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CIVIL AVIATION AUTHORITY

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Federal Aviation Administration
Office of the Chief Council
Attention Rules Docket (AGC-200, Docket No. 28903)
800 Independence Avenue SW
Washington
DC 20591

Our ref 9/61/10CD

1 August, 1997

Dear Dear Sir,

TYPE CERTIFICATION PROCEDURES FOR CHANGED PRODUCTS

Please accept this letter as CAA comment on NPRM 97-7 and Notice of availability of Draft AC 21.101-XX, published in the Federal Register on the 2 May 1997.

Thank you for the opportunity to take part in your rulemaking process.

Yours sincerely

A J Maxwell
Projects Department

enc

FAX MESSAGE
TO: LYLE C DAVIS (FAA)
FAX NO: 1 202 267 5340 PAGE 1 OF 21
ATTENTION: LYLE DAVIS DATE: 1/8/97
RE: TYPE CERT. PROCEDURES CHANGED PRODUCTS
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Blick Label.

CAA Comment on NPRM 97-7 and Draft Advisory Circular 21.101-XX, Type Certification Procedures for Changed Products

1. General Comments

Although it is agreed NPRM 97-7 and Draft AC 21-XX tends to introduce the same text as published by JAA in NPA 21-7 it is noted that the preamble, page 24291 from the text "...The basic premise behind the FAA's current policies for the procedures..." intimates that FAA policy appears to be moving towards accepting previously certificated products with a greater level of change before requiring certification as a new product. This almost appears to override and contradict the very definite criteria set out in 21.19, the "Statement of problem" in the preamble where it is stated that a number of small changes could result in a substantial difference of the original product, and the JAA overriding Safety consideration and the accepted principle of JAA NPA 21-7. The following CAA views provides specific comments on the need to positively limit the extent to which manufacturers should be allowed to change products without being required to certificate a product to the latest standards. It is suggested that the harmonisation of FAA/JAA requirements remains incomplete until it is clearly understood by both FAA/JAA the extent to which the criteria for a changed product is to applied in particular instances.

The objective of the certification policy for changed products should be to ensure, as far as is practicable, that a changed product will achieve the same level of safety as a new product introduced at the same time as the changed product.

It is suggested the proposals of NPRM 97-7 will not achieve this objective for the following reasons:-

a) The proposed 21.101(b)(2) allows areas not affected by the change being considered to continue to use superseded airworthiness requirements, some of which may have been amended with the objective of improving the general level of safety.

   The fact that a product is a changed product, rather than a new product, should not be the reason for allowing it to continue to use outdated safety standards indefinitely. Even for areas not affected by the changes there needs to be a point beyond which a changed product is required to comply with the latest standards where amendments have been made as part of an initiative to improve general safety levels in such areas.

b) The proposed 21.101(b)(3) allow the continued use of superseded airworthiness requirements where compliance *"would not contribute materially to the safety of the changed product"*.

   Although NPRM 97-7 acknowledges the need to assess the accumulative effect of a number of small changes on the level of safety, the text of Paragraph (b)(3) is written in terms of the effect of a single change. As with the comment on Draft AC 21.101-XX, Paragraph 11(c) it is suggested there is a need to establish the datum as the original design standard of the product originally certificated.

c) The Safety/Resource Evaluation Guide described in Appendix 2 of the associated Draft AC 21.101-XX is fundamentally unsound and its use could lead to unacceptable results - see separate comment.

The above comments are not intended to delay the adoption of the changes to FAR 21 that are proposed in NPRM 97-7, however, Appendix 2 of the proposed AC 21.101-XX should either be deleted or fundamentally revised.

The purpose of the above comments is to draw attention to the fact that the current proposals do not solve the fundamental problem of the certification basis of changed products (as recent experience has also shown) and should be seen as an interim measure.

In order to address the fundamental problem, it is proposed that FAA, in collaboration with JAA, should establish a new working group charged with developing revised rules for the certification basis of changed products that ensure that changed products will achieve the same level of safety as a new product introduced at the same time as the changed product.

In addressing this issue, it needs to be recognised that there is a general need to continually improve aviation safety levels with the inevitable effect that changed products are expected to achieve better safety levels than the types from which they are derived.

An additional point that needs to be taken into account is that, so far as is known, aviation manufacturing is the only industry with an important safety focus that does not require manufacturers to adopt new safety standards after some prescribed effective date, even for products that are not otherwise being changed.

2. Paragraph 21.19 Changes requiring a new type certificate

The subject of proposed FAR 21.19 is "change" to an already type-certificated product. It is felt to be entirely appropriate for that text to be located in "Subpart D - Changes To The Type Certificate of JAR-21". Nevertheless it is also suggested that the proposed 21.101(a) should be amended to read as follows:-

> 21.101 **Designation of applicable requirements**
>
> (a) "Where the Administrator finds that an application for a new type certificate is not required under 21.19 and except as provided in paragraph (b)....."

3. Paragraph 21.101(b) Designation of applicable regulations

These paragraphs are difficult to understand and should be re-drafted. In addition, the text of paragraph 21.101(b) needs to be cross referred in some manner to sub-paragraphs (b)(1), (b)(2) and (b)(3).

The following text is proposed for 21.101(b).

> "The applicant may demonstrate in accordance with either paragraphs (b)(1), (b)(2) or (b)(3) that the changed product complies with an earlier amendment of a regulation as required by paragraph (a), and any other regulation the Administrator finds is directly related, provided that the earlier amendment of the regulation does not precede the particular regulation defined in the type certificate."

4. Paragraph...21.101(b)(2), (b)(3) Designation of applicable regulations

The word "area" as used in the text covers a wide and important range of aspects having nothing to do with the "physical size" meaning of the word "area". CAA comment on JAA NPA 21-7 suggested that these requirements paragraphs would benefit by being changed to read :- "For each feature of the product......" as opposed to "For each area, system, component, equipment, or appliance(s)..." It is acknowledged that this proposal would require extensive interpretative material to clarify that the word "feature" is intended to cover a range of issues eg area, system, component , equipment or appliance.

5. Paragraph...21.101(c) Designation of applicable regulations

The words "established by the regulations" are used. It is suggested that the word "established" is incorrect in this context and should be replaced by "intended"

CAA Comment on Draft AC 21.101-XX, Advisory Material for the evaluation of the Certification Basis for changed Aeronautical Products.

1. General Comments

a. The following text is proposed for inclusion in an additional paragraph 16:-.

"16. - Overriding safety considerations

Notwithstanding the above evaluation techniques, there will be occasions when the safety considerations override all arguments with respect to the practicality of complying with the later requirements".

b. CAA believes that it is highly desirable that the proposed new requirement and its AC material should be simplified as much as possible so that the need for training is kept to a minimum. Standardisation should be the goal.

2. Paragraph 11.c Exceptions that would allow compliance with earlier regulations

Certification experience has shown that there are some cases where;

a. a combination of Non-significant changes affecting an "area" or system should be considered to constitute a significant change, and
b. a combination of .significant changes should be considered to constitute a substantial change.

Although the combination of previous relevant changes that might be considered significant is included as a factor in Paragraph 12 of the proposals, it is suggested that paragraphs 11.c.1 and 12 should provide detailed guidance in this respect. It is noted this already features, to a certain extent, in the Figure on Page 5 of the Draft AC.

In conjunction with this principle "change" needs to be defined relative to a datum. It is suggested the datum should generally be the design standard of the product originally Type Certificated. In some cases it may be acceptable to consider the datum as an earlier model at which the certification basis was revised. This should be clearly defined in the AC.

