcommittee or of the full Aviation Rulemaking Advisory Committee. An individual who has expertise in the subject matter and wishes to become a member of the Working Group should write the person listed under the caption **FOR FURTHER INFORMATION CONTACT** expressing that desire, describing his or her interest in the task, and the expertise he or she would bring to the Working Group. The request will be reviewed with the Subcommittee and Working Group Chairs and the individual will be advised whether or not the request can be accommodated.

The Secretary of Transportation has determined that the information and use of the Aviation Rulemaking Advisory Committee and its subcommittees are necessary in the public interest in connection with the performance of duties of the FAA by law. Meetings of the full Committee and any subcommittees will be open to the public except as authorized by section 10(d) of the Federal Advisory Committee Act. Meetings of the Installation Harmonization Working Group will not be open to the public except to the extent that individuals with an interest and expertise are selected to participate. No public announcement of Working Group meetings will be made.

Issued in Washington, DC, on December 4, 1992.

William J. Sullivan,

Executive Director, Transport Airplane and Engine Subcommittee, Aviation Rulemaking Advisory Committee.

[FR Doc. 92-30118 Filed 12-10-92; 8:45 am]

BILLING CODE 4910-13-M

Mr. Craig R. Bolt
Manager, Product Development and Validation
Pratt & Whitney
Mail Stop 162-12
East Hartford, CT 06108

Dear Mr. Bolt:

In an effort to clean up pending Aviation Rulemaking Advisory Committee (ARAC) recommendations on Transport Airplane and Engine Issues, the recommendations from the following working groups have been forwarded to the proper Federal Aviation Administration offices for review and decision. We consider your submittal of these recommendations as completion of the ARAC tasks. Therefore, we have closed the tasks and placed the recommendations on the ARAC website at http://www.faa.gov/avr/arm/arac/index.cfm

Date	**Task**	**Working Group**
December 1999	Interaction of Systems and Structure Part 33 Static Parts	Loads and Dynamics Harmonization Working Group
March 2000	Part 35/JARP: Airworthiness Standards Propellers	Engine Harmonization Working Group
April 2000	Flight Characteristics in Icing conditions	Flight Test Harmonization Working Group
May 2000	Thrust Reversing Systems	Powerplant Installation Harmonization Working Group
September 2000	Lightning Protection Requirements	Electromagnetic Effects Harmonization Working Group
July 2001	Main Deck Class B Cargo Compartments	Cargo Standards Harmonization Working Group
April 2002	Design Standard for Flight Guidance	Flight/Guidance Systems Harmonization Working Group

I wish to thank the ARAC and the working groups for the resources they spent in developing these recommendations. We will continue to keep you apprised of our efforts on the ARAC recommendations at the regular ARAC meetings.

Sincerely,

Anthony F. Fazio
Executive Director, Aviation Rulemaking
  Advisory Committee

MAR 15 2000

Mr. Craig Bolt
Assistant Chair, Transport Airplanes
and Engines Issues Group
400 Main Street
East Hartford, CT 06108

Dear Mr. Bolt:

This letter acknowledges receipt of the following working group technical reports that you have submitted on behalf of the Aviation Rulemaking Advisory Committee (ARAC) on Transport Airplane and Engine Issues (TAE):

Date of Letter	Task No.	Description of Recommendation	Working Group
12/14/00	1, 2, 3	Fast track reports addressing §§ 25.703(a) thru (c) (takeoff warning system); 25.1333(b) (instrument systems; and 25.1423(b) (public address system)	ASHWG
12/17/00	5	Fast track reports addressing §§ 25.111(c)(4), 25.147, controllability in 1-engine inoperative condition; 25.161 (c) (2) and (4), and (e) (longitudinal trim and airplanes with 4 or more engines) 25.175(d) (static longitudinal stability; 25.177(a)(b) (static lateral-directional stability); 25.253(a)(3) (high speed characteristics); 25.1323(c) (airspeed indicating system); 25.1516 (landing gear speeds); 25.1527 (maximum operating altitude); 25.1583(c) and (f) operating limitations) 25.1585 (operating procedures); and 25.1587 (performance information)	FTHWG
12/17/00	7	Fast track report addressing § 25.903(e) (inflight engine failures)	PPIHWG

12/20/00	5	Fast track reports addressing §§ 25.1103 (auxiliary power units); 25.933(a) (thrust reverers); 25.1189 (shutoff means); 25.1141 (powerplant controls); 25.1093 (air intake/induction systems); 25.1091 (air intake system icing protection; 25.943 (thrust reverser system tests); 25.934 (negative acceleration); 25.905(d) (propeller blade debris); 25.903(d)(1) (engine case burn-through); 25.901(d) (auxiliary power unit installation; and 1.1 (general definitions)	PPIHWG
12/20/00	4	Fast track report, category 2 format--NRRM addressing § 25.302 and appendix K (interaction of systems and structures	LDHWG
12/20/00	2	Fast track report—(in NPRM/AC format) addressing §§ 25.361 and 25.362 (engine and auxiliary power unit load conditions)	LDHWG
12/20/00	1	Fast track report addressing § 25.1438 (pressurization and low pressure pneumatic systems)	MSHWG

The above listed reports will be forwarded to the Transport Airplane Directorate for review. The Federal Aviation Administration's (FAA) progress will be reported at the TAE meetings.

This letter also acknowledges receipt of your July 28, 1999, submittal which included proposed notices and advisory material addressing lightning protection. We apologize for the delay. Although the lightning protection task is not covered under the fast track proposal, the FAA recognizes that technical agreement has been reached and we will process the package accordingly. The package has been sent to Aircraft Certification for review; the working group will be kept informed of its progress through the FAA representative assigned to the group.

Lastly, at the December 8 - 9, 1999, TAE meeting, Mr. Phil Salee of the Powerplant Installation Harmonization Working Group indicated that the working group members agreed that § 25.1103 was sufficiently harmonized and that any further action was beyond the scope of task 8 assigned. We agreed with the TAE membership to close the task. This letter confirms the FAA's action to close the task to harmonize § 25.1103.

I would like to thank the ARAC, particularly those members associated with TAE for its cooperation in using the fast track process and completing the working group reports in a timely manner.

Sincerely,

ORGINIAL SIGNED BY
ANTHONY F. FAZIO

Tony F. Fazio
Director, Office of Rulemaking

ARM-209:EUpshaw:fs:6/27/00:PCDOCS #12756v1
cc: ARM-1/20/200/209; APO-300/320, ANM-114
File #1340.12

File #ANM-98-182-A (landing gear shock absorption test requirements) and ANM-94-461-A (Taxi, takeoff, and landing roll design loads)

Recommendation

FINAL DRAFT FROM PPIHWG

Note: FAA has notified PPIHWG that some materials from proposed AC may need to be included in the preamble of this NPRM to more clearly reflect the intent of the rule. PPIHWG have reviewed this issue and decided not to include any of the AC material at this time.*[4910-13]*

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

[14 CFR Parts 1 and 25]

[Docket No. FAA-xxxxx; Notice No.]

RIN: 2120-____________

Transport Category Airplane Turbojet Engine Thrust Reverser System Airworthiness Standards.

AGENCY: *Federal Aviation Administration, DOT.*

ACTION: *Notice of proposed rulemaking.*

SUMMARY: *This proposal would revise the current standards that are applicable to the turbojet reversing systems installed on transport category airplanes. It also would harmonize these standards with the parallel sections of the European Joint Aviation Requirements (JAR). This proposal would provide an optional method of compliance with the current standards. This proposal is the result of an industry-wide investigation into why application of the current standards has not precluded loss of airplane control following unwanted inflight deployment of the thrust reverser. These proposed revised standards would provide operators greater flexibility in developing designs to comply with the current standards, and would increase the level of safety above that historically provided by the current rule.*

DATES: *Comments must be received on or before [insert date 90 days from date of publication].*

ADDRESSES: *Comments on this document should be mailed or delivered, in duplicate, to: U.S. Department of Transportation Dockets, Docket No. ______, 400 Seventh Street SW., Room Plaza 401, Washington, DC 20590. " Comments also may be sent electronically to the following Internet address: 9-NPRM-CMTS@faa.dot.gov.*

Comments may be filed and examined in Room Plaza 401 between 10:00 a.m. and 5:00 p.m. weekdays, except Federal holidays,

In addition, the FAA is maintaining an information docket of comments in the FAA, Transport Airplane Directorate, Aircraft Certification Service, 1601 Lind Avenue S.W., Renton, Washington 98055-4056. Comments in the information docket may be inspected between 7:30 a.m. and 4:00 p.m. weekdays, except Federal holidays.

FOR FURTHER INFORMATION CONTACT: *Michael K. McRae, Propulsion/Mechanical Systems Section, ANM-112, Transport Airplane Directorate, Aircraft Certification Service, FAA, 1601 Lind Avenue S.W., Renton, Washington 98055-4056; telephone (425) 227-2133; facsimile (425) 227-1320.*

SUPPLEMENTARY INFORMATION:

Comments Invited

Interested persons are invited to participate in the making of the proposed action by submitting such written data, views, or arguments as they may desire. Comments relating to the environmental, energy, federalism, or economic impact that might result *from adopting the proposals in this document are also invited. Substantive comments should be accompanied by cost estimates. Comments must identify the regulatory docket or notice number and be submitted in duplicate to the DOT Rules Docket address specified above.*

All comments received, as well as a report summarizing each substantive public contact with FAA personnel concerning this proposed rulemaking, will be filed in the docket. The docket is available for public inspection before and after the comment closing date.

All comments received on or before the closing date will be considered by the Administrator before taking action on this proposed rulemaking. Comments filed late will be considered as far as possible without incurring expense or delay. The proposals in this document may be changed in light of the comments received.

Commenters wishing the FAA to acknowledge receipt of their comments submitted in response to this document must include a pre-addressed, stamped postcard with those comments on which the following statement is made: "Comments to Docket No. ________." The postcard will be date stamped and mailed to the commenter.

Availability of NPRM

An electronic copy of this document may be downloaded using a modem and suitable communications software from the FAA regulations section of the Fedworld electronic bulletin board service (telephone: 703-321-3339), the Government Printing Office's (GPO) electronic bulletin board service (telephone: 202-512-1661), or, if applicable, the FAA's Aviation Rulemaking Advisory Committee bulletin board service telephone: 800-322-2722 or 202-267-5948).

Internet users may reach the FAA's web page at http://www.faa.gov/avr/arm/nprm/nprm.htm or the GPO's webpage at http://www.access.gpo.gov/nara for access to recently published rulemaking documents.

Any person may obtain a copy of this document by submitting a request to the Federal Aviation Administration, Office of Rulemaking, ARM-1, 800 Independence Avenue, SW., Washington, DC 20591; or by calling (202) 267-9680. Communications must identify the notice number or docket number of this NPRM.

Persons interested in being placed on the mailing list for future rulemaking documents should request from the above office a copy of Advisory Circular No. 11-2A, Notice of Proposed Rulemaking Distribution System, which describes the application procedure.

Background

On May 26, 1991, a Boeing Model 767 (Lauda Airlines) was involved in a total hull loss accident during takeoff climb at Bangkok, Thailand. The primary cause of the accident was determined to be loss of aircraft controllability following an unwanted deployment of the engine thrust reverser in flight. The subsequent investigation revealed *that an inflight deployment of a thrust reverser can cause previously unforeseen aerodynamic effects on flight control and lifting surfaces located behind the reverser. These effects can lead to catastrophic consequences if not addressed in a timely manner.*

Because these effects could potentially create unsafe conditions on other previously-approved transport category airplanes that are equipped with thrust reverser systems, the FAA and Aerospace Industries Association (AIA) established a steering committee to assess and address "Transport Turbojet Fleet Thrust Reverser System Safety." This committee was comprised of representatives from various transport airplane and engine manufactures, the FAA, the Joint Airworthiness Authorities (JAA), and Transport Canada. The Steering Committee divided its activities into three tasks:

Task One: Gather relevant in-service information.

Task Two: Develop guidelines for determining if an unsafe condition exists on any turbojet thrust reversing system within the subsonic transport category airplane fleet.

Task Three: Review the existing regulations and evaluate the need for revising them based on information garnered from Tasks One and Two.

The Steering Committee concluded that:

- *assuring adequate control margins is not practical for all transport airplane types, especially those with wing-mounted high bypass ratio turbofan engines; and*
- *improved safeguards against the occurrence of unwanted inflight deployment could provide at least an equivalent level of safety to assurances of adequate control margins following such a deployment.*

Based on this conclusion, the Steering Committee subsequently developed both "controllability" and "reliability" acceptance criteria to assist the FAA in assessing whether or not a catastrophic inflight thrust reverser deployment could be anticipated to occur on a given airplane type design.

