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Study

Loss of control on fast single-engine turboprop aircraft

Case of Socata TBM 700

Updated Version 1991-2010

BEA

Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile

Ministère de l'Ecologie, du Développement durable et de l'Energie

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Glossary

AMSL	Above Mean Sea Level
ATPL	Airline Transport Pilot's Licence
CFR	Code of Federal Regulations
CPL	Commercial Pilot's Licence
CRI	Class Rating Instructor
EADI	Electronic Attitude Director Indicator
EASA	European Aviation Safety Agency
EFIS	Electronic Flight Instrument System
EHSI	Electronic Horizontal Situation Indicator
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FCL	Flight Crew Licensing
FI	Flight Instructor
FL	Flight Level
FTO	Flight Training Organisation
GPS	Global Positioning System
HPA	High Performance Aircraft
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IR	Instrument Rating
JOEB	Joint Operations Evaluation Board
lb	Pound
MDH	Minimum Descent Height
PFD	Primary Flight Display
PPL	Private Pilot's Licence
POH	Pilot's Operating Handbook
TRTO	Type Rating Training Organisation
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VMO	Maximum Operating Velocity

INTRODUCTION

The TBM 700 was designed by SOCATA at the end of the 1980s. It is a pressurised single-engine turboprop. Given its performance capability, comparable with that of a light twin-engine jet, it has been successful, particularly with private pilots.

The aircraft was certified in 1990.

A new version has been available since 2006, the TBM 850; it differs from its predecessor only by increased power at altitude.

The BEA recorded thirty-six accidents involving the TBM 700 between the beginning of 1990 and March 2010. Six of them involved loss of control on banking to the left during arrival. They generally involved a combination of low speed and a landing configuration as well as a rapid increase in thrust. The purpose of this study is to suggest explanatory factors for this.

A loss of control in flight[1] is an extreme manifestation of a deviation from intended flight path in flight. The term "loss of control" covers events during which the attitude and/or the flight path of the aeroplane are no longer controlled by the pilot. This does not necessarily mean that the aeroplane has become uncontrollable.

[1]Source: ICAO ADREP.

Other manufacturers produce single-engine turboprops. The BEA did not have sufficient available data to undertake a comparative study. The TBM 7000 is the only single-engine turboprop in its class produced by a French manufacturer.

1 - GENERAL OUTLINE OF OCCURRENCES

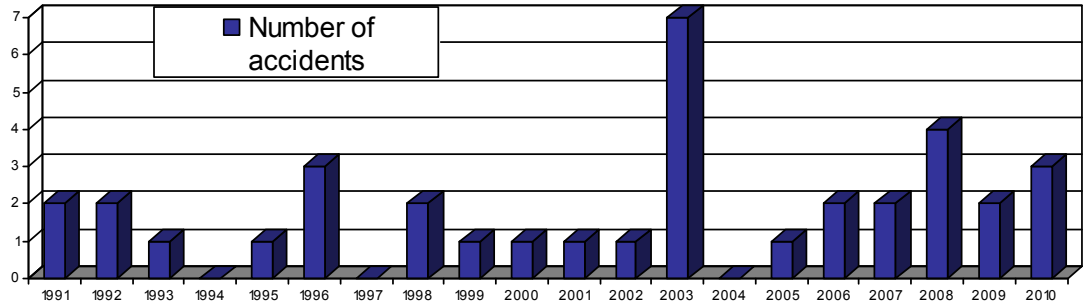
1.1 Source of Data

The study only relates to accidents involving the TBM 700 that were notified to the BEA. The items presented were obtained from the BEA database. They are based on:

- Either accidents occurring in France;
- Or accidents occurring abroad for which information was supplied to the BEA by the bodies that conducted the investigations.