3. Paragraph 15. Impractical

The explanation of the term "impractical" needs to be expressed more simply. Suggested text is as follows:-

Impractical : "Compliance with the regulations in effect at the time of the application for certification of a changed product may be considered impractical if the applicant can show that it results in costs that are not consistent with the safety benefit which would result from applying these later requirements."

4. Appendix 1, General Comment

Performance and handling are effects of changes rather than physical changes in their own right, it can be difficult to assess their significance in the same way as for structural or systems changes. Some minor physical changes may necessitate a major re-evaluation whereas other major changes may be accepted as having little of no effect on flying qualities. Examples quoted in Appendix 1 include a change in the number of blades on a propeller being normally considered as substantial, whereas fitting alternate brakes would be non-significant. From flight considerations, this may be very far from the case. The propeller change may have limited effects, but the "non-significant" change of brakes may necessitate a complete re-evaluation of take-off (RTO) and landing performance, and amendment of much of the performance section of the AFM. Definitions that might be used for determining the flight significance are:-

Non-significant:	can be agreed without flight testing that handling qualities are not affected and that performance is either not affected or can be determined by extrapolation of existing data
Significant:	limited flight testing is required to substantiate that handling qualities remain acceptable and that the existing performance data remain valid
Substantial:	new performance data have to be established or substantial re-evaluation of handling qualities is required

5. Appendix 1 - Paragraph 2.f, Power or Thrust

Although this paragraph comes under paragraph 2 which is headed Airplanes, it would avoid confusion if it was made clear that the text was addressing the Power/Thrust of the total aircraft and not type design changes of engines. This objective could be achieved by simply adding "airplane" before Power or Thrust in title of paragraph f.

6. Appendix 1, Paragraph 4.a.(1), Rotor Stages

It is too simplistic to classify design changes to turbine engines by means of the amount of thrust or power increase. Paragraph 4.a.(1) should be amended as follows:

> "4.a.1(i) An increase in the number of compressor or turbine stages should be regarded as significant.
>
> 4.a.(1)(ii) An increase in power or thrust will be evaluated to assess the design changes which result in the power or thrust increase in order to determine if the design change should be classified as substantial, significant or non-significant."

7. Appendix 1, Paragraph 4.a.(2), Fixed Turbine vs Free-turbine in a shaft Output Engine

This paragraph should be changed to reflect the four forms of propulsion ie Turboshaft, Turboprop, Turbojet and Turbofan.

The title and text would then become:-

"Turboshaft, Turboprop, Turbojet and Turbofan".

"A change in the principle of propulsion would normally necessitate......."

With the inclusion of the above, the reference to the addition of a fan stage to an existing turbomachine in paragraph 4.a.(1) should be deleted.

8. Appendix 1, Paragraph 4.a.(4), Structural Design Changes

Significant in this text seems to imply significant in terms of airworthiness (by reference to bird ingestion capability), rather than the significance of the design change and the necessity of applying a later standard of requirement to the change.

9. Appendix 1, Paragraph 4.b.(4), Fuel Control System

This implies that a change from a float carburetor to an electronic control would be considered as non-significant. In 4.a.(3), such a change from hydromechanical control to FADEC is deemed to be significant. The same philosophy should apply in each case and be classified as significant.

Fundamental changes to cooling system should be addressed. The following should be added as Paragraph 4.b.(5)

"Cooling System"

"Conversion from an air cooled to a water cooled system would be regarded as significant."

10. Appendix 2, Safety Benefit Resource Evaluation, and ICPTF Report

The use of this ICPTF Safety Benefit / Resource Evaluation Guide is challenged on the following technical grounds:-

(a) Definitions. The definitions used in the ICPTF method for the Effectiveness of Actions and required Resources are vague and subjective. This means that there is a strong possibility that different people working independently will obtain different results. Because of the subjective nature of these definitions, successful challenge, or justification, of these results will be difficult.

(b) Large & Small Aircraft. The process only caters for large transport aeroplanes. The method fails to account for smaller aircraft (e.g. small turboprops and rotorcraft). Without the scale effect being taken into account, this method cannot be included for general use.

(c) Assessing Safety Benefits. It is generally accepted that potential safety benefits are very difficult to assess. In the method, significance is placed on the difference between the probability of a hull-loss occurring with and without fatalities. This difference is very difficult to quantify rationally but, in the method, it can result in a proposal being either 'effective' or 'not effective'. Furthermore, the slope of the line on the Risk/"Scale of catastrophe" chart is not consistent with a proper cost benefit assessment. For example, 100% deaths at one risk level and 10% deaths at risk 10 times greater should lead to the same Safety Index; it is obvious that this is not so on these charts.

(d) Assessing Effectiveness. Risk analysis indicates that separation between lines for *Effectiveness of Action* on the risk / Safety Index chart is not consistent with normal understanding of the descriptions of the different effectiveness levels. For example, the spacing between *Level 111* and *Level 1V* lines is only correct if a *Level 111* action is 5 times more effective than a *Level 1V* action. This is not consistent with a normal interpretation of the written descriptions. Moreover, the slope of the *Effective/Not Effective* boundary on the Resource Index / Safety Index chart is not consistent with a slope that would be obtained from a proper cost benefit assessment in which cost would be proportional to risk.

(e) Assessing Economic Impact. The method only addresses part of the economic impact of a proposed regulation. It only accounts for the cost of implementation, not the cost and consequences of an accident. This means that it fails to account correctly for high cost and serious consequence, low probability events. The use of this method of analysis to consider features/design standards included on any in service aircraft appears to ignore 10^{-9} events that are justifiably avoided at the design stage through the application of FAR 25.1309.

(f) Assessing Resources. This is far too simplistic. The scales (i.e. 1, 4, 20, 100 points) are disproportionate and give an unreasonable bias to the final 'cost'. Taking one item, you score 20 points if there is a 2% increase in the commercial operating cost while you score 100 points if there is a 4% increase. What is the basis of these resource numbers? Without any justification, how can anyone trust the method?

(g) Discounting. The method takes no account of future costs and benefits. This is very important because we are always assessing costs and benefits over a long time period. This can only be done by discounting, but the method completely ignores this.

(h) Uncertainty. There is no formal assessment of uncertainties. Sensitivity or Scenario Analyses are essential if any study is to maintain credibility with a wider audience. Indeed, the quality of any study can usually be assessed by the attention given to the uncertainty. As there is no mention of uncertainty the method fails to address all important issues.

(i) Appendix 2 Page 37 - Para 2.2 3rd Line. The text states that the method "..........is not intended to be detailed cost benefit study, but rather to determine if the regulatory change should be implemented." The *only* purpose of conducting a formal detailed cost benefit study is to determine if a regulatory change should be implemented. The text in para 2.2 is very misleading.

(j) Procedure for Evaluating a Changed Product. Although the International Certification Procedures Task Force (ICPTF) Report is now generally available, as indicated at the end of (d) above and in more detail in the attached note on cost benefit analysis **(Attachment)**, this proposed method has serious flaws and its use should not be permitted.

In view of the above, it is considered that the ICPTF Safety Benefit / Resource Evaluation Guide is flawed and should not be used for any FAA Economic Assessment. Pending any agreement on simplified Economic Assessment Methods, where such an assessment is needed, it should be carried out on the basis of normal cost benefit assessment methods.

CAA suggests however, that FAA gives consideration to adopting a simplified cost benefit assessment as described in the attached note on cost benefit analysis **(Attachment)**.

11. Appendix 3 Paragraph 2(d)(1) Service Experience

It is suggested that "In-Flight Shut down rate (IFSD)" should be added to the list of sources.