"Controllability" criteria were based on the premise that the airplane type should be capable of continued safe flight and landing at an airport following any unwanted inflight thrust reversal. "Reliability" criteria were based on the premise that the occurrence of any unwanted inflight thrust reversal that would prevent continued safe flight and landing at an airport should not be anticipated to occur during the fleet life of the airplane type.

Following completion of Tasks One and Two, the FAA initiated a "Thrust Reverser Fleet Review." During this review, the FAA began performing evaluations of the current fleet (under the authority of Section 609 of the Federal Aviation Act). As a result of findings from this review, the FAA issued a number of airworthiness directives (AD) to require modifications to in-service airplanes that did not meet either the "controllability" or "reliability" criteria established by the steering committee. The FAA's Thrust Reverser Fleet Review is still ongoing.

The FAA/AIA Steering Committee also concluded that, based on information gathered and analyzed, changes to the regulations addressing the standards for reversing system design likely would be necessary. In 1992, the FAA tasked the Aviation Rulemaking Advisory Committee (ARAC) with completing the review of existing regulations relevant to thrust reverser systems, and developing any needed revisions to *those regulations and their associated guidance material*

ARAC

The ARAC was formally established by the FAA on January 22, 1991 (56 FR 2190), to provide advice and recommendations concerning the full range of the FAA's safety-related rulemaking activity. This advice was sought to develop better rules in less overall time using fewer FAA resources than were previously needed. The committee provides the opportunity for the FAA to obtain first hand information and insight from interested parties regarding proposed new rules or revisions of existing rules.

There are 56 member organizations on the committee, representing a wide range of interests within the aviation community. Meetings of the committee are open to the public, except as authorized by section 10(d) of the Federal Advisory Committee Act.

The ARAC establishes working groups to develop proposals to recommend to the FAA for resolving specific issues. Tasks assigned to working groups are published in the Federal Register. Although working group meetings are not generally open to the public, all interested parties are invited to participate as working group members. Working groups report directly to the ARAC, and the ARAC must concur with a working group proposal before that proposal can be presented to the FAA as an advisory committee recommendation. The activities of the ARAC will not, however, circumvent the public rulemaking procedures. After an ARAC recommendation is received and found acceptable by the FAA, the agency proceeds with the normal public rulemaking procedures. Any ARAC participation in a rulemaking package will be fully disclosed in the public docket.

The ARAC held its first meeting on May 3, 1991 (56 FR 20492, May 3, 1991). The Transport Airplane and Engine Subcommittee (later renamed the Transport Airplane and Engine Issues Group, TAEIG) was established at that meeting to provide advice and recommendations to the Director of the FAA Aircraft Certification Service regarding the airworthiness standards for transport airplanes, engines, and propellers in parts 25, 33, and 35 of the Federal Aviation Regulations (14 CFR parts 25, 33, and 35). The TAEIG established the Installation Harmonization Working Group (later renamed the Power Plant Installation Harmonization Working Group, PPIHWG) and tasked it (57 FR 58845, December 11, 1992) with developing recommendations concerning new or revised requirements and guidance material for turbojet engine thrust reverser systems (FAR/JAR §25.933). The proposed amendment contained in this notice was developed by the Thrust Reverser Task Group of the PPIHWG, and it was presented to the FAA by the ARAC in response to the TAEIG PPIHWG's Task 4.

Harmonization

The FAA announced at the FAA-JAA Harmonization Conference in Toronto, Ontario, Canada, held in June 1992, that it would consolidate within the ARAC structure an ongoing objective to "harmonize" the Joint Aviation Requirements (JAR) and the Federal Aviation Regulations (FAR).

The need to harmonize all regulatory activity has been identified by U.S. and European airplane manufacturers and airworthiness authorities as a high priority. Part 25 of the FAR contains the airworthiness standards for transport category airplanes. Manufacturers of transport category airplanes must show that each airplane they *produce of a different type design complies with the relevant standards of part 25. These standards apply to airplanes manufactured within the U.S. and other countries for use by U.S.-registered operators.*

In Europe, the JAR were developed by the Joint Aviation Authorities (JAA) to provide a common set of airworthiness standards for use within the European community. The airworthiness standards for European type certification of transport category airplanes, JAR-25, are based on part 25 of the FAR (14 CFR part 25). Airplanes certificated to the JAR-25 standards, including airplanes manufactured in the U.S. for export to Europe, receive a type certificate that is usually accepted by the aircraft certification authorities of 19 European countries who are members of the JAA.

Although FAR part 25 and JAR-25 are very similar, they are not identical. The additional costs of meeting different FAR and JAR requirements when airplanes are type certificated to both standards do not normally bring about a commensurate increase in safety. Recognizing that a common set of standards would not only benefit the aviation industry economically, but also maintain the necessary high level of safety, the FAA and JAA consider harmonization to be a high priority.

The harmonization process included the intention to present the results of JAA/FAA coordination to the public in the form of either a Notice of Proposed Rulemaking or an Advisory Circular.

Relevant Regulatory History

Currently, the relevant standards addressing reversing systems on transport category airplanes are found in §25.933. The precursor to the current 14 CFR §25.933 *was first introduced as CAR 4b.407, amendment 1, effective December 31, 1953. That rule was applicable to "propeller reversing systems," and contained the concept that "no single failure or malfunctioning" should result in "a position substantially below the normal flight low-pitch stop." This established a regulatory concept of preventing "unwanted reverse thrust," which was then applied to all types of "reversing systems" by amendment 11 to CAR 4b.407(a). When 14 CFR part 25 was created, CAR 4b.407(a) was recodified as §25.933(a).*

While other thrust reverser regulatory activity was contained in amendment 11 to CAR 4b.407, as well as in amendments 25-11 (32 FR6912, May 5, 1967) and 25-38 (41 FR 55466, December 20, 1976) to §25.933, it wasn't until amendment 25-40 (42 FR 15042, March 17, 1977) that the approach to regulating unwanted reverse thrust changed significantly.

Amendment 25-40 introduced a requirement within §25.933(a) to show that:

> *"(a) Each engine reversing system intended for ground operation only must be designed so that, during any reversal in flight, the engine will produce no more than flight idle thrust. In addition, it must be shown by analysis or test, or both, that—*

(1) the reverser can be restored to the forward thrust position, or

(2) the airplane is capable of continued safe flight and landing under any possible position of the thrust reverser." [emphasis added]

In part, the justification that the FAA provided for making these changes was:

"A review of the past operating history of airplane engine thrust reversers indicates that fail-safe design features in the reverser systems do not always prevent unwanted deployment in flight. Many of these unwanted deployments are not caused by deficiencies in design, but can be attributed to maintenance omissions, wear, and other like factors that cannot be completely accounted for in the original design and over which the manufacturer generally has no control even when comprehensive maintenance programs are established. Since the existing reverser design standards are inadequate, it is felt that it is incumbent on the airplane manufacturers to investigate the effects of various types of failures either by analysis and or flight and ground tests, as well asestablishing operating limitations and incorporating safety features so that catastrophic situations do not develop from unwanted deployment in flight or on the ground."

Shortly after this amendment was adopted, the FAA realized that the word "or," which connected §25.933(a)(1)(i) and (ii), should have been "and." Since unwanted deployment is likely to render the reverser "inoperable," the FAA thereafter applied the regulation as if it read "each operable reverser [must] be restored to the forward thrust position and the airplane [must be] capable of continued safe flight and landing under any possible position of the thrust reverser". The rule itself was revised to reflect this interpretation by amendment 25-72 (55 FR 29773, July 20, 1990), which became effective July 20, 1990.

Need for Additional Regulatory Change

The service history of airplanes certified under §25.933(1)(a)as being "capable of continued safe flight and landing under any possible position of the thrust reverser" demonstrates that the intent of this "fail-safe" requirement has not been achieved. The relevant service history is summarized in "Criteria for Assessing Transport Turbojet Fleet Thrust Reverser System Safety," Rev. A, dated June 1, 1994, a document developed by the FAA/AIA Thrust Reverser Steering Committee.

Service history shows that accidents have occurred on airplanes that apparently were "capable of continued safe flight and landing" if the flight crew responded to the unwanted deployment in the manner assumed during certification. Accidents have also occurred on airplanes that apparently were not "capable of continued safe flight and landing" regardless of the flight crew's response. In most cases, the influences that caused the associated compliance findings to become "invalid" either were not identified or were oversimplified during certification.

The FAA has determined that, if future type designs are to be "capable of continued safe flight and landing under any possible position of the thrust reverser" as currently required, or are to "prevent unwanted reverse thrust" as required prior to amendment 25-40, then certification compliance substantiation and instructions for continued airworthiness must become more comprehensive than those that have proved ineffective in the past. However, the complexity and diversity of conditions that might influence the actual probability or severity of unwanted reverse thrust make it logistically impractical to explicitly demonstrate compliance for any and all combinations of these conditions. Consequently, it is essential that we establish some acceptableconservative means ofsimplifyingthese compliance substantiations.

The FAA has reviewed some previously-accepted "simplifications" that have been addressed in reversing system compliance substantiations. These simplifications, each with their notable shortcomings, are described below:

1. <u>Assuming that flight, maintenance, or manufacturing/modifying personnel perform their duties as intended</u>: This may be invalid due to the impact of anticipated alternative human behaviors.
2. <u>Assuming that failure modes and effects will/will not occur</u>: This may be invalid because all relevant variables, such as manufacturing/modifying variability, externally applied stresses, situational and conditional variations, etc., may not have been properly accounted for.
3. <u>Assuming that the aircraft is operating "normally" in a "wings level" attitude with no other faults present just prior to deployment</u>: This may be invalid due to the impact of anticipated latent failures, MMEL relief, transient maneuvers, abnormal operations, etc.
4. <u>Assuming that the effects of the initial engine power level are negligible or can be modeled as a simple decaying asymmetric force</u>: This may be invalid

due to non-linear engine power-dependent aerodynamic influences(e.g. lift loss due to reverser effluxinfluences onthe airflow over the wing).

5. Assuming that the "worst case" thrust reverser inflight deployment is a fully deployed reverser at the highest anticipated total pressure flight conditions: This may be invalid because other anticipated thrust reverser failures or flight conditions can be more severe.

6. Assuming that crew procedures and/or airplane simulations can be validated by extrapolating the results of limited testing: This may be invalid because all significant influences may not have been adequately accounted for in the extrapolation.

7. Assuming that an airplane is airworthy if it is capable of recovering from a deployment transient while descending and then landing with the reverser deployed: This may be invalid due to the effects that a deployment would have on range, performance, and/or other capabilities required to assure continued safe flight and landing at a suitable airport under any anticipated conditions.

When the FAA/AIA Thrust Reverser Steering Committee considered making compliance substantiation more comprehensive, it concluded that:

- it is not practical always to assume that a deployment occurs regardless of the probability; and
- certain otherwise beneficial design features can make it impractical to assure continued safe flight and landing following an inflight reverser deployment

for the reasons discussed below under "Evaluation of Regulatory Options Pertaining to Thrust Reverser Systems".

ARAC Thrust Reverser Task Group Activities

The ARAC Thrust Reverser Task Group evaluated the controllability of various airplane types to better understand the effects of thrust reverser deployment on airplane controllability. The Task Group determined that newer technology airplanes with high bypass ratio engines located under the wing typically have the least control margin, particularly at high speeds. The primary causes of this lower control margin are the relatively large diameter and thrust level of the new technology high bypass ratio engines, and the associated engine mounting systems that reduce the distance between the wing and the engine. The "short struts" are needed to reduce aerodynamic drag and provide ground clearance for the larger diameter engines. During a thrust reverser deployment at high speed, these "closely coupled" engines cause a significant disruption of the airflow over the wing upper surface, resulting in a loss of wing lift that induces the airplane to roll and nose down. This reaction can be so dynamic that it is not reasonable to rely on pilot actions alone to correct it.

A review of developing engine technology shows that a major improvement in fuel efficiency is offered by a future generation of engines, which:

- have bypass ratios well in excess of current engines, and
- may incorporate variable geometry of the engine or nacelle to provide the needed reverse thrust (e.g., reversible pitch fan blades similar to current turbopropeller-driven airplanes).

The increased bypass ratios mean that close-coupled mounting systems will continue to be prevalent if these engines are to be used. Some increase in bypass ratio with fixed pitch fans is also likely in the near future.

In developing appropriate revisions to the current standards, the ARAC Thrust Reverser Task Group considered:

- the adverse thrust reverser service history;
- the practical limitations on being "capable of continued safe flight and landing under any possible position of the thrust reverser;" and
- the practical limitation on assuring that a deployment will not occur, as delineated in the justifications for amendment 25-40 to §25.933(a), described above.

