CIVIL AVIATION
SAFETY AUTHORITY
AUSTRALIA

Discussion Paper

Proposed Airworthiness Directive, General Series – Upper Torso Restraints for Occupants in Small Aircraft

Civil Aviation Regulation (1998) Part 39

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by CASA's Certification Standards Branch

Document DP 0109CS — December 2001

Introduction

In 1998, a floatplane carrying fare-paying passengers crashed into terrain north of Sydney with fatal injuries to all on board. Australia's Bureau of Air Safety Investigation (BASI) investigated the accident and made the following Air Safety Recommendation R9802830 in 1999:

> *"The Bureau of Air Safety Investigation recommends that the Civil Aviation Safety Authority mandate the compliance of all manufacturers' service bulletins relating to the provision of upper body restraint to the occupants of FAR 23 certified aircraft engaged in fare-paying passenger operations, and emphasise compliance with their instructions on the correct use of the restraint systems".*

In response to that recommendation and following an intensive review of the rules governing restraints in small aircraft, the Civil Aviation Safety Authority (CASA) has decided to accept BASI's Air Safety Recommendation and proposes to issue an Airworthiness Directive (AD) to require upper torso restraints for occupants in certain small aircraft.

This Discussion Paper (DP) has been prepared to explain the Airworthiness Directive. It proposes that all small aircraft that carry fare-paying passengers (for hire or reward) will need to be fitted with a shoulder restraint for each occupant. A copy of the proposed AD is attached as Annex A.

CASA invites you to comment on the proposal in this DP, the closing date for which is **1 March 2002**. After taking all submissions and responses into consideration, a Summary of Responses (SOR) will be developed along with the CASA evaluation of each comment (or categorised comments) and disposition actions for inclusion in the next stage of consultation, the Notice of Proposed Rule Making (NPRM).

I would like to thank you for expressing interest in this proposal, and wish to emphasise that no rule changes will be taken until all responses and submissions have been considered.

Bill McIntyre
Acting Assistant Director
Aviation Safety Standards

21 December 2001

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Terminology

AD	Airworthiness Directive
ATSB	Australian Transport Safety Bureau
BASI	Bureau of Air Safety Investigation (now part of ATSB)
CASA	Civil Aviation Safety Authority
CASR	Civil Aviation Safety Regulation
DP	Discussion Paper
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
NASA	National Aeronautics and Space Administration
NPRM	Notice of Proposed Rule Making
NTSB	National Transport Safety Board of the USA
RPT	Regular Public Transport
SOR	Summary of Responses
US/USA	United States of America

The Proposals

1. Background

General

1.1 A primary safety function of an aviation regulator is to require unsafe conditions to be corrected on aircraft, aircraft engines, propellers, equipment or instruments, or when such conditions develop in other products of the same design. Unsafe conditions may exist because of a design defect, poor maintenance or other cause. Airworthiness Directives (ADs) are the means used to notify aircraft owners and other interested persons of unsafe and undesirable conditions, and to prescribe the conditions under which the product may continue to be operated.

1.2 CASA can issue an AD under Civil Aviation Regulation (1998) Part when an unsafe condition exists in an aircraft or aeronautical product and the condition exists (or could develop or is likely to exist) in other aircraft or aeronautical products of the same kind.

1.3 All small aeroplanes manufactured since 1986 (as directed by CASA Airworthiness Directive AD/GENERAL/67) and all helicopters manufactured since 1992 (as directed by AD/GENERAL/71) are required to be fitted with an upper body restraint (shoulder harness) in addition to the lap belt at each seat. Both of these requirements reflect similar safety regulations in the USA Federal Aviation Regulations (FARs) 23.2 and 27/29.2.

1.4 There are approximately 7500 small aeroplanes and 700 helicopters on the Australian civil aircraft register that were manufactured before these respective dates. However, only a small number of these aircraft are used to carry fare-paying passengers in either Charter or Regular Public Transport (RPT) operations.