A NOTE ON COST BENEFIT ANALYSIS

Introduction

The International Certification Procedures Task Force (ICPTF) has developed, as part of its work on the Certification Basis of Changed Products, a *Safety/Resource Evaluation Guide* which is intended to provide a means of balancing the costs and benefits associated with requiring a changed product to comply with a new airworthiness requirement.

Although this Safety/Resource Evaluation Guide has no formal status, not having been subjected to either the NPA or the NPRM consultation process, its basic concept has been adopted by the JAA Catch Up Task Force (CUTF) as part of their proposed methodology for evaluating submissions from NAA's for requirements to be added to the certification basis of the State of Manufacture for Catch Up purposes. However, although ICPTF have proposed some "Cost Benefit" criteria in their proposal, these have not been adopted by CUTF because they have not yet been formally adopted.

Recent discussions of the CUTF proposals have focused attention on the ICPTF Safety/Resource Evaluation Guide and prompted some analysis; this in turn has prompted further thinking about Cost Benefit analysis as applied to aircraft safety and the purpose of this note is to record these thoughts and invite discussion and/or comment.

The ICPTF Safety/Resource Evaluation Guide

In principle, the ICPTF Safety/Resource Evaluation Guide provides a method for classifying:-

1. The degree of hazard, and the consequences of its occurrence, for some aircraft feature.

2. The effectiveness of a proposed corrective action, and

3. The cost of implementing the proposed corrective action, in terms of a *"Resource Index"*.

A graphical method is then provided in order to relate the hazard and its consequences, together with the effectiveness of the proposed corrective action, to a *"Safety Index"*. A chart relating *Resource Index* to *Safety Index* is then provided; this chart is then divided into "Effective", "Not Effective" and "Doubtful" region, the concept being that a proposed corrective action which falls into the "Not Effective" region is not Cost Effective and, therefore, too expensive to be worth implementing.

Analysis of the ICPTF Safety/Resource Evaluation Guide

In order to try to explore the concepts of the Safety/Resource Evaluation Guide, some simple analysis has been carried out.

In order to keep this simple, attention has been confined to

- hazards which have a consequence resulting in >10% deaths (the most severe hazard addressed in the guide) - in the following this is taken to be (for descriptive purposes) a catastrophic event, and

- perfect corrective actions, that is actions that are expected to eliminate the particular hazard.

For the above two circumstances, the second and third charts of the Evaluation Guide simply consist of linear relationships between:-

- *Safety Index* and *LOG(risk of occurrence per departure)*, and

- *Safety Index* and *LOG(resource index)*.

The Safety Index/Risk can be eliminated from these relations to give new relations of the form:-

$$RI = a.\left(\frac{r}{r_0}\right)^p$$

where:- ***RI*** is the Resource Index,
a and r_0 are constants, and
r is the risk of catastrophe per departure

These are shown in Figure 1 below, for both the upper Resource Index boundary of the "Effective" region and for the lower Resource Index boundary of the "Not Effective" region.

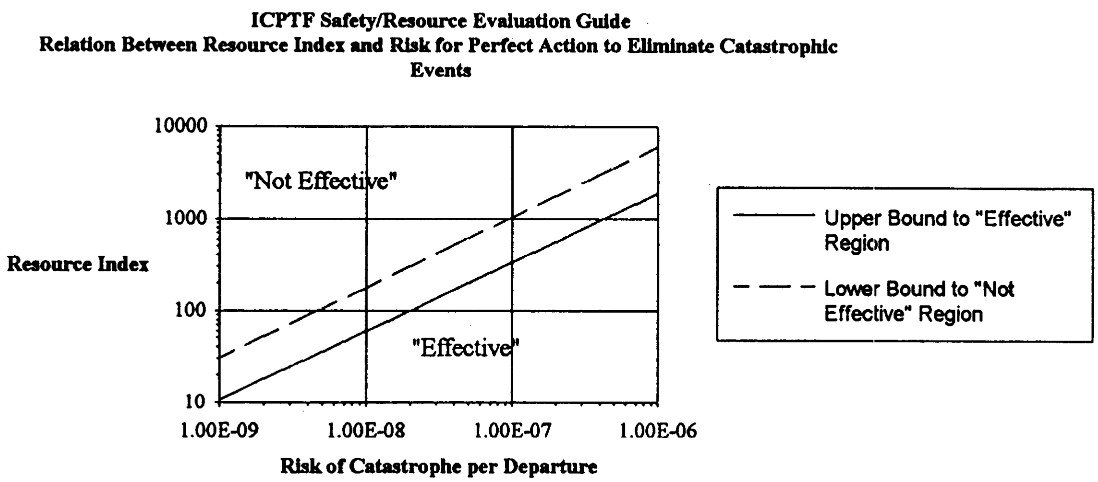


Figure 1

It is notable that, in both cases, the exponent, p, is less than 1! Specifically:-

$p = 0.747$ for the low Resource Index Line, and

$p = 0.765$ for the high Resource Index line

This means that, according to these criteria, the cost that one should be prepared to pay to eliminate a risk rises less rapidly than the risk itself as the risk increases.

Intuitively, this does not seem to be in the spirit of a cost benefit approach. The difference between the above criteria and corresponding criteria in which the acceptable Resource Index rises in proportion to the risk is shown in Figure 2.

ICPTF Safety/Resource Evaluation Guide
Relation Between Resource Index and Risk for Perfect Action to Eliminate Catastrophic Events

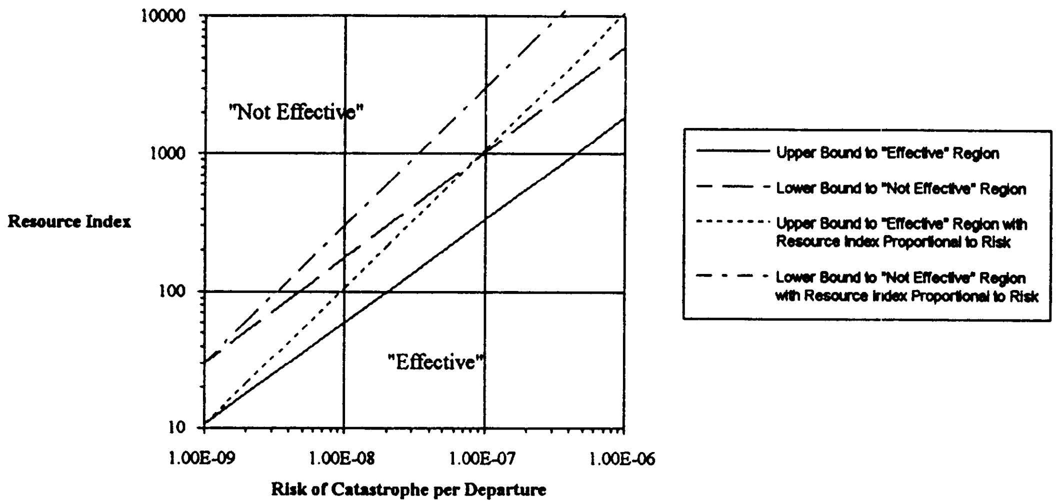


Figure 2

Cost Benefit Approach

In order to explore the concepts inherent in a cost benefit approach, consider the following:-

It is assumed that, under a cost benefit approach, it is acceptable to pay up to, but not more than, the cost of an accident in order to avoid an accident.

Cost Benefit Analysis

Let N be the number of aircraft of a specific type.

L be the expected service life of each aircraft of the specific type.