From these considerations, the Task Group determined that both a regulatory and policy amendment was required to provide the most comprehensive means of assuring an acceptable level of thrust reverser safety in transport category airplanes in the future.

Evaluation of Regulatory Options Pertaining to Thrust Reverser Systems

The Task Group evaluated numerous design options to determine what changes to the current standards would be technically feasible, economically justifiable, and capable of providing the desired level of safety. It finally considered three options:

Option 1. Eliminate thrust reverser systems altogether.

Option 2. Provide adequate assurances of continued safe flight and landing following an assumed unwanted deployment during flight, as intended by the current requirement of §25.933(a)(1) -- the "controllability" option.

Option 3. Provide adequate assurances that unwanted deployment will not occur during flight, as intended by §25.933(a) prior to amendment 25-40 -- the "reliability" option.

The conclusions reached by the team concerning each of the options are as follows:

Option 1. Eliminate Thrust Reverser Systems

Elimination of thrust reverser systems was not found to be an airworthiness improvement or an increase in the level of safety. Although thrust reverser systems are not required by the FAR (14 CFR), these systems are needed to stop airplanes safely on runways with contaminated surfaces. The use of reversers also reduces brake wear. The need for thrust reversers on many airplane types has been demonstrated by recent service history. For example, in addressing the unsafe condition related to the cause of the Boeing 767 (Lauda) accident, the FAA required (for a specific period of time) the deactivation of thrust reverser systems of several airplane types. This resulted in the need for a significant increase in landing field lengths for those airplanes when landing on contaminated surfaces. Additionally, during the short period of time when the thrust reversers systems were required to be deactivated, one operator's aircraft, when landing on an icy runway, experienced an overrun due to lack of stopping power provided by the brakes.

Other options for eliminating thrust reversers that were evaluated included:

- reduced landing speeds such that the use of the thrust reversing systems would not be necessary; and

- installation of runway overrun facilities or arresting gear at each airport.

Given the service history of overruns, the latter option was considered beneficial even if reversers were retained. However, the Task Group concluded that implementing either of these options was considered impractical due to obviously prohibitive costs and logistical problems.

Option 2. Ensure Continued Safe Flight and Landing Following Inflight Deployment ("Controllability Option")

The Task Group concluded that Option 2 would require airplane control margins such that, even with a reasonable delay in flight crew response following an unwanted deployment, the airplane would still clearly be capable of continued safe flight and landing. This means that the control margins on some airplane types would have to be substantially improved. The methods for improving airplane control margins that the Task Group evaluated included:

1. increasing the size of airplane control surfaces;
2. increasing the separation distance between engine and wing so that the resulting reverser efflux would not impinge on the upper wing surface;
3. revising the reverser efflux pattern such that only a minor disruption of airflow over the wing would occur;
4. mounting the engines on the aft fuselage such that a reverser deployment would not result in wing lift loss; and
5. commanding the engine power from high power to low power during an unwanted inflight reversal in a rapid fashion such that the engine compressor

will stall, thereby resulting in only a minor disruption of airflow over the wing.

A detailed economic evaluation of these options is presented later in this preamble. However, the following are brief summaries of the economic evaluation of each of these 5 proposed methods for improving airplane control margins:

To assess the impact and cost of the control system changes required for a typical aircraft to achieve full controllability across the normal flight envelope, a study was conducted in August 1993. Results demonstrated that there would be an increase in direct operating costs of approximately 0.5 % for typical airline operation. This increased cost arises from the additional drag and weight associated with increases in both the control surface area and the actuation system capability. Results for wing-mounted twin and quad jet engine installations were similar.

This assessment did not account for:

- the effect of the harsh ride associated with faster control response;
- the cost of advanced avionics to operate the fast-response aspect; or
- additional significant costs that would be associated with adhering to the roll angle limits, control forces limits, and post-event performance requirements (required by showing compliance with the "controllability" criteria only).

Increasing the wing-to-engine separation distance was found to significantly inhibit airplane design. Installation of large diameter high bypass engines under the wing results in the need to close-couple the engines to the wing in order to maintain the entry door sill heights so that current airport terminals can be used. Additional costs of

increasing the separation distance would include added drag and increased weight, since longer landing gear and engine struts would be required.

Revising the efflux pattern of the thrust reversers, while maintaining the thrust reversers' effectiveness, was found not to be technically feasible. Currently, the thrust reverser efflux pattern is "tuned" so that (1) the airflow is directed away from the fuselage so that foreign object/ice damage to the fuselage will not occur, and (2) the airflow will not discharge under the wing and cause a net lifting of the airframe and subsequent reduced braking effectiveness. Based on these design constraints, wing-mounted engine efflux patterns are generally limited to four areas around the engine circumference at roughly 45-degree angles from the horizontal. Redirection of the efflux pattern in the upper quadrant would result in loss of reverser effectiveness and asymmetric loading of the engine fan, which would significantly increase weight and operating costs.

The option of mounting all future engines in the aft fuselage location or above the wing, so that wing lift loss would not occur, was evaluated and found to result in severe economic penalties. These costs primarily are the result of increased interference drag and weight penalties associated with the aft fuselage location.

The option of designing engines so that a non-recoverable compressor stall would occur if an unwanted inflight deployment were detected was found to be effective at improving airplane controllability for certain airplane types. However, introduction of this feature could reduce engine reliability and increase engine maintenance costs on those airplanes.

Furthermore, even with the engine at low or no power, an inflight thrust reversal could still be catastrophic on certain airplane and engine types. Consequently this option would not always be effective.

Option 3. Ensure Deployment Will Not Occur During Flight ("Reliability")

The requirements used to ensure that other critical systems do not prevent continued safe flight and landing were evaluated to determine if the same requirements could be applied effectively to thrust reverser systems. Unwanted deployments have occurred on thrust reverser systems (that were certificated as critical systems) due to factors "beyond the control of the manufacturer," as described in the preamble to amendment 25-40 to §25.933(a). Even more recent service history indicates that these unwanted deployments continue to occur due to factors such as inappropriate maintenance and intermittent wiring faults, which are not traditionally addressed by system safety assessments.

As a result of other FAA taskings, ARAC is proposing revisions to FAR/JAR §25.1309 ("Equipment, systems, and installations"), and FAR/JAR §25.901(c) ("Powerplant - Installation"), and their associated Advisory Circulars (i.e., AC 25.1309-1B and AC 25.901). The revisions are intended to better address system safety factors that have contributed to previous unwanted thrust reverser deployments.

The Task Group did identify the incorporation of additional redundant locking mechanisms within the reverser system as one option for increasing the safeguards against deployment. Additional redundant locking mechanisms already have been incorporated into several aircraft type designs by AD requirements to address unsafe conditions in service.

Additionally, during several recent FAA transport category airplane certification programs, additional redundant locking mechanisms, in conjunction with more rigorous design and maintenance assessments, have been found to provide an "equivalent level of safety" to compliance with §25.933(a)(1)(ii) (". . . capable of continued safe flight and landing under any possible position of the thrust reverser."). However, this is only one option, and it can result in reduced thrust reverser operational reliability, as well as increased manufacturing and operating costs.

Conclusion Reached

Evaluation of the three options discussed above indicates that there are means of improving the historical level of safety through <u>both</u> Options 2 and 3. Given the foreseeable constraints on transport category airplane type designs, however, neither option can exclusively provide an effective, technologically feasible, and economically practical alternative for all future designs. Consequently, the Task Group concluded that the applicant should be able to select the most suitable option for its particular type design or failure condition.

Some representatives on the task group proposed that any revision to §25.933 and AC 25.933 should restrict the use of the "reliability option" to those cases where the "controllability option" is not practicable-- that is, retain the objective of the current rule, but revise it to provide a "built-in exemption" for designs that could not meet the "controllability" requirements. These representatives contended that, given the justifications specified in amendment 25-40 for no longer allowing only a "reliability option," it would be inappropriate to unconditionally re-introduce the "reliability-only option." The majority of the task group representatives, however, concluded that, given the improved "reliability option" guidance that is available and provided in the proposed advisory materials [See General Action #1], the two options can be viewed as equivalent; therefore no "bias" towards the "controllability-only option" is warranted. (Details of the opinions of the task force representatives are contained in a separate document in the docket associated with the related advisory material, AC 25.933-1.)

Some members of the Task Group proposed that the prescriptive requirements related to "restow" and "flight idle" currently within §25.933(a)(1) should be retained in the revised rule. However, the majority of the Task Group members concluded that, if such design features are required to meet the objective of the revised rule, then they would be implicitly made part of any approved design; on the other hand, if such features are not required to meet the objective of the rule, then there is no justification for making them mandatory. Consequently, the task group concluded that these prescriptive design requirements should not be explicitly included in the proposed revised rule.

Finally, the Task Group concluded that each thrust reversing system intended for ground use only should be inhibited from selection during flight. The Task Group determined that this item should not be part of the proposed revision to §25.933, but instead should be part of another ARAC task that is currently aimed at amending §25.1155 ("Reverse thrust and propeller pitch settings below the flight regime"). That activity relates to preventing the flight crew of turbopropeller-powered airplanes from unwantedly or intentionally placing the power lever below flight idle (beta operation) while in flight, unless the airplane has been certified for inflight beta operation. The scope of that activity would be expanded to include reverse thrust on turbojet airplanes.

Discussion of the Proposal

In consideration of the previous discussion, the FAA proposes to amend 14 CFR §25.933(a)(1), as recommended by the ARAC, to incorporate needed flexibility in the standards applicable to engine thrust reverser systems, and to harmonize these sections with JAR-25. The JAA intends to publish a similar Notice of Proposed Amendment (NPA) that will propose to revise JAR-25 to ensure harmonization in those areas for which the proposed amendments differ from the current JAR-25. When it is published, the NPA will be placed in the public docket for this rulemaking.

Specifically, the FAA proposes to amend §25.933(a)(1) to read as follows:

"(a) For turbojet reversing systems -

(1) Each system intended for ground operation only must be designed so that either—

(i) the airplane can be shown to be capable of continued safe flight and landing during and after any thrust reversal that occurs during flight, or

(ii) it can be demonstrated that inflight thrust reversal is extremely improbable and does not result from a single failure or malfunction."

This proposed revision would allow applicants for certification of designs to show compliance with the criteria described either in paragraph 25.933(a)(1)(i) or in 25.933(a)(1)(ii).

In summary, this proposal would revise the current regulations to provide an additional method of compliance.

Relevant Advisory Materials

The FAA also is preparing to issue a new proposed Advisory Circular 25.933-1 to state a means of compliance with the proposed regulation that would providethe intended level of safety and promote consistent and effective application of the proposed revised standards. Any alternative means of compliance to those delineated in the proposed AC should be shown to provide a similar level of safety. Public comments concerning the proposed AC are invited by separate notice published elsewhere in this issue of the Federal Register.

Paperwork Reduction Act

In accordance with the Paperwork Reduction Act of 1995 [44 U.S.C. 3507(d)], the FAA had determined there are no requirements for information collection associated with this proposed rule.

Compatibility with ICAO Standards

In keeping with U.S. obligations under the Convention on International Civil Aviation, it is FAA policy to comply with International Civil Aviation Organization (ICAO) Standards and Recommended Practices to the maximum extent practicable. The FAA determined that there are no ICAO Standards and Recommended Practices that correspond to this proposed regulation.

Regulatory Evaluation Summary

Changes to Federal regulations must undergo several economic analyses. First, Executive Order 12866 directs that each Federal agency shall propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs. Second, the Regulatory Flexibility Act of 1980 requires agencies to analyze the economic effect of regulatory changes on small entities. Third, the Office of Management and Budget directs agencies to assess the effects of regulatory changes on international trade. And fourth, the Unfunded Mandates Reform Act of 1995 (Pub. L. 104-4) requires agencies to prepare a written assessment of the cots, benefits, and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditure by State, local, or tribal governments, in the aggregate, or by the private sector, of $100 million or more annually (adjusted for inflation). In conducting these analyses, the FAA has determined that this proposed rule: (1) would generate benefits that justify its costs and would not be "a significant regulatory action" as defined in section 3(f) of Executive Order 12866 and, therefore, is not subject to review by the Office of Management and Budget; (2) would not have a significant impact on a substantial number of small entities; (3) would not constitute a barrier to international trade; and (4) would not contain a significant intergovernmental or private sector mandate. These analyses, available in the docket, are summarized below. The FAA invites the public to provide comments and supporting data on the assumptions made in this evaluation. All comments received will be considered in the final regulatory evaluation.