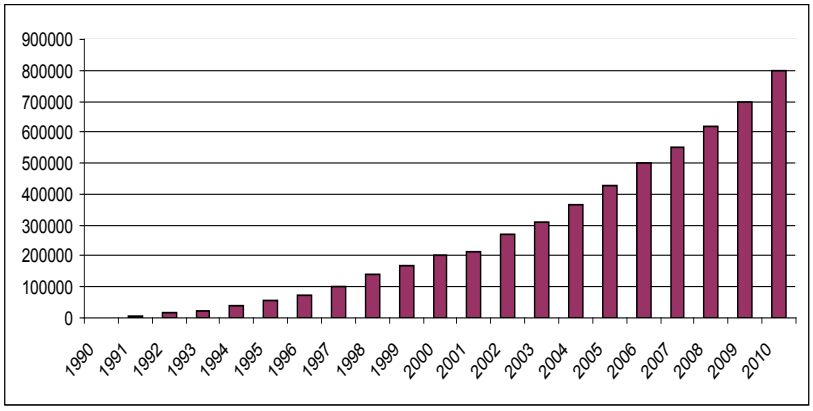
1.2 Breakdown of Occurrences

Thirty-six accidents were recorded between 2 August 1991 and 1 March 2010, broken down as follows:



These accidents caused the deaths of twenty-nine people. Eleven others were injured.

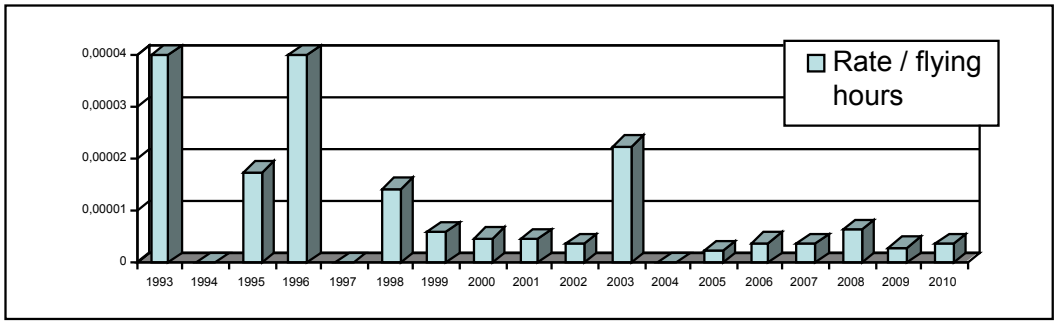
The number of TBM 700 aircraft operated worldwide has increased continuously since 1990, reaching 550 in 2010.



(Data supplied by the manufacturer)

Bars represent the estimated aggregate number of flying hours of the TBM 700 fleet in service at the end of each year.

Thus the number of accidents relative to the number of flying hours has fallen markedly since 1996.



During the first years of TBM 700 production, most of the events notified to the BEA occurred in France. In the last 12 years, they have occurred mostly abroad, especially in the United States, where the vast majority of these aircraft have been sold.

1.3 Characteristics and Consequences of Accidents

Amongst the thirty-six accidents considered for this study, nineteen could be classified in the category of loss of control in flight without any technical failures. These losses of control are characterised by an inappropriate aircraft attitude given the phase of flight, or an uncontrolled trajectory. The latter may be the consequence of inadequate control of the aircraft's attitude. Fourteen people died and ten were injured in these accidents.

The following table presents the aeronautical qualifications held by the pilots of these nineteen accident aircraft:

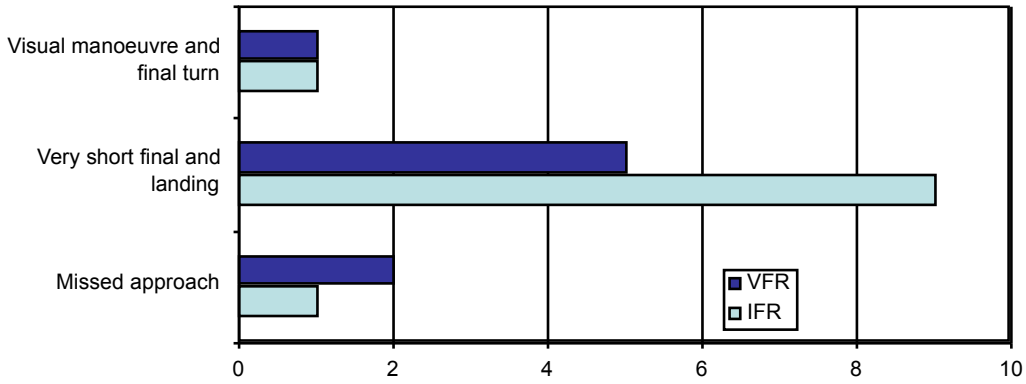
Composition of flight crew	Number of accidents
Private pilot alone	6
Private pilot accompanied by professional aircrew	4
Professional aircrew (CPL or ATPL)	5
Unknown	4