C be the total cost to society of an accident to an aircraft of the specific type.

r be the risk of an accident (measured in the same units as the expected service life) due to a specific aircraft feature.

Then:-

The expected number of accidents due to the feature under consideration for the specific fleet of aircraft is:-

$$N.L.r$$

and the expected cost of these accidents is:-

$$C.N.L.r$$

and so the expected cost per aircraft is:-

$$C.L.r$$

This is the amount that, under the cost benefit approach, society would be prepared to pay, per individual aircraft of the type, in order to eliminate accidents due to the specific feature being considered.

Note that this confirms the intuitive view given above that the acceptable cost of eliminating a risk should rise in proportion to the risk; the fact that the ICPTF Safety/Resource Evaluation Guide does not have this property indicates that the ICPTF Safety/Resource Evaluation Guide has a **fundamental flaw!**

Accident Costs

The cost of an aircraft accident can essentially be considered to consist of three parts:-

i. The cost of the damage to the aircraft. In the event of a catastrophic accident, or a hull loss, this is the airframe value. For airworthiness requirement purposes it is considered that it is appropriate to use the new aircraft price. Typical values might be:-

   $135 million for a Boeing 747-400

   $6.9 million for a Jetstream 41

   {both values have been taken from the Avmark Database of aircraft prices, published in March 1994}

ii. The cost of the occupant injuries/lives lost; for a catastrophic accident to small aircraft the number of lives lost should be assumed to equal or exceed the maximum number of passengers; for a catastrophic accident to a Boeing 747-400, the cost benefit analysis ought to be based on the loss of at least 400 lives, although the TCDS allows 660 pax!

   The typical value of a life lost is considered to be $3 million (£2 million, loosely)

iii. Ancillary costs of rescue, accident investigation and follow up, etc.

Using the above figures, the catastrophic accident costs (ignoring ancillary costs) are:-

Boeing 747-400	$\$1.336 \times 10^9$
Jetstream 41	$\$9.39 \times 10^7$

Cost Benefits for a 10^{-9} per hour Event

For a typical Boeing 747-400, assume that the expected service life is 100,000 hours; for a Jetstream 41 assume 50,000 hours.

The relationships given above then show that, according to the cost benefit concept, it is worthwhile to eliminate a feature with a risk of catastrophe of 10^{-9} per hour provided that the cost does not exceed:-

$133,600 for a Boeing 747-400

$4,695 for a Jetstream 41.

Figure 3 shows equivalent results for a range of risks.

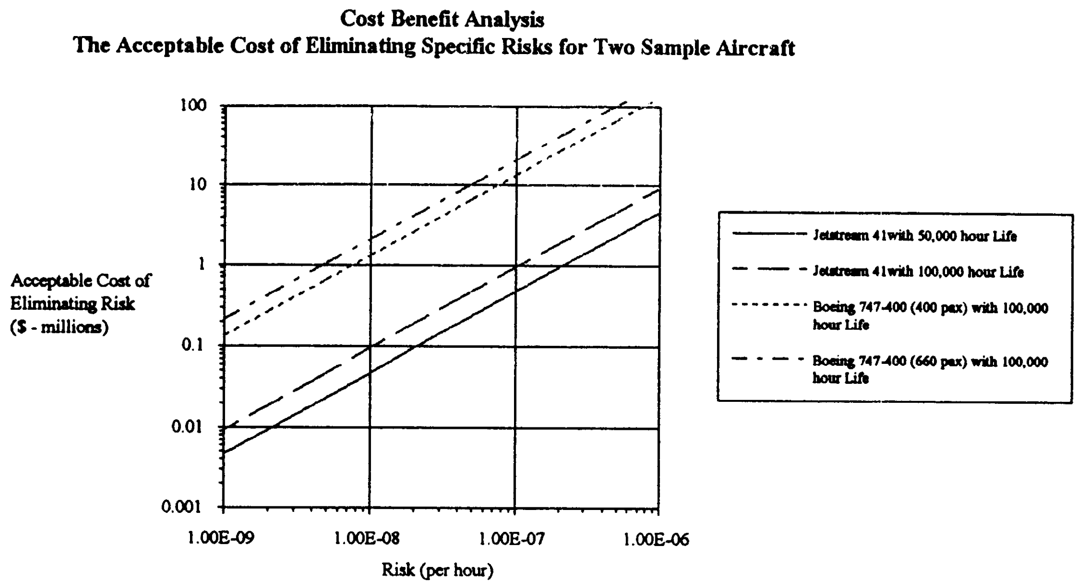


Figure 3

The results from Figure 3 can also be expressed by relating the acceptable cost of eliminating the risk to the cost of the aircraft. This is shown in Figure 4:-

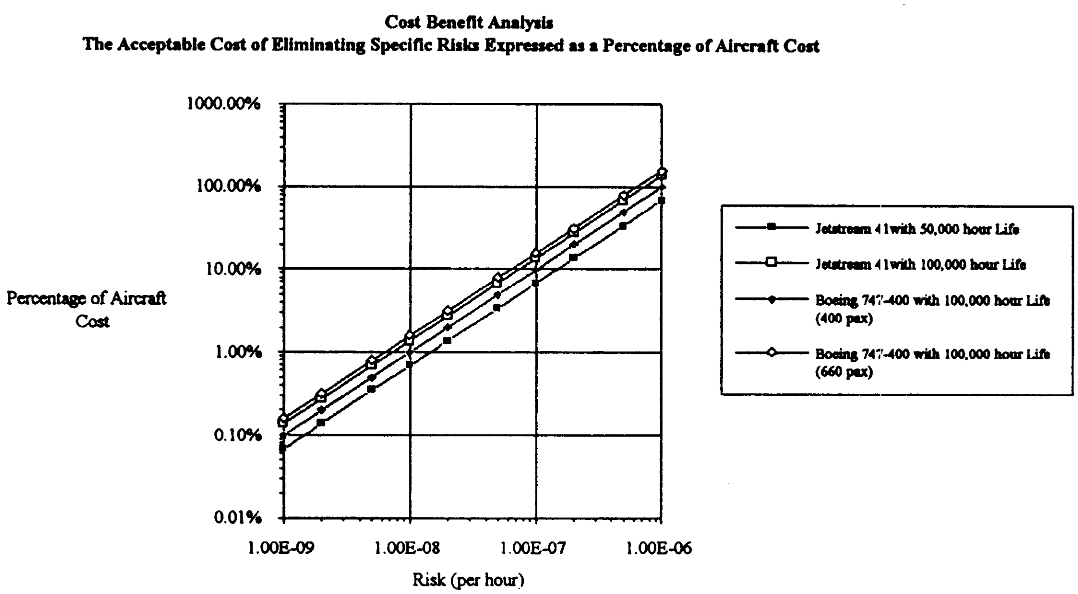


Figure 4

This shows, that when based on the maximum certificated number of passengers and the same expected service life, the results for Jetstream 41 and B747-400 are almost identical when the cost measure is *Percentage of Aircraft Cost.*

Other Aircraft Types

Information from the 1994 Avmark Database of aircraft prices, together with information on the maximum certificated number of passengers shows the relationship in figure 5 below:-