Initial Economic Evaluation

[INITIAL EVALUATION TO BE COMPLETED BY APO]

Benefits

The proposed rule would generate two types of benefits:

- The first type of benefit would be the increased safety that the continued use of thrust reversers provides during landings and rejected takeoffs, particularly on contaminated runways. As discussed elsewhere in this Notice, without the reliability alternative provided by this rule change, incorporation of thrust reversers would not be practicable for some types of transport airplanes.

- The second type of benefit would be to reduce future compliance costs because the proposed rule would allow manufacturers to achieve the intended level of safety in the most cost-effective manner for their individual future airplane models.

The FAA cannot precisely quantify the potential increased safety benefits of facilitating the installation of reversers .However, the fact that nearly all turbofan airplanes use thrust reversers, even though they are expensive to maintain and operate and they are not required equipment for compliance with FAA regulations, presents strong evidence that operators view thrust reversers as an important component of airplane safety. A January 1994, National Aeronautics and Space Administration (NASA)/FAA/Industry Aircraft Deceleration Working Group study ("Thrust Reversers: Are They Really Needed?") estimated (p. 4] that the annual thrust reverser system costs for a large transport category airplane is approximately $221,550 per airplane (updated to 1997 dollars). It also reported (p. 4) that thrust reversers reduce annual braking system maintenance by about $13,775 per airplane (study estimate updated to 1997 dollars). Thus, the annualized net cost of using thrust reversers was estimated to be about $207,775 per airplane. Clearly, most operators have determined that these expensive systems provide a positive (although unquantified in this analysis) safety benefit. The FAA requests commenters to provide quantified estimates of and supporting data for the safety benefits from using thrust reverser systems.

Although the FAA cannot quantify this potential future cost savings from allowing either reliability or controllability because the forms that future technologies will take and their impacts on costs is not capable of being predicted, the FAA concludes that greater compliance flexibility could reduce compliance costs. The FAA requests comments on this conclusion; commenters should provide supporting data.

Costs of Compliance

Since the Model 767 (Lauda) accident in 1991, enhanced criteria have been used when demonstrating an airplane is controllable under the existing rule. This proposal does not change the existing controllability requirements; it merely provides a reliability-based alternative. Under this proposal, an applicant would have to demonstrate either that the airplane is controllable as required by the existing rule, or that the thrust reverser system meets the optional reliability requirements added by this proposal. Since the costs of demonstrating controllability are unchanged and demonstrating reliability is optional, this proposal does not require any additional compliance costs to be incurred. The FAA requests comments on this determination; commenters should provide supporting data.

Alternative Means of Addressing This Issue

In addition to the proposed rule, at least six other alternative means of addressing this issue were reviewed. As discussed previously, one alternative was to eliminate thrust reversers; a second alternative was to require greater airplane controllability without allowing the option of the applicant meeting a reliability criterion. The other 4 alternatives would require specific methods that could, potentially, provide greater airplane controllability, but which have been rejected for technical reasons delineated elsewhere in this Notice and economic reasons delineated below.

Alternative (1): Benefits and Costs from Eliminating Thrust Reversers

With respect to eliminating thrust reversers, the1994 NASA/FAA/Industry study, described previously, reported (p. 8) that thrust reversers contribute less than 20 percent of the overall stopping force on a dry runway. However, on a slippery runway (from rain, snow, etc.) the thrust reverser braking effect can nearly equal wheel braking forces. Similarly, thrust reversers significantly contribute to stopping an airplane safely during a rejected takeoff. The FAA evaluated several compensating factors for thrust reversers (such as reducing landing speeds, extending runways, and having arresting gear at airports), but determined that, with the current state of technology, these compensating factors wouldbeeither more hazardous or impracticable. As a result, the FAA finds that eliminating thrust reversers would reduce overall airline operational safety because reversers contribute to an increased level of safety especially on contaminated runways. However, since reversers are only one means of providing suitable operating safety, the FAA have concluded that requiring reverser would also be unwarranted. The FAA requests comments on this finding; commenters should provide supporting data.

Alternative (2): Benefits and Costs from Requiring Greater Airplane Controllability for All Airplanes

As previously discussed, the FAA considers that compliance with the reliability criterion of the proposed rule would provide the same level of safety as compliance with the controllability criterion. Thus, requiring all airplanes to meet the controllability criterion would not increase the level of safety.

It is likely that some transport category airplanes could achieve greater airplane controllability at little or no additional cost. However, given current technology, some other transport category airplanes, especially those using high bypass turbofan engines, could only attain greater airplane controllability through a redesign that would necessitate additional equipment. This additional equipment would, in turn, increase those airplanes' weight, aerodynamic drag, and maintenance. Thus, this alternative would generate increased annual operating costs as well as increased manufacturing costs.

In order to estimate the potential cost increases that would occur if only the controllability criterion were allowed, the FAA assumes that the typical future larger transport category airplane would be similar in overall design to recent certificated models.

Weight. The FAA has relied upon two manufacturers' estimates of the impact that compliance with only the controllability criterion would produce. For those airplane models, the manufacturers estimated that compliance would require a 50 percent increase in the airplane's rudder surface (a 0.2 percent increase in the airplane's weight) and the addition of 12 spoilers and 4 ailerons (a 0.3 percent increase in the airplane's weight). Thus, this alternative would increase an airplane's weight by about 0.5 percent.

Fuel Costs. The FAA assumes that the percentage increase in weight would approximately translate into an equivalent percentage increase in fuel and oil consumption. The FAA's "Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs" (Table 4-1B on p. 4-4) indicates that the average fuel and oil cost per airborne hour is:

- $2,703 for a four-engine widebody,
- $1,152 for a two-engine widebody, and
- $665 for a two-engine narrowbody.

Applying the 0.5 percent increased weight factor produces an increased per airborne hourly cost of about:

- $13.50 for a four-engine widebody,
- $5.75 for a two-engine widebody, and
- $3.30 for a two-engine narrowbody.

Using data derived from the "FAA Aviation Forecasts Fiscal Years 1998-2009" (Tables 16 and 17, pp. IX-18 and IX-19), the average annual airborne hours is about:

- 3,000 hours for a four-engine widebody,
- 3,100 hours for a two-engine widebody, and
- 2,800 hours for a two-engine narrowbody.

Thus, the increased annual fuel and oil costs that would be due to this additional weight are estimated to be about:

- $40,000 per four-engine widebody,
- $17,825 for a two-engine widebody, and
- $9,250 for a two-engine narrowbody.

IncreasedDrag Costs. In addition to the increased weight, the larger rudder surface would raise aerodynamic drag by 1.5 percent, which would be equivalent to a 0.35 percent increase in direct operating costs. The FAA estimates that the direct operating costs per airborne hour would be about:

- $4,880 for a four-engine widebody,
- $2,265 for a two-engine widebody, and
- $1,340 for a two-engine narrowbody.

Multiplying those per airborne hour additional cost by the reported number of average airborne hours per year and then by 0.35 percent produces an additional annual per airplane cost due to the increased aerodynamic drag of about:

- $49,400 for a four-engine widebody,
- $24,550 for a two-engine widebody, and
- $13,125 for a two-engine narrowbody.

Maintenance Costs. Further, the additional spoilers and ailerons would require annual maintenance that would cost (in 1992 dollars) about $1 per airborne hour for each aileron and on average, $0.05 per airborne hour for each spoiler. Updating the estimated costs to 1997 dollars results in an annual increased maintenance cost of $5.15 per airborne hour. Multiplying these per airborne hour additional maintenance by the reported number of annual airborne hours per airplane produces an additional annual maintenance cost of about:

- $15,450 for a four-engine widebody,
- $15,950 for a two-engine widebody, and
- $14,425 for a two-engine narrowbody.

Consequently, the total increase in annual operational costs per airplane due to the increased weight and drag would be about:

- $104,850 for a four-engine widebody,
- $58,325 for a two-engine widebody, and
- $36,800 for a two-engine narrowbody.

Equipment Costs. In 1997 dollars, the reported cost would be about $8,960 for each spoiler actuator and would be about $11,200 each aileron actuator. Thus, this additional equipment would cost about $107,500 for the 12 additional spoiler actuators and $44,800 for the 4 additional aileron actuators, for a cost increase of $152,300 per airplane.

In addition, the oversized flight controls would need more complex control systems that are estimated to add 0.1 percent to the price of the airplane. Based on average prices of about $140 million for a new four-engine widebody, about $100 million for a new two-engine widebody, and about $40 million for a new two-engine narrowbody, the FAA estimates that the resultant increase in airplane cost due to the more complex control systems would be about:

- $140,000 for a new four-engine widebody,
- $100,000 for a new two-engine widebody, and

- $40,000 for a new two-engine narrowbody.

Thus, the total increase in the cost of a new airplane due to the additional or upgraded equipment would be about:

- $292,300 for a four-engine widebody,
- $252,300 for a two-engine widebody, and
- $192,300 for a two-engine narrowbody.

Revenue. In addition to the increased operational costs, the additional weight and drag may reduce an airplane's revenue because the operator may be required either to offload people and cargo or to limit the flight range on certain flights. The difficulty in estimating this revenue loss is that an offloaded person would generally either take a different flight on that airline or take a different airline. Thus, the loss to one operator may result in a revenue gain to another operator. One manufacturer estimated that the effect of these factors would be a 1.5 percent range loss or a 3.5 percent seat capacity loss for a typical 7,000 mile mission. For a hypothetical typical European airline with 40 long range aircraft and 120 short/medium range aircraft, the manufacturer estimated that the annual total revenue loss from these limitations would be $20 million, for an average annual aircraft revenue loss of $125,000. As detailed in the Initial Regulatory Evaluation for this proposed rulemaking (which is contained in the public docket), the FAA estimates that the annual average revenue loss from these limitations would be about:

- $110,000 for a four-engine widebody,
- $53,000 for a two-engine widebody, and
- $10,000 for a two engine narrowbody.

The FAA requests comments on this issue; commenters are requested to supply supporting data.

Total Annual Negative Economic Impact. Consequently, the FAA estimates that the range (including the manufacturer's estimated per airplane lost revenue of $125,000 per airplane) of total annual negative economic impact (increased annual operational cost plus annual lost revenue) would be:

- between $402,000 and $417,000 for a four engine widebody,
- between $305,000 and $377,000 for a two-engine widebody, and
- between $202,000 and $317,000 for a two-engine narrowbody.

Unquantifiable Factors. Finally, it should be noted that there are several other factors that would increase costs but were not able to be quantified. For example:

- the costs from the additional weight and the increased manufacturing costs associated with reinforcing the wing structure;
- the costs of the advanced avionics to operate the fast-response aspect; and
- the costs associated with adhering to the proposed roll angle limits, control forces limits, and post-event performance requirements required by the controllability option.

Alternative (3): Benefits and Costs of the Other Alternatives Reviewed

The <u>third</u> alternative would be to lengthen the separation distance (the length of the nacelle) between the wing and the engine, which would improve airplane controllability after an unwanted inflight thrust reversal. By lengthening the nacelles, aerodynamic drag and operational costs would be increased. In addition, airplane weight would be increased because longer landing gear and engine struts would be required. However, the increased length required for the desired level of safety would depend on the specific airplane/engine/thrust reverser combination. Consequently, the FAA could not quantify these potential increased operational costs.

Further, the future larger diameter high bypass ratio engines will require either

- a shorter distance between the wing and the engine because the airplane would need to maintain entry door sill heights in order to use current airport terminals, or
- a reduction in the engine's ground clearance.

The FAA finds that it would be very costly for airports to modify terminal gate heights to adjust to airplanes with different entry door sill heights. In addition, the closer the engine is to the ground, the greater the probability that a hard landing or an airplane roll during a landing or a takeoff could cause the engine to strike the pavement, resulting in potential engine loss, damage, or fire and associated damage to the hull. Given these limitations, the FAA is unwilling to require this alternative in the proposed rule.

The fourth alternative would be to revise the efflux pattern of the thrust reversers. Since this alternative was considered to be technologically impracticable, no consideration was given to its potential economic impact.

The fifth alternative would be to require that future engines be located either in the aft fuselage or above the wing, which would eliminate the loss of wing lift during an unwanted inflight thrust reversal. However, for large high bypass turbofan engines, such locations would generate severe economic penalties due to increased interference drag and weight penalties. The FAA was unable to quantify these operational costs. As a further consideration, these alternative engine locations may increase overall risk because they could have a significantly negative effect on an airplane's weight and balance configuration. Further, they may produce substantial additional stresses on the fuselage, which may result in more rapid aging of the airframe. Given these limitations, the FAA is unwilling to require this alternative in the proposed rule.