1.5 Due to the ad hoc nature of Charter operations by privately-owned aircraft, the actual number of aircraft engaged in fare-paying operations is unknown. On 26 July 1998, one such aircraft, a Cessna A185A floatplane, crashed onto a ridge north of Sydney during a 'go-around' manoeuvre following an unsuccessful landing approach. All five occupants suffered fatal injuries. Upper body restraints were only available to the front seat occupants, although neither had theirs fastened at the time of impact. Although the crash was considered unsurvivable for the front seat occupants, the rear seat occupants may have survived the impact had adequate lap belt and upper body restraints been fitted and worn.

> Note: Refer to the then Bureau of Air Safety Investigation's Accident/Incident Report No. R9802830 for a detailed analysis and recommendations. Available at www.atsb.gov.au/aviation/acci/hts.cfm

1.6 The Airworthiness Directive proposed in this Discussion Paper is not based on this one accident. There is extensive evidence to demonstrate that the addition of an upper body restraint provides a major increase in the chance of an occupant's survival in both land and air transport. A comprehensive study on general aviation crashworthiness by the US National Transportation Safety Board (NTSB) concluded that, ….*"if all occupants wear shoulder harnesses, fatalities are expected to be reduced by 20 percent and 88 percent of seriously injured persons are expected to experience fewer life-threatening injuries"*. Paragraph 1.24 refers.

Survivability in Small Aircraft – Increased Impact Forces

1.7 Survivability of an aircraft accident is influenced by the following aspects:

- a livable structure during the impact sequence;
- the impact forces transmitted to the occupant;
- occupant retention;
- post-crash fire; and
- evacuation.

1.8 The proposal in this Discussion Paper addresses increased occupant protection during impact.

1.9 Not only would an increase in occupant protection reduce direct impact fatalities, in the opinion of the Authority it would also reduce the risk of incapacitating injury resulting in less-impaired evacuation.

1.10 The level of impact energy transmitted to the occupants is determined by the actual impact speed of the airframe and the degree of energy absorbed due to buckling of the airframe and seat structure. In a "typical survivable crash", a small aircraft with a low stall speed will have lower impact energy than larger aircraft. However, the amount of structure to absorb this impact energy is significantly less than in larger transport aircraft where underfloor cargo areas, combined with a generally longer "slide-out" (the aircraft sliding along the ground), result in a lower force transmitted to the occupants despite the higher initial impact energy.

1.11 As a result, the forces transmitted to occupants of small aircraft are higher than those transmitted to occupants in large transport category aircraft. This concept is supported by the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA) research and testing to establish an appropriate crash pulse for a potentially survivable impact.

1.12 In the early 1980s, NASA conducted a series of full-scale crash tests using a selection of single and twin-engine small aircraft. This data was correlated with information from accidents with similar impact scenarios, tests on fuselage sections and seats, and computer simulation results to develop representative dynamic impact test criteria for different aircraft categories and sizes. The USA's Federal Aviation Regulations (FARs) were subsequently amended to require seats and restraints to meet these new dynamic test criteria.

Dynamic Test Criteria

1.13 For the small aeroplane design standard in FAR 23.562, the dynamic test criteria issued in 1988 requires that the seat and restraint system undergo dynamic tests with peak decelerations of 15-19g predominantly vertically and 21-26g predominantly longitudinally (two separate tests). The parallel requirements for large transport aeroplanes in FAR 25.562 are 14g and 16g respectively. This reflects the comments above regarding airframe size. For helicopters, the figures are 30g vertically and 18.4g horizontally, reflecting the predominantly vertical impact for a "typical" helicopter crash landing.

1.14 In conjunction with these dynamic tests, injury criteria were developed which address key survivability aspects such as head impact, spinal compression and chest injury (addressed by restraint strap loads) for improved impact protection.

Human Tolerance and Shoulder Restraint

1.15 The type of restraint system installed will affect the ability of the human body to withstand the level of impact force transmitted to the occupant. Extensive research has shown that human tolerance for a well-restrained forward facing seated occupant, ranges between 25g and 45g in the forward direction, and 10g to 20g vertically, depending on the rate of onset and duration of the impact event.

Note: Refer to the US Army Crash Survival Design Guide Volume II for details.

1.16 For an occupant restrained only by a lap belt, the human tolerance figures are 15g longitudinally and 4g vertically. Therefore, the addition of a shoulder restraint could increase the chance of survival by a factor of 2 for a longitudinal impact, and up to 5 for a vertical impact.