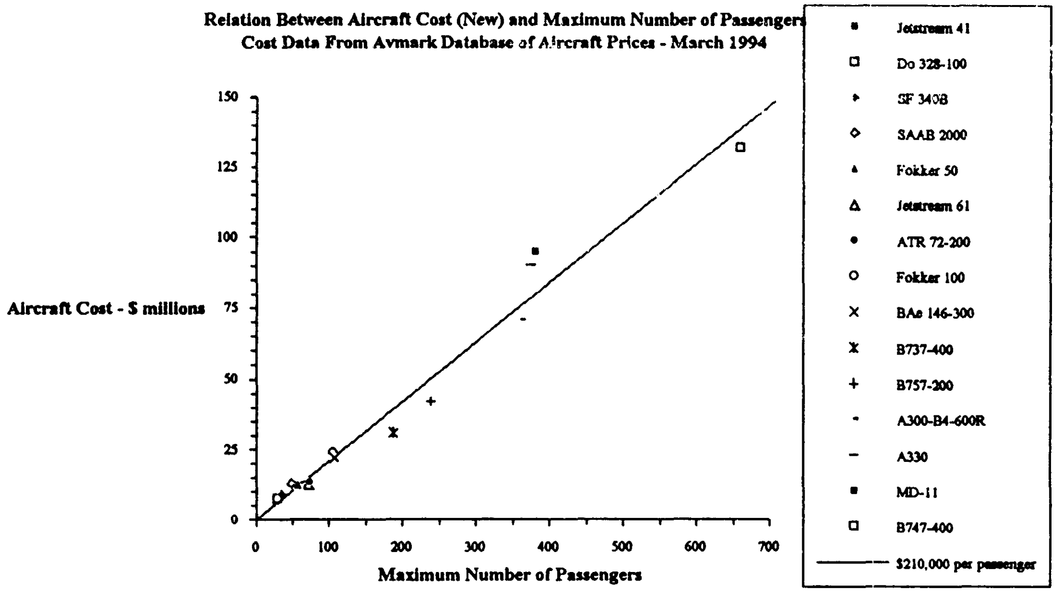


Figure 5

This shows a remarkable correlation between aircraft cost and maximum certificated number of passengers at least for large fixed wing aeroplanes - such aircraft cost approximately $210,000 per passenger!" (at 1994 prices).

The above relationship gives the following (figure 6) which assumes an expected aircraft service life of 100,000 hours:-

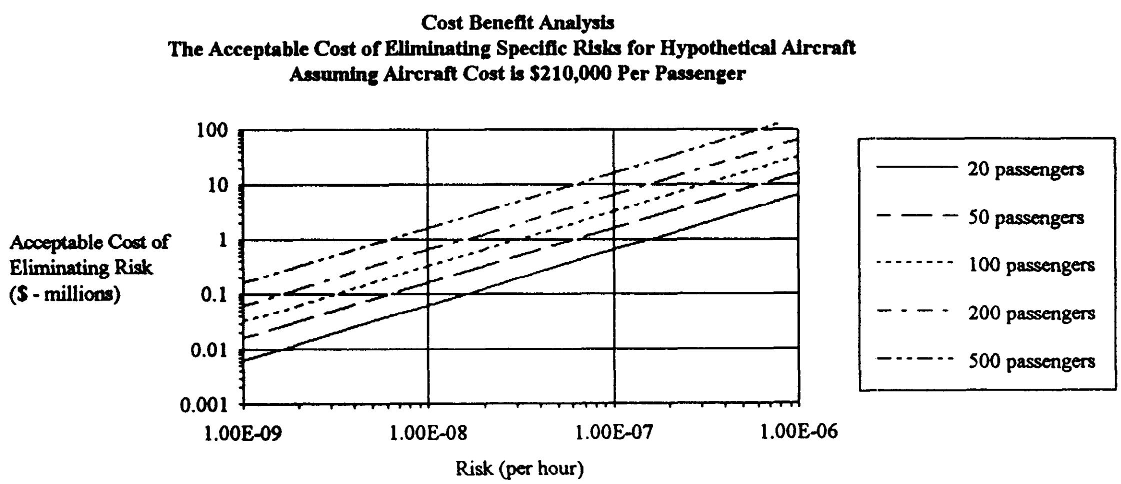


Figure 6

The above results can be combined with those of Figure 4 to give the following:-

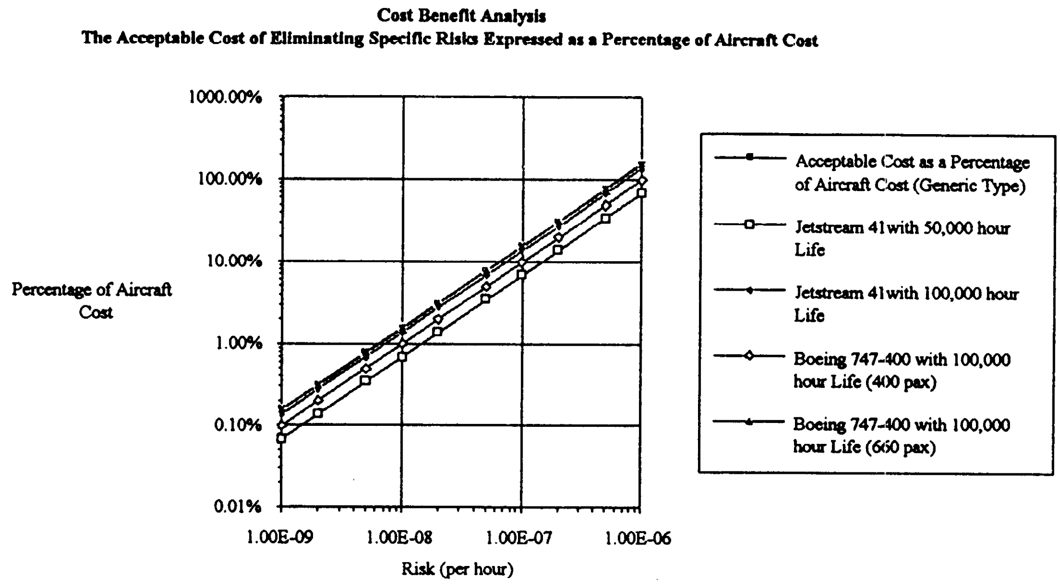


Figure 7

The above results strongly suggest that, for all practicable purposes, it will be acceptable to use a single generic relationship to express the allowable cost of eliminating a catastrophic risk under a cost benefit analysis in terms of the aircraft cost. This takes the form:-

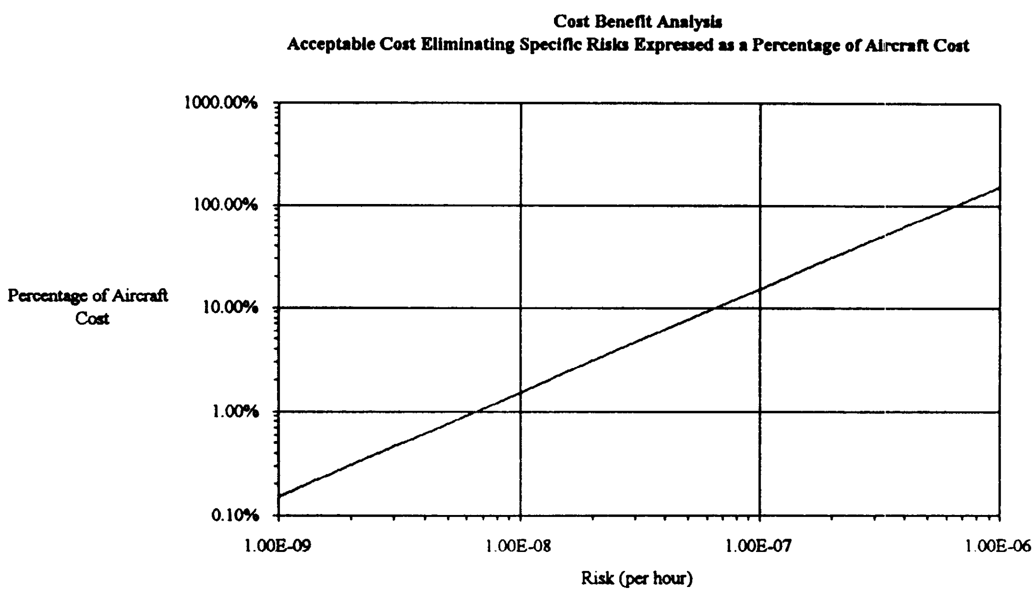


Figure 8

The Effect of Partially Eliminating a Risk

The discussion so far has concentrated determining how much one should be prepared to pay, under the principles of a cost benefit analysis, in order to eliminate a specific catastrophic risk.

