Department of Transport

Bureau of Air Safety Investigation

INFORMATION PAPER

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The Status of Commercial Passenger Operations in Turbine Powered Single Engine Aeroplanes

BASI
Bureau of Air Safety Investigation

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ABBREVIATIONS

AIP	Aeronautical Information Publication
AMSL	Above Mean Sea Level
ANO	Air Navigation Order
ARP	Aviation Regulatory Proposal
BASI	Bureau of Air Safety Investigation
CAA	Civil Aviation Authority
CAO	Civil Aviation Order
CAR	Civil Aviation Regulation
DASR	Directorate of Aviation Safety Regulation
EFIS	Electronic Flight Information System
ETOPS	Extended-Range Twin Engine Operations
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FCU	Fuel Control Unit
FedEx	Federal Express Corporation
FL	Flight Level
fpm	Feet per Minute
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
IFSD	Inflight Shutdown
IMC	Instrument Meteorological Conditions
JAA	Joint Aviation Authority
JAR-Ops	Joint Airworthiness Requirement (Operations)
kts	Knots
MEL	Minimum Equipment List
MTB	Mean Time Between
MTBF	Mean Time Between Failure
MTOW	Maximum Takeoff Weight
RAC	Air Traffic Rules and Services
RFDS	Royal Flying Doctor Service
RoC	Rate of Climb
SAB	Safety Analysis Branch
TAS	True Airspeed
Vmca	Minimum Control Airspeed
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

FOREWORD

This information paper describes matters which relate to the proposed carriage of commercial passengers in turbine powered single engine aircraft. It examines the issue of engine reliability, summarises the risk analysis conducted by Transport Canada, and outlines the current regulatory situation in Australia, Canada, the United States, and Europe to December 1993.

The paper also briefly considers some operational aspects of three particular aeroplane types which would be affected by the proposed regulatory change. No position is taken for or against the introduction of commercial passenger operations in Australia with single turbine engine aeroplanes.

1. INTRODUCTION

Annex 6, Part I ("Commercial Air Transport") of the ICAO Convention states that "Single engine aeroplanes shall only be operated in conditions of weather and light, and over such routes and diversions therefrom, that permit a safe forced landing to be executed in the event of engine failure."

Australian regulations have conformed with this recommended practice, prohibiting commercial operations in single engine aircraft at night or under IFR. An exception has been made for commercial operations which do not carry passengers for hire or reward (ie. freight-only commercial operations). This has also been the practice in most major ICAO signatory States.

These prohibitions were formulated decades ago on the basis of the reliability of the reciprocating engines of the time. Many people now consider that gas turbine engines offer far greater reliability and performance than the powerplants on which existing regulations are based.

The civil aviation regulatory authorities of several nations are in the process of reviewing their standards, and further changes are anticipated.

2. INTERNATIONAL SITUATION

This section provides an overview of the single engine commercial passenger-carrying situation in three aviation nations.

2. 1 CANADA

The Canadian Minister of Transport signed Policy Letter 80 into law on 1 February 1993. This ruling offers an unprecedented exemption from the Canadian ANOs, allowing commercial passenger-carrying operations in approved single engine aeroplanes at night and/or in IMC. A number of conditions apply to this exemption:

1. It applies only to factory-built, turbine-powered aeroplanes. Types will be considered on an individual basis, and types having had conversions from existing reciprocating engines will not be considered.

2. Engines must prove an MTBF of 0.01/1,000 hours, demonstrated over 100,000 hours in service.

3. The aeroplane must be equipped and dispatched with the following:

   (a) two attitude indicators, powered separately and independently;
   (b) two independent power generating sources, each capable of sustaining essential flight instruments and electrical equipment;
   (c) an auto-ignition system, or a requirement for Continuous Ignition to be selected "ON" for takeoff, landing, and in heavy precipitation;
   (d) a chip detector to warn of excessive ferrous material in the lubrication system;
   (e) a radar altimeter; and
   (f) a manual throttle which bypasses the FCU governor, permitting unrestricted engine operation after failure of the FCU.

4. Pilots-in-command must receive initial and recurrent training and checks in both approved simulators and aeroplanes, covering all normal and emergency procedures.

5. Particular "Designated Mountainous Regions" as defined in the Canadian Designated Airspace Handbook may not be overflown with passengers.