1.17 For aeroplanes (i.e. fixed wing aircraft), the most commonly recognised safety value of a shoulder restraint is to reduce the risk of head impact. This is particularly obvious for front seat occupants where a solid item such as an instrument panel is within close proximity to the occupant's head. However, the extent of head excursion during the impact sequence and the severity of any impact can be greater than may first be thought. Impact with more solid areas of seat backs or even the occupant's own knees can have fatal consequences.

1.18 Helicopter crashes tend to involve a predominantly vertical load component, and this is recognised by the dynamic test criteria for helicopters in FAR 27.562 and FAR 29.562, which reflect this crash scenario by having a high peak g requirement for the vertical impact test. As mentioned previously, an upper body restraint not only increases the tolerance to longitudinal impacts, but will also have increased benefits for occupants who experience high vertical impact forces, as the susceptibility of the spine to vertical load is exacerbated by a less than upright posture. A shoulder harness will maintain an occupant in a more upright position during the impact sequence and therefore improve tolerance to vertical as well as longitudinal loads.

1.19 Overall, for both fixed- and rotary-winged aircraft, an upper body restraint significantly reduces the incidence of disabling or fatal injuries.

Restraint Regulatory Requirements

1.20 Due to the dynamic test criteria referred to above, all newly type-certificated aircraft since 1988 are fitted with seats and restraint systems which provide demonstrated occupant protection performance as specified in FAR 23.562. Previously, an injury criterion was subjective and the strengths of seats and restraints were addressed separately.

1.21 All previously type-certificated small aeroplanes *manufactured* since December 1986 (under FAR 23.2) and helicopters *manufactured* since September 1992 (under FARs 27.2 and 29.2) are fitted with shoulder harnesses in *all* seats. This significantly improves their occupant protection performance and recognises the significant increase in safety afforded by an upper body restraint and the increased risk to occupants in small aircraft due to higher impact forces. These requirements are reflected in CASA Airworthiness Directives AD/GENERAL/67 and AD/GENERAL/71.

1.22 Since the early 1970s there has been a requirement for shoulder harnesses for front seat occupants in all Australian aircraft. This was originally issued through individual Airworthiness Directives for each aircraft type which are now being progressively replaced by AD/GENERAL/74. A list of the individual ADs being replaced has been included at Annex B of this DP.

1.23 However, passengers in aircraft manufactured before 1986/1992 are not afforded this demonstrated improved crash protection unless an owner or operator has voluntarily installed shoulder harnesses to meet the FAR standards.

Accident Statistics

1.24 The US National Transport Safety Board (NTSB) conducted a study regarding general aviation crashworthiness in 1985. Analysis of data from 1,982 accidents revealed that shoulder harnesses:

- may have prevented 20 percent of the fatalities; and
- significantly reduced 88 percent of the original serious injuries found in the survivable accident data.

Note: Refer to NTSB/SR-85/01 for details.

1.25 A similar study in the Journal of the American Medical Association in 1998 reported on the survivability of pilots in single and twin-engined aeroplane crashes between 1983 and 1992. In the USA, there has been no retrospective action of shoulder harnesses for pilots and many aircraft manufactured before 1978 are not fitted with a shoulder harness in any seat. The study revealed the relative risk to pilots wearing both lap and shoulder restraint was nearly half that for pilots wearing only a lap belt. The report notes that this reduced risk is consistent with other studies of both motor vehicle and aircraft crashes.

2. Issue

2.1 The BASI report of the crash of the Cessna A185A floatplane in 1998 recommended that CASA *"mandate the compliance of all manufacturers' service bulletins relating to the provision of upper body restraint to occupants of FAR Part 23 certificated aircraft engaged in fare-paying passenger operations …"* The Cessna A185A was, in fact, already certificated to Part 3 of the USA's Civil Air Regulations — the predecessor to FAR Part 23.

2.2 In severe but potentially-survivable impacts, passengers have received fatal injuries when restrained by a lap belt only.

2.3 Research by many organisations, including NASA, the US Army and the FAA, has shown that upper body restraints can provide substantial injury protection against impact forces and, in some instances, would increase injury tolerance by up to five times that provided by lap belts alone.