The sixth alternative would be to design engines so that a non-recoverable compressor stall would occur if an unwanted inflight thrust reversal were detected. The FAA determined that this alternative would be effective at improving airplane controllability for certain airplane models. However, this feature could reduce engine reliability and increase engine maintenance costs in those same airplane models. The FAA was unable to quantify these potential increased costs, however. In addition, this alternative would not be effective on certain airplane models or engine types. Given these limitations, the FAA is unwilling to require this alternative in the proposed rule.

Nevertheless, although the FAA considers that it is unlikely at this time that future type certificated airplanes would elect to use any of these specified alternatives, the FAA would not preclude their use in this proposed rulemaking because future technology developments may make one or more of them technologically and economically viable at some future time. The FAA requests comments on these alternatives; commenters should provide supporting data.

Initial Regulatory Flexibility Determination

The Regulatory Flexibility Act of 1980 (RFA), 50 U.S.C. 601-612, was enacted by Congress to ensure that small entities are not unnecessarily or disproportionately burdened by Government regulations. The RFA requires a regulatory flexibility analysis if a proposed rule has a significant economic impact on a substantial number of small business entities. FAA Order 2100.14A, Regulatory Flexibility Criteria and Guidance, establishes threshold costs and small entity size standards for complying with RFA requirements.

The proposed rule would provide an optional way of complying with the standards, and therefore would impose no new compliance costs on any entity. Based on this, the FAA certifies that the proposed rule would not have a significant economic impact on a substantial number of small entities.

International Trade Impact Statement

Consistent with the Administration's belief in the general superiority, desirability, and efficacy of free trade, it is the policy of the Administrator to remove or diminish, to the extent feasible, barriers to international trade, including both barriers affecting the export of American goods and services to foreign countries and those affecting the import of foreign goods and services into the United States.

In accordance with that policy, the FAA is committed to develop as much as possible its aviation standards and practices in harmony with its trading partners. Significant cost savings can result from this, both to American companies doing business in foreign markets, and foreign companies doing business in the United States.

This proposed rule would be a direct action to respond to this policy by increasing the harmonization of the U.S. Federal Aviation Regulations with the European Joint

Aviation Requirements. The result would be a positive step toward removing impediments to international trade.

The provisions of this proposed rule would have little or no impact on trade for U.S. firms doing business in foreign countries and foreign firms doing business in the United States.

Federalism Implications

The regulations proposed herein would not have a substantial direct effect on the States, on the relationship between the national Government and the States, or on the distribution of power and responsibilities among the various levels of government. Therefore, in accordance with Executive Order 12612, it is determined that this proposal would not have sufficient federalism implications to warrant the preparation of a federalism assessment.

Unfunded Mandates Assessment

Title II of the Unfunded Mandates Reform Act of 1995 (the Act), codified in 2 U.S.C. 1501-1571, requires each Federal agency, to the extent permitted by law, to prepare a written assessment of the effects of any Federal mandate in a proposed or final agency rule that may result in the expenditure by State, local, and tribal governments, in the aggregate, or by the private sector, of $100 million or more (adjusted annually for inflation) in any one year. Section 204(a) of the Act, 2 U.S.C. 1534(a), requires the Federal agency to develop an effective process to permit timely input by elected officers (or their designees) of State, local, and tribal governments on a proposed "significant intergovernmental mandate." A "significant intergovernmental mandate" under the Act is any provision in a Federal agency regulation that will impose an enforceable duty upon State, local, and tribal governments, in the aggregate, of $100 million (adjusted annually for inflation) in any one year. Section 203 of the Act, 2 U.S.C. 1533, which supplements section 204(a), provides that before establishing any regulatory requirements that might significantly or uniquely affect small governments, the agency shall have developed a plan that, among other things, provides for notice to potentially affected small governments, if any, and for a meaningful and timely opportunity to provide input in the development of regulatory proposals.

This proposed rule does not contain a Federal intergovernmental or private sector mandate that exceeds $100 million in any one year.

Environmental Analysis

FAA Order 1050.1D defines FAA actions that may be categorically excluded from preparation of a National Environmental Policy Act (NEPA) environmental assessment or environmental impact statement. In accordance with FAA Order 1050.1D, appendix 4, paragraph 4(j), this rulemaking qualifies for a categorical exclusion.

List of Subjects in 14 CFR Part 25

Aircraft, Aviation safety, Thrust Reverser Requirements

The Proposed Amendment

In consideration of the foregoing, the Federal Aviation Administration (FAA) proposes to amend 14 CFR part 25 of Title 14, Code of Federal Regulations, as follows:

PART 25 - AIRWORTHINESS STANDARDS - TRANSPORT CATEGORY AIRPLANES

1. The authority citation for part 25 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701-44702, and 44704.

2. Amend § 25.933 by revising paragraph (a)(1) to read as follows:

§ 25.933 Reversing systems.

(a) For turbojet reversing systems—

(1) Each system intended for ground operation only must be designed so that either—

(i) The airplane can be shown to be capable of continued safe flight and landing during and after any thrust reversal in flight; or

(ii) It can be demonstrated that inflight thrust reversal is extremely improbable and does not result from a single failure or malfunction.

* * * * *

Issued in Renton, Washington, on

Transport Airplane Directorate
Aircraft Certification Service

Draft 3/8/99

TASK PPI #4 23018

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: UNWANTED INFLIGHT THRUST REVERSAL OF TURBOJET THRUST REVERSERS	Date: Initiated by: ANM-110	AC No.: 25.933X

THIS DOCUMENT IS A WORKING DRAFT AND IS NOT FOR PUBLIC RELEASE.

1. PURPOSE. This Advisory Circular (AC) describes various acceptable means, for showing compliance with the requirements of §25.933(a)(1)and (a)(2), "Reversing systems, of 14 CFR part 25 of the Federal Aviation Regulations (FAR), as they apply to transport category airplanes. These means are intended to provide guidance to supplement the engineering and operational judgment that must form the basis of any compliance findings relative to inflight thrust reversal of turbojet thrust reversers.

The guidance provided in this document is directed to airplane manufacturers, modifiers, foreign regulatory authorities, and Federal Aviation Administration transport airplane type certification engineers and their designees.

Like all advisory circular material, this AC is not, in itself, mandatory, and does not constitute a regulation. It is issued to describe an acceptable means, but not the only means, for demonstrating compliance with the requirements for transport category airplanes. Terms such as "shall" and "must" are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance described in this document is used.

2. RELATED FAR SECTIONS. Sections 25.111, 25.143, 25.251, 25.571, 25.901, 25.903, 25.1155, 25.1305, 25.1309, 25.1322 and 25.1529

3. APPLICABILITY. The requirements of §25.933(a) apply to turbojet thrust reverser systems. Section 25.933(a)(1) specifically applies to reversers intended for ground operation only, while Section 25.933(a)(2) applies to reversers intended for both ground and inflight use. **This AC applies only to unwanted thrust reversal in flight phases**

when the landing gear is not in contact with the ground; other phases (i.e., ground operation) are addressed by § 25.901(c) and § 25.1309.

4. BACKGROUND

4.a. General. Most thrust reversers are intended for ground operation only. Consequently, thrust reverser systems are generally sized and developed to provide high deceleration forces while avoiding foreign object debris (FOD) ingestion, airplane surface efflux impingement, and airplane handling difficulty during landing roll. Likewise, aircraft flight systems are generally sized and developed to provide lateral and directional controllability margins adequate for handling qualities, maneuverability requirements, and engine-out V_{MC} lateral drift conditions.

In early turbojet airplane designs, the combination of control system design and thrust reverser characteristics resulted in control margins that were capable of recovering from unwanted inflight thrust reversal even on ground-use-only reversers; this was required by the versions of FAR 25.933 that were established by Amendments 25-40 and 25-72.

As the predominant large transport airplane configuration has developed into the high bypass ratio twin engine-powered model, control margins for the inflight thrust reversal case have decreased. Clearly, whenever and wherever thrust reversal is intended, the focus must remain on limiting any adverse effects of thrust reversal. However, when demonstrating compliance with FAR 25.933(a)(1) or 25.933(a)(2), the FAA has accepted that applicants may either provide assurance that the airplane is controllable after an inflight thrust reversal event or that the unwanted inflight thrust reversal event will not occur.

Different historical forms of the rule have attempted to limit either the effect or the likelihood of unwanted thrust reversal during flight. However, experience has demonstrated that neither method is always both practical and effective. The current rule, and this related advisory material, are intended to allow either of these assurance methods to be applied in a manner which recognizes the limitations of each, thereby maximizing both the design flexibility and safety provided by compliance with the rule.

4.b. Minimizing Adverse Effects. The primary purpose of reversing systems, especially those intended for ground operation only, is to assist in decelerating the airplane during landing and during an aborted takeoff. As such, the reverser must be rapid-acting and must be effective in producing sufficient reverse thrust. These requirements result in design characteristics (actuator sizing, efflux characteristics, reverse thrust levels, etc.) that, in the event of thrust during flight, could cause significant adverse effects on airplane controllability and performance.

If the effect of the thrust reversal occurring in flight produces an unacceptable risk to continued safe flight and landing, then the reverser operation and de-activation system must be designed to prevent unwanted thrust reversal. Alternatively, for certain airplane configurations, it may be possible to limit the adverse impacts of unwanted thrust reversal on airplane controllability and performance such that the risk to continued safe flight and landing is acceptable (discussed later in this AC).

For reversing systems intended for operation in flight, the reverser system must be designed to adequately protect against unwanted inflight thrust reversal.

FAR 25.1309 and 25.901(c) and the associated AC's (AC25.1309-1B and AC25.901-1)[See AC Action #1] provide guidance for developing and assessing the safety of systems at the design stage. This methodology should be applied to the total reverser system, which includes:

- the reverser;
- the engine (if it can contribute to thrust reversal);
- the reverser motive power source;
- the reverser control system;
- the reverser command system in the cockpit; and
- the wiring, cable, or linkage system between the cockpit and engine.

Approved removal, deactivation, reinstallation, and repair procedures for any element in the reverser or related systems should result in a safety level equivalent to the certified baseline system configuration.

Qualitative assessments should be done, taking into account potential human errors (maintenance, airplane operation).

Data required to determine the level of the hazard to the airplane in case of inflight thrust reversal and, conversely, data necessary to define changes to the reverser or the airplane to eliminate the hazard, can be obtained from service experience, test, and/or analysis. These data also can be used to define the envelope for continued safe flight.

There are many opportunities during the design of an airplane to minimize both the likelihood and severity of unwanted inflight thrust reversal. These opportunities include design features of both the airplane and the engine/reverser system. During the design process, consideration should be given to the existing stability and control design features, while preserving the intended function of the thrust reverser system.

Some design considerations, which may help reduce the risk from inflight thrust reversal, include:

4.b.(1) **Engine location to**:

4.b.(1)(a) Reduce sensitivity to efflux impingement.

4.b.(1)(b) Reduce effective reverse thrust moment arms

4.b.(2) **Engine/Reverser System design to:**

4.b.(2)(a) Optimize engine/reverser system integrity and reliability.

4.b.(2)(b) Rapidly reduce engine airflow (i.e. auto-idle) in the event of an unwanted thrust reversal. Generally, such a feature is considered a beneficial safety item. In this case, the probability and effect of any unwanted idle command or failure to provide adequate reverse thrust when selected should be verified to be consistent with AC 25.1309 and 25.901(c).

4.b.(2)(c) Give consideration to the airplane pitch, yaw, and roll characteristics.

4.b.(2)(d) Consider effective efflux diameter.

4.b.(2)(e) Consider efflux area.

4.b.(2)(f) Direct reverser efflux away from critical areas of the airplane.

4.b.(2)(g) Expedite detection of unwanted thrust reversal, and provide for rapid compensating action within the reversing system.

4.b.(2)(h) Optimize positive aerodynamic stowing forces.

4.b.(2)(i) Inhibit inflight thrust reversal of ground-use-only reversers, even if commanded by the flight crew.

4.b.(2)(j) Consider incorporation of a restow capability for unwanted thrust reversal.

4.b.(3) **Airframe/System design to:**

4.b.(3)(a) Maximize aerodynamic control capability.

4.b.(3) (b) Expedite detection of thrust reversal, and provide for rapid compensating action through other airframe systems.

4.b.(3) (c) Consider crew procedures and responses.

The use of formal "lessons learned"-based reviews early and often during design development may help avoid repeating previous errors and take advantage of previous successes.

5. DEFINITIONS. The following definitions apply for the purpose of this AC : Editorial Note: consider including "Catastrophic", "Hazardous" and "Major" definition cross references to AC25.1309

5.a. Continued Safe Flight and Landing: The capability for continued controlled flight and safe landing at an airport, possibly using emergency procedures, but without requiring exceptional pilot skill or strength. Some airplane damage may be associated with a failure condition, during flight or upon landing.