6. Single pilot operations under these provisions must be approved under an Operations Specification for Single Pilot Night/IMC Operations. This specification would contain additional requirements similar to those mandated for any single pilot commercial operation under Canadian ANO Series VII No. 3 section 39(4), including an MEL requirement for an operating autopilot and route-specific approval for operators.

2.2 UNITED STATES

The United States FAA is actively reviewing its policy, with a view to passing regulations similar to the Canadian document. As part of this review, a database of accidents involving single turboprop-powered aircraft is being compiled. The FedEx fleet of Cessna Caravans flies more than 100,000 hours per year on freight operations in North America, so a significant quantity of data will be collected. A rulemaking proposal is expected during the first half of 1994.

The FAA has for some time permitted commercially operated single engine aircraft to conduct limited departures and approaches in IMC. Under US FAR Part 135.181 American charter, freight, or intrastate passenger flights in other than high capacity aircraft may "take off from the departure airport in IFR conditions and fly in IFR conditions to a point no more than 15 minutes' flying time at normal cruise speed from that airport", "if the latest weather reports or forecasts ... indicate that the weather along the planned route allows flight under VFR under the ceiling (if a ceiling exists) beginning at a point no more than 15 minutes' flying time at normal cruise speed from the departure airport".

2.3 EUROPE

The European JAA has drafted a JAR-Ops which proposes a move in a direction opposite to that of the North American authorities, prohibiting all single engine operations under IFR. At present, private operations are permitted, as in Australia and elsewhere.

It is understood that this proposal is subject to active debate. Counter-argument from manufacturers and operators has been strong and a more liberal regulation may yet be drafted.

3. AUSTRALIAN SITUATION

3.1 PRESENT

Pertinent Australian regulations are CARs 174B and 175A. These prohibit commercial passenger operations in single engine aircraft at night or under IFR. Contravention carries a penalty of $2,500. These rules are repeated in CAO 20.7.4 subsection 11.1 and AIP RAC-21 paragraphs 20.1.3 and 20.2.

The Australian distributors of two single engine turboprop aeroplanes, the Cessna 208 Caravan and the Socata TBM 700, made a submission dated 8 March 1993 to the Standards Development Branch of CAA DASR. It seeks amendment of, or dispensation from, the above regulations. The submission was endorsed by Pilatus, maker of the PC-12, another single engine turboprop aeroplane.

The joint submission is based on the Canadian Policy Letter 80 which has set the precedent for regulatory approval. CAA Standards Development is presently developing a discussion paper in order to obtain industry comment on whether the present regulatory standard ought to be reviewed.

3.2 OUTLOOK

If its discussion paper was favourably received by industry, CAA Standards Development would usually then draft an ARP.

Under any new regulations, each prospective operator would probably require individual CAA approval to conduct single engine commercial passenger operations. Standards Development have suggested that in order to gain approval, operators may need to demonstrate the reliability of particular engine/airframe combinations by means of a trend monitoring programme. Such a programme could involve regular engine oil analysis and automatic fleetwide monitoring of engine parameters, as well as crew training.

4. DISCUSSION

This section discusses the principal operational aspects which relate to commercial passenger carriage in single engine turbine aeroplanes.

4.1 ENGINE RELIABILITY

The regulatory change being considered by the CAA potentially affects three aeroplanes: the Cessna 208 Caravan, Socata TBM 700, and Pilatus PC-12. All are powered by the Pratt & Whitney PT6A, a free turbine turboprop engine with three or four (according to engine version) axial compressor stages and one centrifugal compressor; a single annular combustion chamber, single stage gas generator turbine, and single- or two-stage (according to version) power turbine.

4.1.1 PRATT & WHITNEY DATA

The Canadian approval for single engine commercial passenger carriage in IMC or at night requires powerplant reliability to be demonstrated over a period of 100,000 hours in service. Approximately 24,000 PT6 turboprop engines have, in various versions, flown more than 160 million hours. FedEx PT6A-114/A engines have flown more than 600,000 hours.

The mean time between IFSDs for PT6 turboprop engines is quoted by Pratt & Whitney as being 125,000 hours on a six-month rolling average to the end of the second quarter 1993.