2.4 Due to the lack of protection from the 'crushable fuselage structure' in small aircraft, a higher proportion of the impact forces are transmitted to occupants than in transport aircraft where the larger aircraft structure provides significant energy absorption. Combined with the higher accident rate, occupants of small aircraft are therefore at a higher risk of serious or fatal injuries.

2.5 Passengers may have limited knowledge of, or control over, the type of restraint available and the potential risks to which they may be exposed when flying. They would often be unaware of the different levels of safety for a passenger with a lap belt in a large and small aircraft.

2.6 Kits for installation of shoulder harnesses are available for most small aircraft. However, as demonstrated by the 1998 floatplane accident referred to above, some aircraft carrying fare-paying passengers have only been fitted with harnesses in the front seats as required by current Australian legislation. Therefore, legislative intervention is required to ensure that all fare-paying passengers are afforded the same level of protective safety.

3. Objective

3.1 The objective of this Discussion Paper is to:

- consider BASI air safety recommendation R9802830; and
- make proposals to improve the occupant protection for passengers in a class of aircraft which has exhibited a high risk of accident and impact injury.

In making its proposal, CASA will consider the practicality, cost-effectiveness and economic impact of the available options.

4. Options considered

4.1 In a survivable crash, an occupant restrained by only a lap belt is at higher risk than an occupant provided with an upper body restraint.

4.2 The options considered to address this identified risk include:

- **Option 1:** do nothing and accept the risk;
- **Option 2:** reduce the chance of a crash;
- **Option 3:** reduce the potential for high impact force;
- **Option 4:** reduce the level of impact forces transmitted to the occupant;
- **Option 5:** require shoulder harnesses for all occupants in all small aircraft;
- **Option 6:** provide other means to increase human tolerance; and
- **Option 7:** require shoulder harnesses for all occupants in small aircraft engaged in fare-paying passenger operations.

5. Impact Analysis of Options

5.1 **Option 1 – Do nothing and accept the risk**. This option proposes to maintain the current situation of non-mandated upper-torso restraints for aircraft passenger seats. CASA does not accept this as a viable option because it exposes fare-paying passengers to higher risk, when this risk could be significantly reduced with the introduction of restraints at relatively little expense. Research studies and accident investigations demonstrate that the use of upper torso restraints can significantly reduce the risk of fatality or injury. Therefore, CASA does not agree that the non-restraint of fare-paying passengers should continue.

5.2 **Option 2 – Reduce the chance of a crash**. Despite all efforts to reduce accidents, aircraft (particularly smaller aircraft) do crash for a variety of reasons. Required increased reliability of the aircraft and improved experience/training of the pilot could be considered. However, conditions such as turbine engine or higher pilot ratings for all small aircraft which carry fare-paying passengers may be unnecessarily restrictive on small operators.

5.3 **Option 3 – Reduce the potential for high impact force**. The level of impact energy in a survivable crash is linked to the stalling speed of the aircraft. As most small aircraft have similar stall speeds, the potential for reducing the impact force is small.

5.4 **Option 4 – Reduce the level of impact forces transmitted to the occupant**. As discussed previously, impact energy is first absorbed by buckling of fuselage structure followed by distortion of seats. Again, most small aircraft have similar fuselage structures and restrictions forcing the use of more substantial aircraft would be impractical. With the introduction of the dynamic test criteria, aircraft seats and restraint systems are required to demonstrate a degree of impact energy absorption in order to meet the injury criteria of the test requirements. However, mandating the dynamic test criteria for all small aircraft which carry fare-paying passengers would restrict Australian operators to post-1988 aircraft types and therefore may also be unnecessarily restrictive.

5.5 **Option 5 – Require shoulder harnesses for all occupants in all small aircraft**. A shoulder harness is the most cost-effective means of improving human tolerance to impact forces experienced in a survivable small aircraft crash. However, if shoulder harnesses were required in all small aircraft, more than 8000 aircraft would be potentially affected and the cost to Australia's aviation industry would be high.

5.6 **Option 6 – Provide other means to increase human tolerance**. In a small aircraft, human tolerance would be improved by:

- removing items from the head strike envelope; *and*
- providing a means of maintaining upright posture during impact.