5.b. Controllable Flight Envelope and Procedure: An area of the Normal Flight Envelope where, given an appropriate procedure, the airplane is capable of continued safe flight and landing following an inflight thrust reversal.

5.c. Deactivated Reverser: Any thrust reverser that has been deliberately inhibited such that it is precluded from performing a normal deploy/stow cycle, even if commanded to do so.

5.d. Exceptional Piloting Skill and/or Strength: Refer to § 25.143(c) ("Controllability and Maneuverability -- General") and AC 25-7 ("Flight Test Guide").

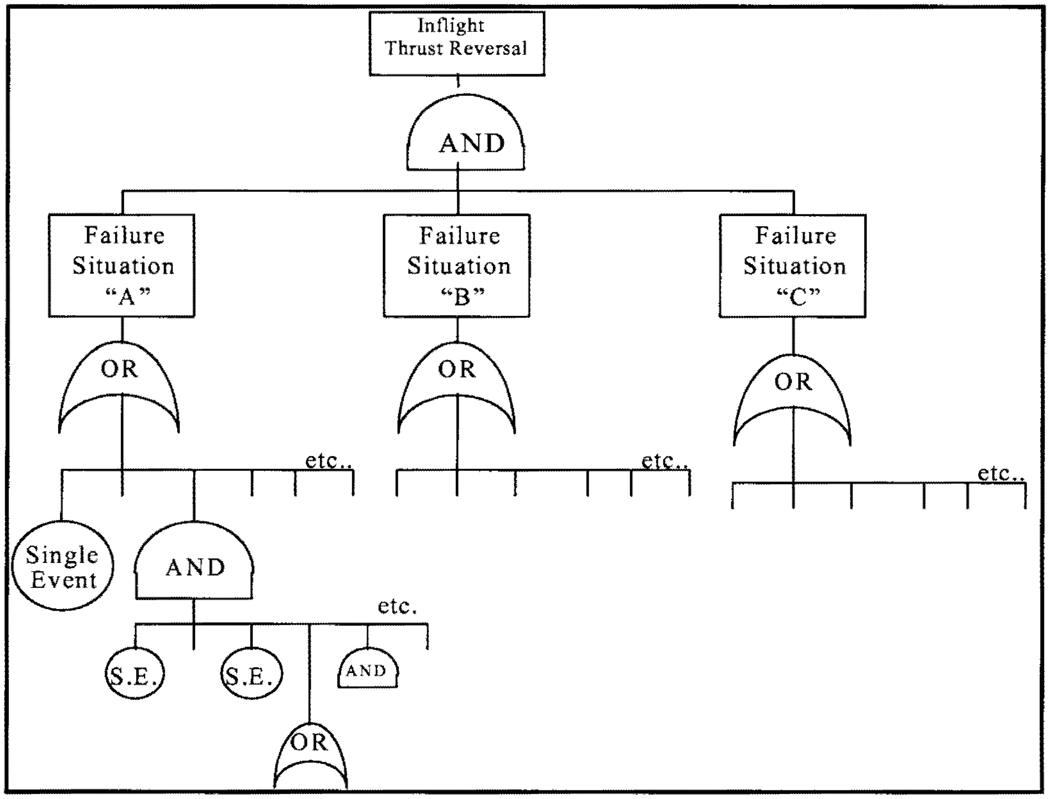
5.e. Extremely Improbable: see AC 25.1309

5.f. Extremely Remote: see AC 25.1309

5.g. Failure: see AC 25.1309

5.h. Failure Situation: All failures that result in the malfunction of one independent command and/or restraint feature that directly contributes to the top level Fault Tree Analysis event (i.e., unwanted inflight thrust reversal). For the purpose of illustration, **Figure 1**, below, provides a fault tree example for a scenario of three "failure situations" leading to unwanted inflight thrust reversal.

<u>Figure 1</u>:
TOP EVENT



Reverser System with three independent command/restraint features shown for reference only.

5.i. <u>Inflight</u>: that part of airplane operation beginning when the wheels are no longer in contact with the ground during the takeoff and ending when the wheels again contact the ground during landing.

5j. <u>Light Crosswind</u>: For purposes of this AC, a light crosswind is a 10 Kt. wind at right angles to the direction of takeoff or landing which is assumed to occur on every flight.

5.k. <u>Light Turbulence</u>: Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, and/or yaw), which is assumed to occur on every flight.

5.l. <u>Maximum exposure time</u>: The longest anticipated period between the occurrence and elimination of the failure.

5.m. Normal Flight Envelope: An established boundary of parameters (velocity, altitude, angle of attack, attitude) associated with the practical and routine operation of a specific airplane that is likely to be encountered on a typical flight and in combination with prescribed conditions of light turbulence and light crosswind.

5.n. Pre-existing failure: Failure that can be present for more than one flight.

5.o. Thrust Reversal: A movement of all or part of the thrust reverser from the forward thrust position to a position that spoils or redirects the engine airflow.

5.p. Thrust Reverser System: Those components that spoil or redirect the engine thrust to decelerate the airplane. The components include:

- the engine-mounted hardware,
- the reverser control system,
- indication and actuation systems, and
- any other airplane systems that have an effect on the thrust reverser operation.

5.q Turbojet thrust reversing system: Any device that redirects the airflow momentum from a turbojet engine so as to create reverse thrust. Systems may include:

- cascade-type reversers,
- target or clamshell-type reversers,
- pivoted-door petal-type reversers,
- deflectors articulated off either the engine cowling or airplane structure,
- targetable thrust nozzles, or
- a propulsive fan stage with reversing pitch.

5.r. Turbojet (or turbofan): A gas turbine engine in which propulsive thrust is developed by the reaction of gases being directed through a nozzle.

6. DEMONSTRATING COMPLIANCE WITH §25.933(a)(1). The following Sections 7 through 10 of this AC provide guidance on specific aspects of compliance with §25.933(a)(1), according to four different means or methods:

- Controllability (Section 7)
- Reliability (Section 8)

- Mixed controllability/reliability (Section 9)
- Deactivated reverser (Section 10)

7. "CONTROLLABILITY OPTION": PROVIDE CONTINUED SAFE FLIGHT AND LANDING FOLLOWING ANY INFLIGHT THRUST REVERSAL

The following paragraphs provide guidance regarding an acceptable means of demonstrating compliance with § 25.933(a)(1)(i).

7.a. General. For compliance to be established with §25.933(a)(1) by demonstrating that the airplane is capable of continued safe flight and landing following any inflight thrust reversal (the "controllability option" provided for under §25.933(a)(1)(i)), the aspects of structural integrity, performance, and handling qualities must be taken into account. The level of accountability should be appropriate to the probability of inflight thrust reversal, in accordance with the following sections.

To identify the corresponding failure conditions and determine the probability of their occurrence, a safety analysis should be carried out, using the methodology described in FAR 25.1309. The reliability of design features, such as auto-idle and automatic control configurations critical to meeting the following controllability criteria, also should be considered in the safety analysis.

Appropriate alerts and/or other indications should be provided to the crew, as required by §25.1309(c) (Ref. AC 25.1309).

The inhibition of alerts relating to the thrust reverser system during critical phases of flight should be evaluated in relation to the total effect on flight safety (Ref. AC 25.1309).

Thrust reversal of a cyclic or erratic nature (e.g., repeated deploy/stow movement of the thrust reverser) should be considered in the safety analysis and in the design of the alerting/indication systems.

Input from the flight crew and human factors specialists should be considered in the design of the alerting and/or indication provisions.

The controllability compliance analysis should include the relevant thrust reversal scenario that could be induced by a rotorburst event.

When demonstrating compliance using this "controllability option" approach, if the airplane might experience an inflight thrust reversal outside the "controllable flight envelope" anytime during the entire operational life of all airplanes of this type, then further compliance considerations as described in Section 9 ("MIXED RELIABILTY / CONTROLLABILITY OPTION") of this AC, below, should be taken into account.

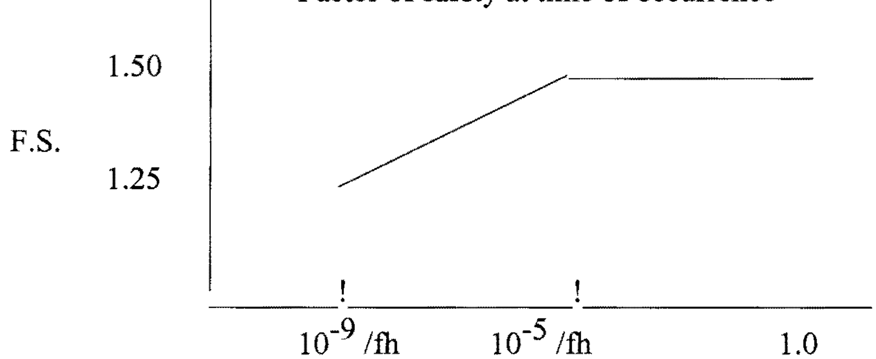
7.b. Structural Integrity. For the "controllability option," the airplane must be capable of successfully completing a flight during which anunwanted inflight thrust reversal occurs. An assessment of the integrity of the airplane structure is necessary, including an assessment of the structure of the deployed thrust reverser and its attachments to the airplane.

In conducting this assessment, the normal structural loads, as well as those induced by failures and forced vibration (including buffeting), both at the time of the event and for continuation of the flight, must be shown to be within the structural capability of the airplane.

At the time of occurrence, starting from 1-g level flight conditions, at speeds up to V_C, a realistic scenario, including pilot corrective actions, should be established to determine the loads occurring at the time of the event and during the recovery maneuver. The airplane should be able to withstand these loads multiplied by an appropriate factor of safety that is related to the probability of unwanted inflight thrust reversal. The factor of safety is defined in **Figure 2**, below. Conditions with high lift devices deployed also should be considered at speeds up to the appropriate flap limitation speed.

Figure 2

Factor of safety at time of occurrence



P - probability of unwanted inflight thrust reversal per flight hour

For continuation of the flight following inflight thrust reversal, considering any appropriate reconfiguration and flight limitations, the following apply:

7.b.(1) **Static strength** should be determined for loads derived from the following conditions at speeds up to V_C, or the speed limitation prescribed for the remainder of the flight:

7.b.(1)(a) 70% of the limit flight maneuver loads; and separately

7.b.(1)(b) the discrete gust conditions specified in FAR 25.341(a) (but using 40% of the gust velocities specified for V_C).

7.b.(2) **For the airplane with high lift devices deployed, static strength** should be determined for loads derived from the following conditions at speeds up the appropriate flap design speed, or any lower flap speed limitation prescribed for the remainder of the flight:

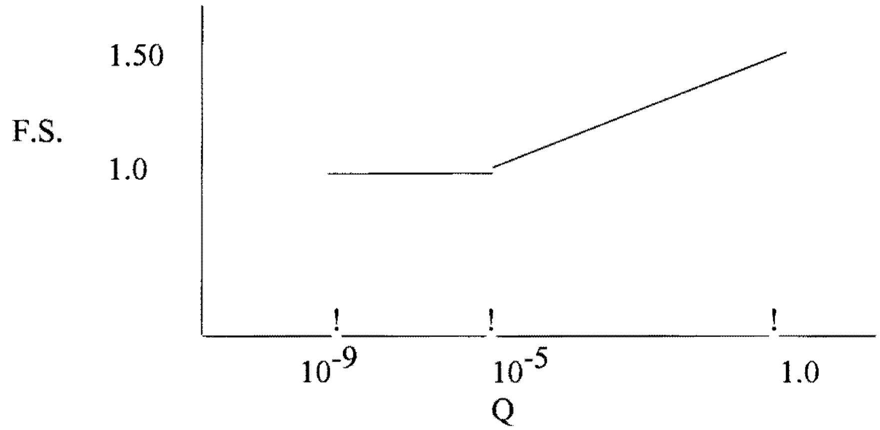
7.b.(2)(a) A balanced maneuver at a positive limit load factor of 1.4; and separately

7.b.(2)(b) the discrete gust conditions specified in FAR 25.345(a)(2) (but using 40% of the gust velocities specified).

7.b.(3) **For static strength substantiation**, each part of the structure must be able to withstand the loads specified in sub-paragraph 7.b.(1) and 7.b.(2) of this paragraph, multiplied by a factor of safety depending on the probability of being in this failure state. The factor of safety is defined in **Figure 3**, below.