Another issue that needs to be considered is whether or not the above principles can be used to address a situation in which a proposed safety improvement reduces, but does not eliminate, a particular risk. This can be addressed quite simply as follows:-

Let P_1 be the price that it is worth paying, under a cost benefit analysis, to eliminate risk r_1

P_2 be the price that it is worth paying, under a cost benefit analysis, to eliminate risk r_2

Then, assuming $r_2 < r_1$:-

$$P_1 = C.L.r_1$$

$$P_2 = C.L.r_2$$

$$P_1 - P_2 = C.L.(r_1 - r_2)$$

or:-

$$\Delta P = C.L.\Delta r$$

and, as $P = C.L.r$, this can be written as :-

$$\frac{\Delta P}{P} = \frac{\Delta r}{r}$$

Thus, if *P* is the price that it is cost effective to pay in order to eliminate a risk, then it is equally cost effective to pay *x%* of *P* in order to eliminate *x%* of the risk.

Summary

The results of the above analysis can be summarised as follows:-

1. For all practicable purposes, a cost benefit assessment of a potential safety improvement can be based on a generic relationship between aircraft cost and maximum certificated number of passengers.

2. The generic relationship between aircraft cost and maximum certificated number of passengers, for large fixed wing aeroplanes at 1994 prices, is

   Aircraft Cost = 0.21 x (Number of Passengers) - (Millions of US$)

3. A Safety Improvement, for a large fixed wing aeroplane, is cost effective if its cost does not exceed:-

$$\varepsilon \bullet \frac{0.15}{100} \bullet \left(\frac{r}{10^{-9}}\right) \bullet \left(\frac{L}{10^{5}}\right) \bullet AircraftCost$$

Where:-

$\varepsilon = \frac{\Delta r}{r}$ *is the "efficiency" of the Safety Improvement in terms of the change in risk resulting from implementation of the improvement*

L *is the expected service life*

r *is the risk of catastrophe due to the feature being addressed by the improvement.*

Comparison with the ICPTF Safety/Resource Evaluation Guide.

The Appendix shows how the results obtained from the method described in this note can be presented in a similar form to, and compared with, the ICPTF Safety/Resource Evaluation Guide.

This shows that the ICPTF method has a number of fundamental flaws in the relationships between the key variables.

Effect of Discounting.

In formal cost benefit assessments, it is customary to discount the value of future benefits and costs using discount rates in the region of 6% to 8% per year. This has the effect of changing the current values of costs and benefits but does not affect the relationship between benefit and risk with the result that the conclusions about the flaws in the ICPTF relationships remain valid.

Conclusions

The analysis presented in this note shows a very simple method for establishing whether or not a proposed safety improvement is cost effective. While this approach can be extremely useful in categorising such proposed safety improvements, the analysis shows that the cost benefit approach will result in some features that are not consistent with current aviation safety policies and it is, therefore, not clear that it would be acceptable to use this approach as a decision making tool in all circumstances.

In particular:-

a. The cost benefit approach clearly shows that the acceptable price to pay, per aircraft, for a given safety improvement varies significantly with aircraft size and expected service life. For example, to eliminate a 10^{-9} per hour catastrophic risk from a 660 passenger aircraft with a 100,000 hour expected service life, it is worth paying $210,000 per aircraft; for a 29 passenger aircraft this becomes $9,000 and if its expected service life is 50,000 hours the figure becomes $4,500.

   These figures show that the use of the cost benefit concept as a sole decision making tool would lead to different classes of aircraft having different safety levels and it is far from clear that this would be acceptable to the public; certainly, the recent public concerns about the relative safety of commuter aircraft and large jets bears this out. In addition, of course, this is not compatible with the use of one airworthiness requirement code for all fixed wing aircraft above 5700 kg.

b. Because of the effect of the expected service life on "acceptable price to pay", the use of a cost benefit assessment as a decision making tool for, say, proposed Airworthiness Directive action could lead to a situation where, for example, one would find that a proposed mandatory modification would be cost effective when applied to a new Boeing 737 but not cost effective for an old 737. To make such an applicability distinction in practice would probably be too difficult to explain to the public.

c. Many papers on risk analysis and cost benefit assessment draw attention to the concept of *"maximum individual risk"*. This is a risk level at which, if it is exceeded, *measures to reduce the risk must be taken **without regard to cost**, or the activity must cease*. This principle, which intuitively has always been part of SRG's decision making process, is a constraint on the use of pure cost benefit analysis as a decision making tool.

This work has also shown that the ICPTF Safety / Resource Evaluation Guide has fundamental flaws in each of its basic charts.

D O N James
November 28, 1995

APPENDIX

COMPARISON WITH THE ICPTF SAFETY/RESOURCE EVALUATION GUIDE.

The results given in the main body of this note can be presented in the same format as the presentation used in the ICPTF Safety / Resource Evaluation Guide.

In order to do this when making provision for an event which does not involve the loss of all lives on the aircraft, it is necessary to make assumptions about the proportion of the aircraft value that is lost when $x\%$ of the lives are lost. For simplicity, it is assumed that an accident involving loss of $x\%$ of the lives also involves the loss of $x\%$ of the aircraft value.

The results are shown in figure 9.

More detailed comparisons are given in figures 10, 11 and 12.

These show that each of the three basic charts used in the ICPTF method has fundamental flaws in the relationships between the key variables compared to a rational cost benefit assessment.