An alternative to a shoulder harness could be the use of airbags to supplement lap belt restraints. This is currently being investigated for passengers in large transport category aircraft. However, it has yet to be substantiated and does not address the protection against the higher vertical impact loads experienced in smaller aircraft.

5.7 **Option 7 – Require shoulder harnesses for all occupants in small aircraft engaged in fare-paying passenger operations**. Option 7 is CASA's preferred option. The installation of a shoulder harness is considered the most practical and cost-effective solution to improve occupant protection for passengers in a class of aircraft which has exhibited a high risk of accident and impact injury. Although all passengers in small aircraft would benefit from improved restraint, the large number of affected aircraft would impose a significant cost to the aviation industry. As only a small percentage of these aircraft is engaged in carrying fare-paying passengers, restricting the applicability to this type of operation would minimise the overall cost. While the risk is the same for all passengers in small aircraft, fare-paying passengers have less control over their own safety and need to be protected by legislation. It is suggested that a safety awareness programme be provided to the general aviation community to advise the risks for private passengers, and to encourage installation of shoulder harnesses.

Persons affected

5.8 The persons affected by this proposal are:

- operators of small aircraft carrying fare-paying passengers who would be required to fit shoulder harnesses in seats where they are not already installed;
- suppliers of suitable shoulder harnesses;
- installers of shoulder harnesses in aircraft; and
- fare-paying passengers who will be afforded improved protection during an otherwise survivable impact, but may face higher ticket prices should the operators pass on the costs.

Effect on existing regulation

5.9 There is no expected effect on existing legislation.

Expected costs and benefits

5.10 The cost of installation of shoulder harnesses to each passenger seat will depend on:

- the current design of the aircraft cabin;
- the existence of any existing (built-in) harness attachment fittings – this is unlikely in aircraft manufactured before 1980; and
- on the larger aircraft, there may be difficulty attaching the shoulder strap to the fuselage. If the shoulder strap is attached to the seat back, the seat structure may need strengthening to cope with the additional load.

5.11 Advice from potential aircraft repair/modification organisations has indicated that an average cost for designing and installing the modification would be less than $1000 per aircraft seat including the cost of the harness. Many aircraft manufacturers have issued service documents and already produce modification kits for retrospective installations. Therefore, installation costs are expected to be less for the more common aircraft makes.

5.12 The exact number of aircraft affected is unknown but is conservatively estimated to be no more than 10 percent of Australia's general aviation fleet. This would give a total of approximately 800 aircraft affected with an estimated average of four seat installations per aircraft. Therefore the initial total cost to the aviation industry would be approximately $2.4 M with minimal expected additional ongoing costs.

5.13 The benefit from this proposal – to install shoulder restraints – will be to provide a significantly higher chance of occupant survival for passengers in small aircraft. Given the results of the 1985 NTSB study mentioned at paragraph 1.24, the currently accepted value of $1.5 M for each fatality and >$0.5 M for each serious injury, the potential benefit to the Australian community would significantly outweigh the costs to the aviation industry. The saving of only two lives over the life of the aircraft fleet would provide a positive benefit/cost ratio.

5.14 Other options identified above would result in higher costs, although the number of lives saved would be greater if shoulder harnesses were fitted in all small aircraft regardless of operation. Comments are sought on option 5.

Effect on the environment by implementing this proposal

5.15 CASA considers there will not be any effect on the environment by implementing this proposal.

Compliance

5.16 If not already fitted, shoulder restraints would be required to be fitted within one calendar year of the effective date of the proposed Airworthiness Directive.

6. Consultation

6.1 Following the fatal crash of the floatplane north of Sydney in 1998, and taking into consideration BASI's subsequent recommendation, CASA conducted a review of the rules governing light aircraft seat restraints.

6.2 A notice seeking the aviation industry's opinions on estimated costs, possible difficulties in harness installations and other issues was printed in CASA's *Flight Safety Australia* magazine. The magazine is published bimonthly and distributed to more than 80,000 readers in the aviation community. A copy of the article from the September/October 1999 issue is published below.

CALL FOR INDUSTRY COMMENT

Shoulder harnesses for small planes?