The Cessna Aircraft Company provides accident data for Cessna 208, 208A, and 208B Caravans which are powered by the PT6A-114 and -114A engine versions. The quoted figures are a mean time between all engine failure accidents of 350,000 hours, and a MTB fatal engine failure accidents of 1,400,000 hours.

Newer versions of the PT6A which have not flown the required 100,000 hours in service, such as the PT6A-64 which powers the Socata TBM 700, are claiming demonstrated reliability based upon the time in service of their components. For example, the reduction gearbox of the PT6A-64 is identical to that of the PT6A-41/42/61 (15,604,000 hours in service) and its gas generator is identical to that of the PT6A-66/67A/67B (684,700 hours in service).

4. 1. 2 AUSTRALIAN ARMY PILATUS PORTERS

Engine reliability data were obtained from the Australian Army Aviation Corps' operation of the Pilatus PC-6B Porter. The Porter was powered by an earlier version of the same engine, the PT6A-20. The Army operated the Porter for approximately 23 years and during that period experienced no engine failures which resulted in a fatality. A maintenance monitoring program was carried out throughout the Porters' operating life. This included spectroscopic analysis of oil and the inspection of a ferrous chip detector (which was accessible only during maintenance and did not provide a cockpit indication).

Data from flying operations were available back to 1980. During this period the Porter fleet flew approximately 53,500 hours. One genuine engine failure occurred during this time, resulting from a roller bearing failure, and a successful forced landing was carried out. The IFSD rate was therefore nearly twice the maximum which would be required for civil commercial passenger approval under the new Canadian regulation. There were a further 24 partial power loss occurrences, of which three led to aircraft damage, resulting from either engine surges or such component failures as fuel pumps and air in fuel governor lines.

The operating environment of the Porters in Army service included some very rudimentary airstrips, the abrupt handling associated with low flying, and some extremes of loading and weather. Commercial passenger operations may impose a less onerous environment upon engines.

4. 1. 3 CIVIL EXPERIENCE

The Royal Flying Doctor Service has signed contracts for the purchase of two Pilatus PC-12 aeroplanes to be delivered from September 1994, and options on the purchase of a further three. The RFDS will thus be among the first major Australian civil organisations to gain single engine turbine experience with operations in a hot environment of dusty, unswept airstrips.

Two Cessna Caravans are presently operated in Queensland and one TBM 700 is registered in Western Australia. The BASI air safety database holds no records of engine-related occurrences involving these three aircraft. There are also three Pilatus Porters which have Australian civil registrations.

The PC-12 is expected to gain FAA certification about March 1994 and will have a built-in engine monitoring function as part of the EFIS. This monitoring system will automatically record engine parameters every two minutes, as well as parameter limit exceedances for later analysis. (No regulatory change is required for the RFDS, since its operations are classified as "aerial work" and are not "commercial".)

4. 2 HAZARDS

Several of the Canadian requirements (see Section 2. 1) attempt to ensure the reliability of an aircraft's engine and systems. These are the mandatory use of a turbine engine with demonstrated reliability, and the requirement for a chip detector, automatic ignition source, and manual throttle.

However, some other requirements relate to hazards which have been identified as being associated with the type of flying operation, rather than with the operation of single engine aircraft in particular.

The single turbine engine passenger operations which are likely to be conducted under changed regulations would usually be conducted by a single pilot. It is recognised that a single pilot operating at night or under IFR must manage a significant workload. This has led to the Canadian requirement for an approved Operations Specification covering single pilot operations.

The remaining Canadian requirements address the hazards associated with flight at night and in IMC. The mandating of dual attitude indicators and power generating sources is already reflected in current Australian rules for commercial IFR flight (CAO 20.18 Appendix III). Commercial operations under night VFR require only one attitude indicator, but this still requires a duplicated power supply (CAO 20.18 Appendix IV).

Further, an approved flight crew training program is required under the Canadian regulation for commercial passenger operations in single engine aeroplanes at night or in IMC. This relates more to the hazards of the single pilot IFR environment than to the operation of single engine aeroplanes.

4. 3 RISK ANALYSIS

The System Safety Directorate of Transport Canada conducted an Operational Safety Review of turbine powered single engine aeroplane commercial passenger operations at night and in IMC. The review aimed "to identify potential hazards and assess associated risks" of such operations.