COST BENEFIT ASSESSMENT RESULTS IN ICPTF FORMAT

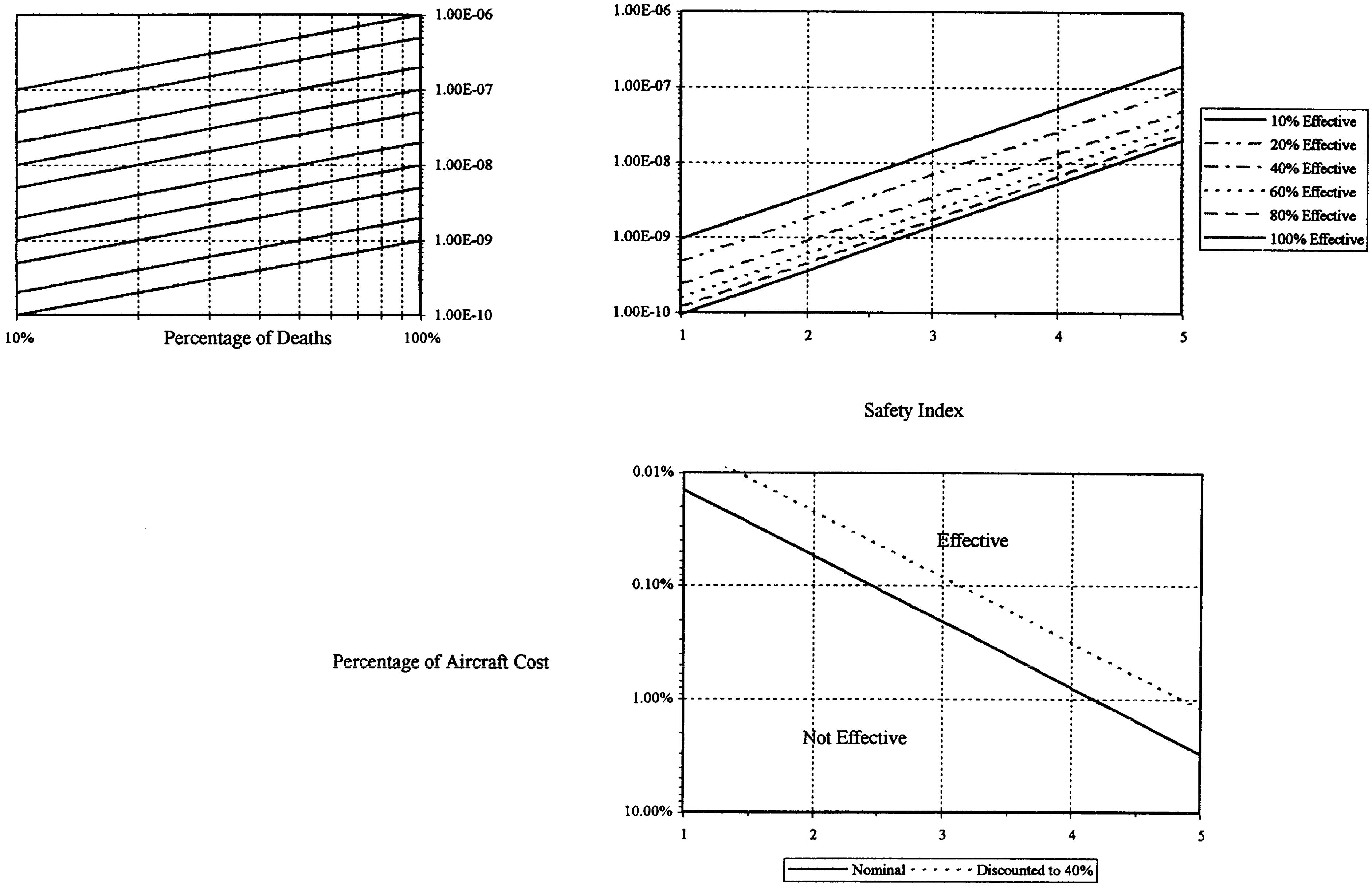
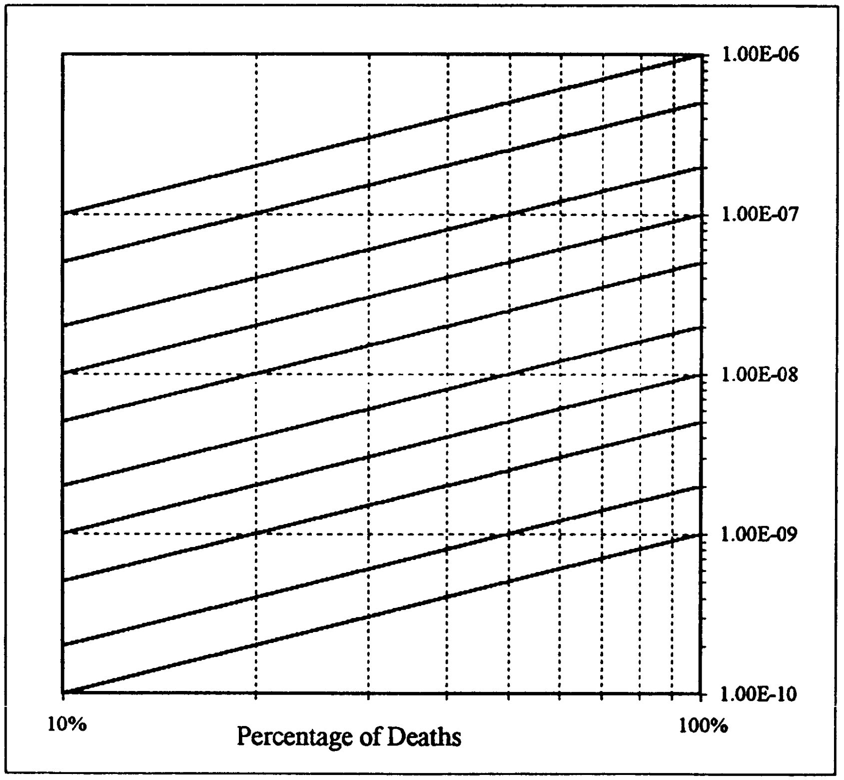