LAST YEAR'S CRASH OF A South Pacific Seaplanes Cessna 185 floatplane could become the trigger for a change in regulations on shoulder harnesses.

The fatal accident, which occurred during a go-around manoeuvre north of Sydney, has prompted CASA to review the rules governing light aircraft restraints following a recommendation from the Bureau of Air Safety Investigation (BASI).

The pilot and front passenger had shoulder harnesses fitted – the remaining passengers, seated to the rear of the aircraft, had lap belts only.

Although there was no Australian regulatory requirement for the rear passengers to have shoulder harnesses, BASI investigators believe they could have saved the lives of those on board.

Regulations currently only require rear-seat shoulder harnesses to be fitted in light aircraft manufactured after December 1986.

Research has shown that shoulder harnesses provide substantial protection against injury on impact, in some cases up to five times better protection than that provided by a lap belt.

The head of the review, CASA crashworthiness and survivability specialist, Bruce Byers, is seeking industry opinions on costs, difficulty of installation and other issues.

Information will form part of an upcoming notice of proposed rule making. Contact Bruce Byers on ph 131 757.

6.3 No comments were received in response to the article's call for industry comments.

6.4 Public comment is now being sought through this Discussion Paper to provide a more accurate determination of the economic impact of this proposal.

How to submit comments on this DP

In order to simplify the collation and summarising of comments, please respond on the Response Sheet provided (see page 17) or a copy of the sheet, with additional comments attached as necessary.

Written comments quoting ***DP 0109CS*** should be forwarded by **1 March 2002** to CASA's Regulatory Documentation Coordinator by one of the following means:

Post (no stamp required)
Civil Aviation Safety Authority
Standards Coordination & Support Branch
Reply Paid 2005
Canberra ACT 2601, Australia

E-mail DPcar39@casa.gov.au

Fax 1800 653 897 (free call)
international +612 6217 1691

Additional information is available from:

Bruce Byers, Specialist Engineer – Crashworthiness

Post (no stamp required)
Civil Aviation Safety Authority
Certification Standards Branch
Reply Paid 2005
Canberra ACT 2601, Australia

E-mail byers_b@casa.gov.au

Telephone 02 6217 1866 or 131 757 (for the cost of a local call)
international +612 6217 1866

Fax 02 6217 1914
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What CASA does with your comments?

At the end of the response period for public comments, all submissions will be analysed, evaluated and considered for inclusion in the next stage of consultation – the preparation of a Notice of Proposed Rule Making (NPRM).

CASA is required to register each comment and submission received, but will not individually acknowledge a response unless specifically requested. However, the names of contributors will be published in the subsequent NPRM and Summary of Responses, except where CASA is advised otherwise.

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DP Response Sheet

Proposal for Airworthiness Directive General Series
Upper Torso Restraint for Occupants in Small Aircraft – CAR Part 39

Please return your response by 1 March 2002
by post or by e-mail to the addresses provided at page 15 of the DP, or by fax to 1800 653 897

Please indicate your acceptance or otherwise of the proposal presented in this Discussion Paper by ticking [✓] the appropriate box below.

Any additional constructive comments, suggested amendments or alternative action will be welcomed and may be provided on this response sheet or by separate correspondence.

[ ] The proposal presented **is acceptable without change**.

[ ] The proposal presented **is acceptable but would be improved if changes were made.** *(Please provide explanatory comment in the space below.)*

[ ] The proposal presented is **not acceptable but would be acceptable if changes were made.** *(Please provide explanatory comment in the space below.)*

[ ] The proposal presented is **not acceptable under any circumstances.** *(Please provide explanatory comment in the space below.)*

continue over page if required

Your name: ________________________ ARN* (if known): _______

Organisation: ________________________

Address: ________________________

____

____

* Aviation Reference Number, usually your CASA-issued licence or certificate number

Do you consent to have your name published as a respondent to this DP? YES [ ] NO [ ]

Signed: ………………………………………….. Date: ………………….……

To submit comments on this

Discussion Paper

Proposed Airworthiness Directive, General Series – Upper Torso Restraint for Occupants in Small Aircraft

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Additional information is available from:

Bruce Byers, Specialist Engineer Crashworthiness

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