<u>Figure 3</u>

Factor of safety for continuation of the flight



Q - is the probability of being in the configuration with the unwanted inflight thrust reversal

Q = (T)(P) where:
T = average time spent with unwanted inflight thrust reversal(in hours)
P = probability of occurrence of unwanted inflight thrust reversal (per hour)

If the thrust reverser system is capable of being restowed following a thrust reversal, only those loads associated with the interval of thrust reversal need to be considered. Historically, thrust reversers have often been damaged as a result of unwanted thrust reversal during flight. Consequently, any claim that the thrust reverser is capable of being restowed must be adequately substantiated, taking into account this adverse service history.

7.c. <u>Performance</u>

7.c.(1) **General Considerations:** Most failure conditions that have an effect on performance are adequately accounted for by the requirements addressing a “regular” engine failure (i.e., involving only loss of thrust and not experiencing any reverser anomaly). This is unlikely to be the case for failures involving an unwanted inflight thrust reversal, which can be expected to have a more adverse impact on thrust and drag than a regular engine failure. Such unwanted inflight thrust reversals, therefore, should be accounted for specifically, to a level commensurate with their probability of occurrence.

The performance accountability that should be provided is defined in Sections 7.c.(2) and 7.c.(3) as a function of the probability of the unwanted inflight thrust reversal. Obviously, for unwanted inflight thrust reversals less probable than 1 E-9/fh, certification may be based on reliability alone, as described in Section 8

("RELIABILITY OPTION") of this AC. Furthermore, for any failure conditions where unwanted inflight thrust reversal would impact safety, the airplane must meet the safety/reliability criteria delineated in FAR 25.1309.

7.c.(2) **Probability of unwanted inflight thrust reversal greater than 1 E-7/fh:** Full performance accountability must be provided for the more critical of a regular engine failure and an unwanted inflight thrust reversal. To determine if the unwanted inflight thrust reversal is more critical than a regular engine failure, the normal application of the performance requirements described in FAR 25, Subpart B, as well as the applicable operating requirements, should be compared to the application of the following criteria, which replace the accountability for a critical engine failure with that of a critical unwanted inflight thrust reversal:

- **FAR 25.111, "Takeoff path":** The takeoff path should be determined with the critical unwanted thrust reversal occurring at V_{LOF} instead of the critical engine failure at V_{EF}. No change to the state of the engine with the thrust reversal that requires action by the pilot may be made until the aircraft is 400 ft above the takeoff surface.

- **FAR 25.12, "Climb: one-engine-inoperative":** Compliance with the one-engine-inoperative climb gradients should be shown with the critical unwanted inflight thrust reversal rather than the critical engine inoperative.

- **FAR 25.123, "En-route flight paths":** The en-route flight paths should be determined following occurrence of the critical unwanted inflight thrust reversal(s) instead of the critical engine failure(s), and allowing for the execution of appropriate crew procedures. For compliance with the applicable operating rules, an unwanted inflight thrust reversal(s) at the most critical point en-route should be substituted for the engine failure at the most critical point en-route.

Performance data determined in accordance with these provisions, where critical, should be furnished in the Airplane Flight Manual as operating limitations.

Operational data and advisory data related to fuel consumption and range should be provided for the critical unwanted inflight thrust reversal to assist the crew in decision making. These data may be supplied as simple factors or additives to apply to normal all-engines-operating fuel consumption and range data. For approvals to conduct extended range operations with two-engine airplanes (ETOPS), the critical unwanted inflight thrust reversal should be considered in the critical fuel scenario [paragraph 10d(4)(iii) of AC 120-42A].

7.c.(3) **Probability of unwanted inflight thrust reversal equal to or less than 1 E-7/fh, but greater than 1 E-9/fh:** With the exception of the takeoff phase of flight, which needs not account for unwanted inflight thrust reversal, the same criteria should be applied as in Section 7.c.(2), above, for the purposes of providing advisory data and procedures to the flight crew. Such performance data, however, need not be applied as operating limitations. The takeoff data addressed by Section 7.c.(2), above (takeoff speeds, if limited by V_{MC}, takeoff path, and takeoff climb gradients), does not need to be provided, as it would be of only limited usefulness if not applied as a dispatch limitation.

However, the takeoff data should be determined and applied as operating limitations if the unwanted inflight thrust reversal during the take-off phase is the result of a single failure.

As part of this assessment, the effect of an unwanted inflight thrust reversal on approach climb performance, and the ability to execute a go-around maneuver should be determined and used to specify crew procedures for an approach and landing following a thrust reversal. For example, the procedures may specify the use of a flap setting less than that specified for landing, or an airspeed greater than the stabilized final approach airspeed, until the flight crew is satisfied that a landing is assured and a go-around capability need no longer be maintained. Allowance may be assumed for execution of appropriate crew procedures subsequent to the unwanted thrust reversal having occurred. Where a number of thrust reversal states may occur, these procedures for approach and landing may, at the option of the applicant, be determined either for the critical thrust reversal state or for each thrust reversal state that is clearly distinguishable by the flight crew.

Operational data and advice related to fuel consumption and range should be provided for the critical unwanted inflight thrust reversal to assist the crew in decision-making. These data may be supplied as simple factors or additives to apply to normal all-engines-operating fuel consumption and range data.

7.d. Handling Qualities

7.d.(1) **Probability of unwanted inflight thrust reversal greater than 1 E-7/fh:** The more critical of an engine failure [or flight with engine(s) inoperative], and an unwanted inflight thrust reversal, should be used to show compliance with the controllability and trim requirements of part 25, Subpart B. In addition, the criteria defined in Section 7.d.(2), below, also should be applied. To determine if the unwanted inflight thrust reversal is more critical than an engine failure, the normal application of the part 25, Subpart B, controllability and trim requirements should be compared to the application of the following criteria, which replace the accountability for a critical engine failure with that of a critical unwanted inflight thrust reversal:

- **FAR 25.143, "Controllability and Maneuverability - General"**
  - The effect of a sudden unwanted inflight thrust reversal of the critical engine, rather than the sudden failure of the critical engine, should be evaluated in accordance with § 25.143(b)(1) and the associated guidance material.
  - Control forces associated with the failure should comply with § 25.143(c).

- **FAR 25.147, "Directional and lateral control"**
  - The requirements of § 25.147(a), (b), (c), and (d) should be complied with following critical unwanted inflight thrust reversal(s) rather than with one or more engines inoperative.

- **FAR 25.149, "Minimum control speed"**

- The values of V_{MC} and V_{MCL} should be determined with a sudden unwanted inflight thrust reversal of the critical engine rather than a sudden failure of the critical engine.

- **FAR 25.161, "Trim"**
  - The trim requirements of § 25.161(d) and (e) should be complied with following critical unwanted inflight thrust reversal(s), rather than with one or more engines inoperative.

Compliance with these requirements should be demonstrated by flight test. Simulation or analysis will not normally be an acceptable means of compliance for such probable failures.

7.d.(2) **Probability of unwanted thrust reversal equal to or less than 1 E-7/fh, but greater than 1 E-9/fh:** Failure conditions with a probability equal to or less than 1 E-7/fh are not normally evaluated against the specific controllability and trim requirements of part 25, Subpart B. Instead, the effects of unwanted inflight thrust reversal should be evaluated on the basis of maintaining the capability for continued safe flight and landing, taking into account pilot recognition and reaction time. One exception is that the minimum control speed requirement of § 25.149 should be evaluated to the extent necessary to support the performance criteria specified in Section 7.c.(3), above, related to approach, landing, and go-around.

Recognition of the failure may be through the behavior of the aircraft or an appropriate failure alerting system, and the recognition time should not be less than one second. Following recognition, additional pilot reaction times should be taken into account, prior to any corrective pilot actions, as follows:

- **Landing** .... no additional delay
- **Approach** .... 1 second
- **Climb, cruise, and descent**.........3 seconds; except when in auto-pilot engaged maneuvering flight, or in manual flight, when 1 second should apply.

Both auto-pilot engaged and manual flight should be considered.

The unwanted inflight thrust reversal should not result in any of the following:

- exceedance of an airspeed halfway between V_{MO} and V_{DF}, or Mach Number halfway between M_{MO} and M_{DF}.
- a stall.
- a normal acceleration less than a value of 0g.
- bank angles of more than 60° en-route, or more than 30° below a height of 1000 ft.
- degradation of flying qualities assessed as greater than *Major* for unwanted inflight thrust reversal more probable than 1 E-7/fh; or assessed as greater than *Hazardous* for failures with a probability equal to or less than 1 E-7/fh, but greater 1 E-9/fh.[See AC Action #2]
- the roll control forces specified in § 25.143(c), except that the long term roll control force should not exceed 10 lb.
- structural loads in excess of those specified in Section 7.b., above.

Demonstrations of compliance may be by flight test, by simulation, or by analysis suitably validated by flight test or other data.

7.d.(3) **Probability of inflight thrust reversal less than 1 E-9/fh:** Certification can be based on reliability alone as described in Section 8, below.

8. "<u>RELIABILITY OPTION": PROVIDE CONTINUED SAFE FLIGHT AND LANDING BY PREVENTING ANY INFLIGHT THRUST REVERSAL</u>

The following paragraphs provide guidance regarding an acceptable means of demonstrating compliance with § 25.933(a)(1)(ii).

8.a. General. For compliance to be established with §25.933(a)(1) by demonstrating that unwanted inflight thrust reversal is not anticipated to occur (the "reliability option" provided for under §25.933(a)(1)(ii)), the aspects of system reliability, maintainability, and fault tolerance; structural integrity; and protection against zonal threats such as uncontained engine rotor failure or fire must be taken into account.

8.b. System Safety Assessment (SSA): Any demonstration of compliance should include an assessment of the thrust reverser control, indication and actuation system(s), including all interfacing power-plant and airplane systems (such as electrical supply, hydraulic supply, flight/ground status signals, thrust lever position signals, etc.) and maintenance.

The reliability assessment should include:

- the possible modes of normal operation and of failure;
- the resulting effect on the airplane considering the phase of flight and operating conditions;
- the crew awareness of the failure conditions and the corrective action required;
- failure detection capabilities and maintenance procedures, etc.; and
- the likelihood of the failure condition.

Consideration should be given to failure conditions being accompanied or caused by external events or errors.

The SSA should be used to identify critical failure paths for the purpose of conducting in-depth validation of their supporting failure mode, failure rates, exposure time, reliance on redundant subsystems, and assumptions, if any. In addition, the SSA can be used to determine acceptable time intervals for any required maintenance intervals (ref. AC/AMJ 25.1309 and AC25.19).

The primary intent of this approach to compliance is to improve safety by promoting more reliable designs and better maintenance, including minimizing **pre-existing** faults. However, it also recognizes that flexibility of design and maintenance are necessary for practical application.

8.b.(1) The thrust reverser system should be designed so that any inflight thrust reversal that is not shown to be controllable in accordance with Section 7,above, is **extremely improbable** (i.e., average probability per hour of flight of the order of 1 E-9/fh. or less) and does not result from a single failure or malfunction. **And**

8.b. (2) For configurations in which combinations of two-failure situations (ref. Section 5, above) result in inflight thrust reversal, the following apply:[See AC Action #3 & General Action #1]

- Neither failure may be pre-existing (i.e., neither failure situation can be undetected or exist for more than one flight); the means of failure detection must be appropriate in consideration of the monitoring device reliability, inspection intervals, and procedures.
- The occurrence of either failure should result in appropriate cockpit indication or be self-evident to the crew to enable the crew to take necessary actions such as discontinuing a take-off, going to a controllable flight envelope en-route, diverting to a suitable airport, or reconfiguring the system in order to recover single failure tolerance, etc.

And

8.b. (3) For configurations in which combinations of three or more failure situations result in inflight thrust reversal, the following applies:

- In order to limit the exposure to pre-existing failure situations, the maximum time each pre-existing failure situation is expected to be present should be related to the frequency with which the failure situation is anticipated to occur, such that their product is 1 E-3 or less.
- The time each failure situation is expected to be present should take into account the expected delays in detection, isolation, and repair of the causal failures.

8.c. Structural Aspects: For the "reliability option," those structural load paths that affect thrust reversal should be shown to comply with the static strength, fatigue, damage tolerance, and deformation requirements of part 25. This will ensure that unwanted inflight thrust reversal is not anticipated to occur due to failure of a structural load path, or due to loss of retention under **ultimate** load throughout the operational life of the airplane.

8.d. Uncontained Rotor Failure: In case of rotor failure, compliance with § 25.903(d)(1) should be shown, using advisory materials (AC, user manual, etc.) supplemented by the methods described below. The effects of associated loads and vibration on the reverser system should be considered in all of the following methods of minimizing hazards:

8.d.(1) Show that engine spool-down characteristics or potential reverser damage are such that compliance with Section 7, above, can be shown.

8.d. (2) Show that forces that keep the thrust reverser in stable stowed position during and after the rotor burst event are adequate.

8.d. (3) Locate the thrust reverser outside the rotor burst zone.