The Safety Review Team's risk assessments led to the broad conclusion that greater risks are posed to a flight by reason of it being conducted in IMC, or by a single pilot, than by it being conducted in a single engine aircraft. Operational experience indicates that engine failures are not a statistically significant problem, with the mean time between inflight shutdowns for all PT6 turboprops reported by Pratt and Whitney to be one per 125,000 flying hours to 30 June 1993.

It was found by the Safety Review Team that "engine failure on a single engine aeroplane was considerably less probable than the predictable occurrence of a number of other identified hazards associated with this operation." The US FAA now says that the modern turbine engine is more reliable than many ancillary aircraft systems, "including the pilot".

The designs of the three particular aeroplanes attempt to address the reliability of these ancillary systems by such means as duplicated vacuum pumps, inclusion of an alternator in addition to the starter/generator, and an additional, separate electrical bus for essential systems. These measures are thought to mitigate the hazards inherent in the intended system of single pilot IFR operations.

4. 4 CRASHWORTHINESS

To obtain certification from the FAA, single engine aeroplanes must have a stall speed of no more than 61 knots in the approach configuration. The three aeroplanes above achieve this by having large flaps, thereby significantly extending the lower ends of their speed regimes. They can therefore land at speeds rather lower than those of the twin engine aeroplanes with which they may be compared, and in the event of a forced landing would require a smaller area of land and may contact the ground with less energy.

4. 5 CONTROLLABILITY

With the exception of the Cessna Caravan, the cruise altitudes of these aeroplanes are generally above 20,000 feet AMSL. This provides significant glide capability in the event of engine failure, increasing the prospects of a glide to a safe area. This differs from existing reciprocating single engine aeroplanes which normally operate at altitudes no higher than ten thousand feet.

The failure of one engine in a twin engine aeroplane creates several control problems. An asymmetric flight condition requires that the airspeed does not reduce below the aircraft's minimum control airspeed (Vmca) in order that the rudder has sufficient airflow to counter the yawing moment of the working engine. This narrows the safe flight regime, and raises pilot workload.

Australian data from the five years 1986-1990 indicate that twin engine aeroplanes flew 771,000 hours per serious accident (involving fatal/serious injuries), whereas single engine aeroplanes flew 1,805,000 hours. Given a reasonable degree of engine reliability and the greater complexity of handling a twin engine aeroplane, it is questionable whether twin engine aeroplanes are indeed safer in all cases.

5. SUMMARY

The status of commercial passenger operations in turbine powered single engine aeroplanes is presently under review by the civil aviation regulatory authorities of several nations. In this information paper BASI offers no argument for or against the introduction of such operations.

Present regulations on commercial passenger carriage were developed prior to the availability of the turboprop engines which are now in operation.

Transport Canada has set a world precedent in permitting commercial passenger carriage in single turbine engine aeroplanes. Australia, the United States, and other nations are in the process of determining whether to do the same. The issue is subject to active debate in Europe and the likely outcome in that jurisdiction is unknown at this stage.

Turboprop engines with substantial demonstrated reliability are available for commercial passenger aeroplanes. Hazard and risk analyses indicate that engine failure in these aircraft is statistically less significant than other known hazards within the single pilot IFR/night operating environment.

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Transport Canada (1993), Policy Letter 80: *Commercial Operations of Single Engine Aeroplanes with Passengers at Night and/or under Instrument Meteorological Conditions (IMC)*

APPENDIX

Performance Comparison

This appendix provides a brief comparative overview of the three aeroplane types which would be affected by any regulatory change by the CAA.

	Cessna 208 Caravan	Socata TBM 700	Pilatus PC-12
Powerplant	PT6A-114	PT6A-64	PT6A-67
MTOW (kg)	3,980	2,990	4,000
Max Altitude (feet)	10,000	30,000	30,000
Pressurised ?	No	Yes	Yes
Max Cruise Speed (TAS)	184 kts @ A100	300 kts @ FL 260	269 kts @ FL 200
Stall Speed (knots) (landing configuration)	61	61	61
Initial RoC (@ MTOW)	975 fpm	2,380 fpm	2,040 fpm
Takeoff Distance (over a 50 foot obstacle)	737 m	650 m	555 m
Landing Distance (over a 50 foot obstacle)	505 m	620 m	560 m
Number in Australia	2	1	nil (5 on order)