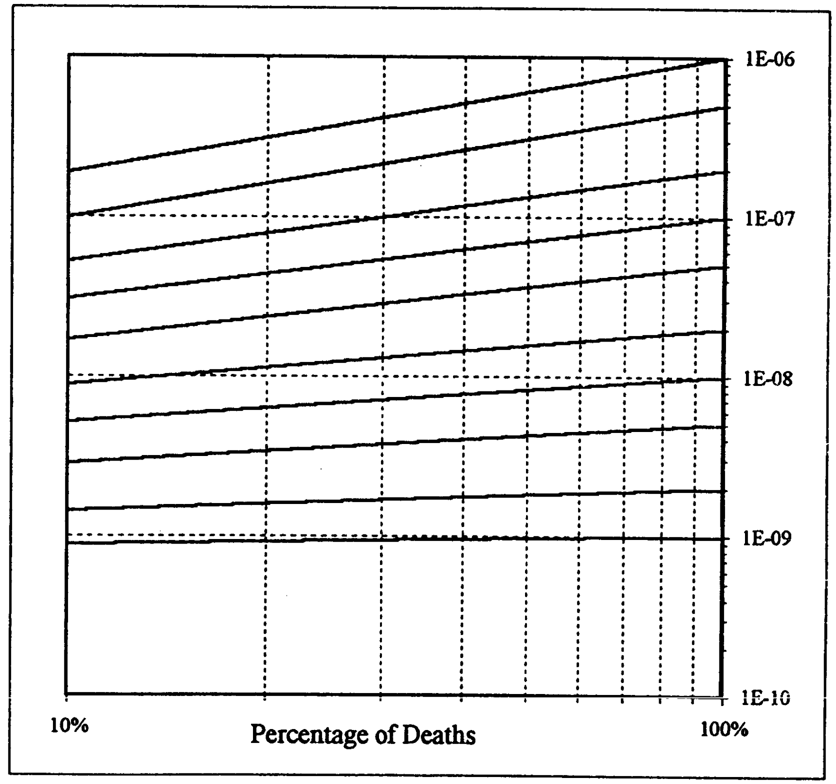
Figure 9

ACCOUNTING FOR PERCENTAGE DEATHS

DIFFERENCE BETWEEN ICPTF METHOD AND "RATIONAL" METHOD



"RATIONAL" METHOD

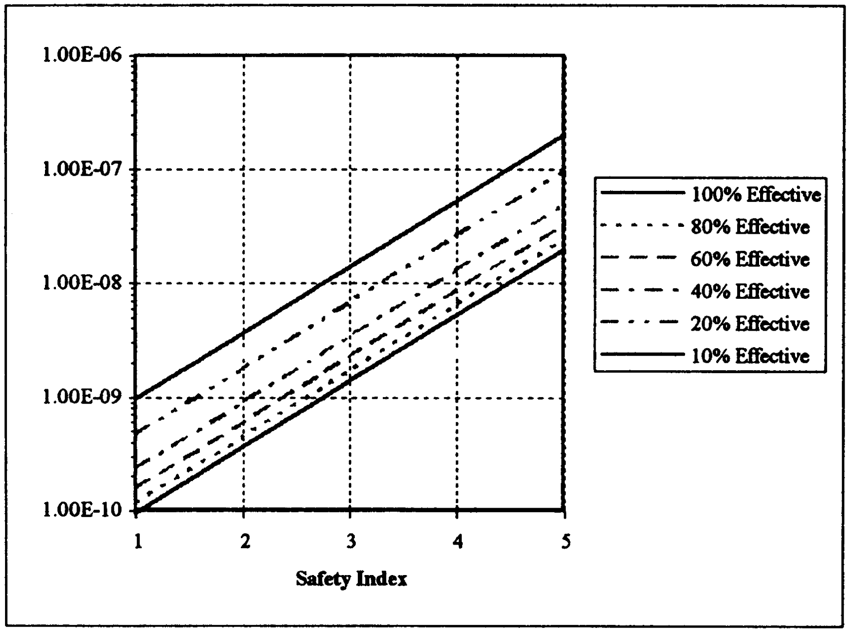


ICPTF METHOD

Figure 10

COMPARISON OF EFFECTIVENESS MEASURES

"RATIONAL" METHOD



ICPTF METHOD

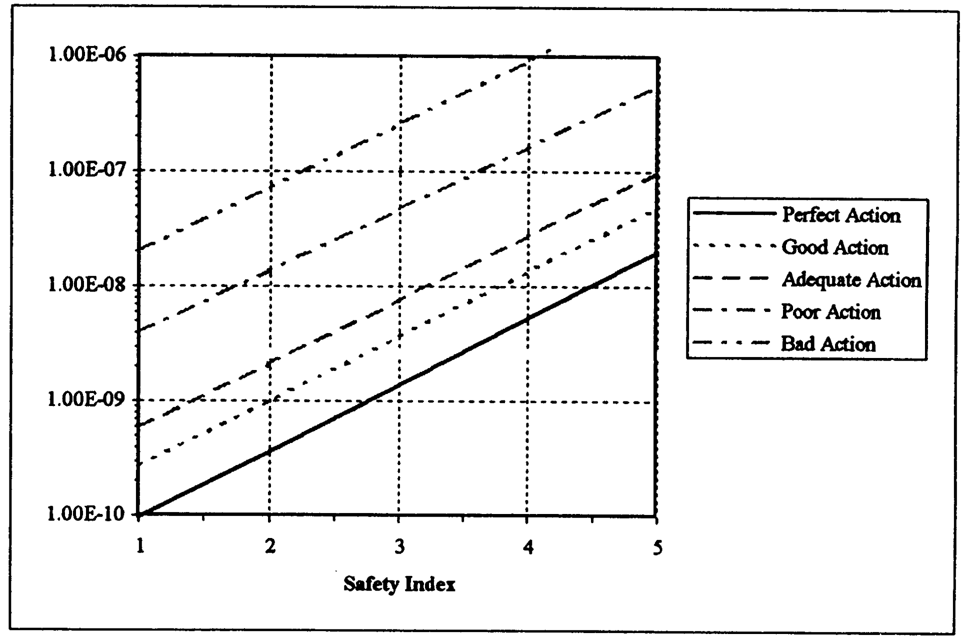
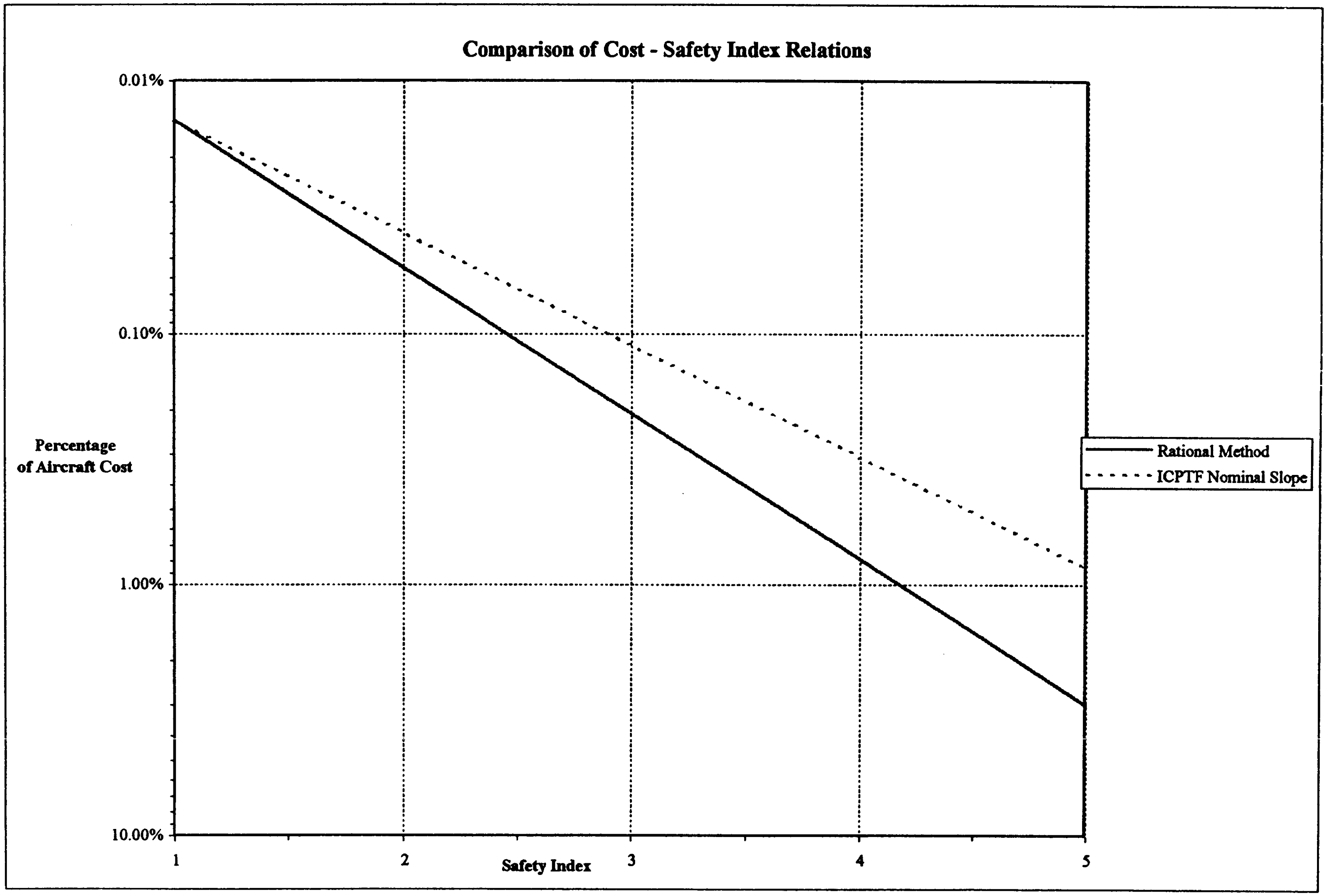


Figure 11



Comparison of Cost - Safety Index Relations
0.01%
0.10%
1.00%
10.00%
Percentage
of Aircraft Cost
1
2
3
4
5
Safety Index
Rational Method
ICPTF Nominal Slope

Figure 12