8.d. (4) Protection of thrust reverser restraint devices: The following guidance material describes methods of minimizing the hazard to thrust reverser stow position restraint devices located within rotorburst zones. The following guidance material has been developed on the basis of all of the data available to date and engineering judgment.

8.d.(4)(a) *Fragment Hazard Model:*

8.d.(4)(a)(i) **Large Fragments**

- <u>Ring Disks</u> (see **<u>Figure 4.a.</u>**) - Compressor drum rotors or spools with ring disks have typically failed in a rim peeling mode when failure origins are in the rim area. This type of failure typically produces uncontained fragment energies, which are mitigated by a single layer of conventional aluminum honeycomb structure. (Note: This guidance material is based upon field experience and, as such, its application should be limited to aluminum sheet and honeycomb fan reverser construction. Typical construction consists of a half inch thickness of .003-.004 aluminum foil honeycomb with .030" thick aluminum facing sheets. Alternative materials and methods of construction should have at least equivalent impact energy absorption characteristics). Failures with the origins in the bore of these same drum sections have resulted in fragments which can be characterized as a single 1/3 disk fragment and multiple smaller fragments. The 1/3 disk fragment may or may not be contained by the thrust reverser structure. The remaining intermediate and small disk fragments, while escaping the engine case, have been contained by the thrust reverser structure.
- <u>Deep Bore Disks</u> (see **<u>Figure 4.b</u>**.) ***and Single Disks*** (see **<u>Figure 4.c</u>**.) - For compressor drum

rotors or spools with deep bore disks, and single compressor and turbine disks, the experience, while limited, indicates either a 1/3 and a 2/3 fragment, or a 1/3 fragment and multiple intermediate and small discrete fragments should be considered. These fragments can be randomly released within an impact area that ranges ± 5 degrees from the plane of rotation.

8.d.(4)(a)(ii) **Small Fragments (Debris):** Consider small fragments (reference AC 20-128A, paragraph 9.d.) that could impact the thrust reverser at ± 15 degrees axial spread angle.

8.d.(4)(b) *Minimization*: Minimization guidance provided below is for fragments from axial flow rotors surrounded by fan flow thrust reversers located over the intermediate or high-pressure core rotors.

NOTE: See attached **Figure 5**: Typical High Bypass Turbofan Low and High Pressure Compressor with Fan Thrust Reverser Cross Section

8.d.(4)(b)(i) **Large Fragments**: For the large fragments defined in Section 8.d.(4)(a)(i), above, the thrust reverser retention systems should be redundant and separated as follows:

- Ring Disks Compressor Spools:
  Retention systems located in the outer barrel section of the thrust reverser should be separated circumferentially (circumferential distance greater than the 1/3 disk fragment model as described in AC 20-128A) or axially (outside the ± 5 degree impact area) so that a 1/3 disk segment can not damage all redundant retention elements and allow thrust reversal (i.e., deployment of a door or translating reverser sleeve half). Retention systems located between the inner fan flow path wall and the engine casing should be located axially outside the ± 5 degree impact area.

- Deep-bore Disk Spools and Single Disks:
  Retention systems should be separated axially with at least one retention element located outside the ± 5 degree impact area.

8.d.(4)(b)(ii) **Small Fragments:** For the small fragments defined in Section 8.d.(4)(a)(ii), above, thrust reverser retention systems should be provided with either:

- At least one retention element shielded in accordance with AC 20-128A, paragraph 7(c), or capable of maintaining its retention capabilities after impact; or

- One retention element located outside the ± 15 degree impact area.

9. "MIXED CONTROLLABILITY/RELIABILITY " OPTION: If the airplane might experience an unwanted inflight thrust reversal outside the "controllable flight envelope" anytime during the entire operational life of all airplanes of this type, then outside the controllable envelope reliability compliance must be shown, taking into account associated risk exposure time and the other considerations described in Section 8, above.

Conversely, if reliability compliance is selected to be shown within a given limited flight envelope with associated risk exposure time, then outside this envelope controllability must be demonstrated taking into account the considerations described in Section 7, above.

Mixed controllability/reliability compliance should be shown in accordance with guidance developed in Sections 7 and 8, above, respectively.

10. DEACTIVATED REVERSER: The thrust reverser system deactivation design should follow the same "fail-safe" principles as the actuation system design, insofar as failure and systems/hardware integrity. The effects of thrust reverser system deactivation on other airplane systems, and on the new configuration of the thrust reverser system itself, should be evaluated according to Section 8.a., above. The location and load capability of the mechanical lock-out system (thrust reverser structure and lock-out device) should be evaluated according to Sections 8.b. and 8.d., above. The evaluation should show that the level of safety associated with the deactivated thrust reverser system is equivalent to or better than that associated with the active system.

11. FAR Section 25.933(a)(2) COMPLIANCE: For thrust reversing systems intended for inflight use, compliance with § 25.933(a)(2) may be shown for unwanted inflight thrust reversal, as appropriate, using the methods specified in Sections 7 through 10, above.

12. CONTINUED AIRWORTHINESS:

12.a. Manufacturing/Quality: Due to the criticality of the thrust reverser, manufacturing and quality assurance processes should be assessed and implemented, as appropriate, to ensure the design integrity of the critical components.

12.b. Reliability Monitoring: An appropriate system should be implemented for the purpose of periodic monitoring and reporting of in-service reliability performance. The system should also include reporting of in-service concerns related to design, quality, or maintenance that have the potential of affecting the reliability of the thrust reverser.

12.c. Maintenance and Alterations: The following material provides guidance for maintenance designs and activity to assist in demonstrating compliance with Sections 7 through 10, above (also reference § 25.901(b)(2) and § 25.1529/Appendix H). The criticality of the thrust reverser and its control system requires that maintenance and maintainability be emphasized in the design process and derivation of the maintenance control program, as well as subsequent field maintenance, repairs, or alterations.

12.c.(1) **Design**: Design aspects for providing adequate maintainability should address :

12.c.(1)(a) *Ease of maintenance.* The following items should be taken into consideration:

- It should be possible to operate the thrust reverser for ground testing/trouble shooting without the engine operating.

- Lock-out procedures (deactivation for flight) of the thrust reverser system should be simple, and clearly described in the maintenance manual. Additionally, a placard describing the procedure may be installed in a conspicuous place on the nacelle.

- Provisions should be made in system design to allow easy and safe access to the components for fault isolation, replacement, inspection, lubrication, etc. This is particularly important where inspections are required to detect latent failures. Providing safe access should include consideration of risks both to the mechanic and to any critical design elements that might be inadvertently damaged during maintenance.

- Provisions should be provided for easy rigging of the thrust reverser and adjustment of latches, switches, actuators, etc.

12.c.(1)(b) *Fault identification and elimination:*

- System design should allow simple, accurate fault isolation and repair.

- System design personnel should be actively involved in the development, documentation, and validation of the troubleshooting/fault isolation manual and other maintenance publications. The systems design personnel should verify that maintenance assumptions critical to any SSA conclusion are supported by these publications (e.g., perform fault insertion testing to verify that the published means of detecting, isolating, and eliminating the fault are effective).

- Thrust reverser unstowed and unlocked indications should be easily discernible during pre-flight inspections.

- If the airplane has onboard maintenance monitoring and recording systems, the system should have provisions for storing all fault indications. This would be of significant help to maintenance personnel in locating the source of intermittent faults.

12.c.(1)(c) *Minimization of errors*: Minimization of errors during maintenance activity should be addressed during the design process. Examples include physical design features, installation orientation markings, dissimilar connections, etc. The use of a formal "lessons learned"-based review early and often during design development may help avoid repeating previous errors.

12.c.(1)(d) *System Reliability*: The design process should, where appropriate, use previous field reliability data for specific and similar components to ensure system design reliability.

12.c.(2) **Maintenance Control:**

12.c.(2)(a) *Maintenance Program*: The development of the initial maintenance plan for the airplane, including the thrust reverser, should consider, as necessary, the following:

- Involvement of the manufacturers of the airplane, engine, and thrust reverser.

- The compatibility of the SSA information and the Maintenance Review Board Report, Maintenance Planning Document, Master Minimum Equipment List, etc. (ref AC 25.19).

- Identification by the manufacturer of all maintenance tasks critical to continued safe flight. The operator should consider these tasks when identifying and documenting Required Inspection Items.

- The complexity of lock-out procedures and appropriate verification.

- Appropriate tests, including an operational tests, of the thrust reverser to verify correct system operation after the performance of any procedure that would require removal, installation, or adjustment of a component; or disconnection of a tube, hose, or electrical harness of the entire thrust reverser actuation control system.

12.c.(2)(b) *Training*: The following considerations should be taken into account when developing training documentation:

- The reason and the significance of accomplishing critical tasks as prescribed. This would clarify why a particular task needs to be performed in a certain manner.

- Instructions or references as to what to do if the results of a check or operational test do not agree with those given in the Airplane Maintenance Manual (AMM). The manual should recommend some corrective action if a system fails a test or check. This would help ensure that the critical components are not overlooked in the trouble shooting process.

- Emphasis on the total system training by a single training source (preferably the airplane manufacturer) to preclude fragmented information without a clear system understanding. This training concept should be used in the initial training and subsequent retraining.

- Inclusion of fault isolation and troubleshooting using the material furnished for the respective manuals.

- Evaluation of the training materials to assure consistency between the training material and the maintenance and troubleshooting manuals.

12.c.(2)(c) *Repairs and Alterations:* The Instructions for Continued Airworthiness essential to ensure that subsequent repairs or alterations do not unintentionally violate the integrity of the original thrust reverser system type design approval should be provided by the original airframe manufacturer. Additionally, the original airframe manufacturer should define a method of ensuring that this essential information will be evident to those that may perform and approve such repairs and alterations. One example would be maintaining the wire separation between relevant thrust reverser control electrical circuits. This sensitivity could be communicated by statements in appropriate manuals such as the Wiring Diagram Manual, and by decals or placards placed on visible areas of the thrust reverser and/or airplane structure.

12.c.(2)(d) *Feedback of Service Experience:* The maintenance process should initiate the feedback of service experience that will allow the monitoring of system reliability performance and improvements in system design and maintenance practices. Additionally, this service experience should be used to assure the most current and effective formal "lessons learned" design review process possible.

12.c.(2)(d)(i) **Reliability Performance:** [See AC Action # 4]

- Accurate reporting of functional discrepancies.

- Service investigation of hardware by manufacturer to confirm and determine failure modes and corrective actions if required.

- Update of failure rate data. (This will require coordination between the manufacturers and airlines.)

12.c.(2)(d)(ii) **Improvements suggested by maintenance experience:**

- Manuals
- Troubleshooting
- Removal/replacement procedures.

12.c.(2)(e) *Publications/Procedures:* The following considerations should be addressed in the preparation and revisions of the publications and procedures to support the thrust reverser in the field in conjunction with § 25.901(b)(2) and § 25.1529 (Appendix H).

12.c.(2)(e)(i) Documentation should be provided that describes a rigging check, if required after adjustment of any thrust reverser actuator drive system component.

12.c.(2)(e)(ii) Documentation should be provided that describes powered cycling of the thrust reverser to verify system integrity whenever maintenance is performed. This could also apply to any manual actuation of the reverser.

12.c.(2)(e)(iii) The reasons and the significance of accomplishing critical tasks should be included in the AMM.

12.c.(2)(e)(iv) The AMM should include instructions or references as to what to do if the results of a check or operational test do not agree with those given in the AMM.

12.c.(2)(e)(v) Provisions should be made to address inefficiencies and errors in the publications:

- Identified in the validation process of both critical and troubleshooting procedures.
- Input from field.
- Operators conferences.

12.c.(2)(e)(vi) Development of the publications should be a coordinated effort between the thrust reverser, engine, airplane manufacturers and airline customers especially in the areas of:

- AMM
- Troubleshooting
- Fault isolation
- Maintenance data computer output
- Procedure Validation
- Master Minimum Equipment List

12.c.(2)(e)(vii) Initial issue of the publication should include the required serviceable limits for the complete thrust reverser system.

13. **FLIGHT CREW TRAINING:** In the case of compliance with the "controllability option," and when the nature of the inflight thrust reversal is judged as unusual (compared to expected consequences on the airplane of other failures, both basic and recurrent), flight crew training should be considered on a training simulator that is equipped with thrust reverser inflight modelization to avoid flight crew misunderstandings:

13.a. Transient maneuver: Recovery from the unwanted inflight thrust reversal.

13.b. Continued flight and landing: Maneuvering appropriate to the recommended procedure (included trim and unattended operation) and precision tracking (ILS guide slope tracking, speed/altitude tracking, etc.).