1.4 Breakdown of Loss-of-control Accidents

1.4.1 According to meteorological environment

In the majority of cases, the flight was executed on instruments in adverse weather conditions: conditions below minimum operational conditions, fog, heavy icing, etc. Some accidents occurred at night.

1.4.2 According to flight phase



- Four accidents occurred following a stall at low speed on landing;
- Two accidents were subsequent to spatial disorientation leading to loss of control of the aeroplane;
- One accident was subsequent to landing in a fog bank;
- One accident occurred during a go-around climbing through on thousand feet;
- Two accidents were related to inadequate taking into account of a cross wind on landing;
- One accident was due to a hard landing;
- Two losses of control occurred on approach without the technical investigation being able to determine their cause. The investigations put forward the hypothesis of an increase in power to return to level flight or distraction of the pilot in one case and an aircraft stabilisation defect in the instrument procedure in the other case.

The other six losses of control occurred on final approach, close to the ground, when speed was relatively low. The BEA data did not show any technical anomalies. The circumstances of these occurrences are detailed below.

1.5 Findings in Six Cases of Loss-of-control

In general, the following conditions must be met simultaneously to cause loss of control on banking to the left:

- Speed lower than that specified in the flight manual for the selected configuration;
- Rapid application of power from idle to full throttle.

The absence of a flight recorder made it generally difficult to establish accurately the circumstances which contributed to the loss of control. The radar recordings and testimony did however provide useful elements for the investigation. In specific cases, the pilot survived and was able to describe the end of his flight.

The investigations did not bring to light factors relating to:

- Incorrect adjustment of the roll trim during approach;
- Pilot incapacitation;
- Fuel imbalance in the tanks;
- The influence of cross wind;
- The influence of icing.

However, a certain number of common points were highlighted.

These accidents occurred while the pilot had manual control, with the autopilot disengaged.

Observation of the sites and wreckage revealed a significant bank to the left at the moment of the accident. The impact was sometimes preceded by deviation of the flight path to the left. When witnesses had seen the accident, they confirmed this movement before the impact.

These cases of loss of control occurred at low speed and increasing engine power. The following extracts from reports support this:

- *1st event.* Although visibility was less than the minimum required and aiming to check this visibility, the pilot performed a final approach in clean configuration, followed by passage at low height over the runway. Not seeing the runway, he made a go-around. At the moment of the turbine power increase, the aeroplane swerved to the left. The left wing and the propeller struck the runway. The pilot decreased power, the aeroplane bounced on the runway and crashed 400 metres further on.
  Summary of the report on the accident to F-GLBC on 15 November 1991 at Epinal, France.

- *2nd event.* During a demonstration flight, the pilot in the right seat performed a visual approach. Whereas the speed on final was low and pitch attitude high, the turbine's rapid increase in power caused a left bank effect that the pilot could not control. The left wing struck the runway, the aeroplane left the runway laterally and then got stuck.
  Summary of the report on the accident to F-GLBD on 10 December 1992 in Oxford, United Kingdom.

- *3rd event.* During a third attempt at a standard instrument approach, the pilot was visual with the runway at minimum descent altitude. As he came closer to the runway, he noted that the aeroplane was descending too fast. He increased thrust but was surprised by the time it took for the turbine to gain power, which he reported as being unusually slow. When the power was effective, the aeroplane banked to the left and the left wing struck the ground.
  Summary of the report on the accident to N45PM on 15 December 2000 at Harrisburg - United States.

- *4th event.* "…approach was normal at a speed of 85 kt, undercarriage down and full flaps. A little before the flare, estimating that he was going "to be a little short", he [the pilot] pulled the nose up while increasing power slightly. Judging that the pitch-up attitude was becoming excessive, he started a go-around. The aircraft rolled to the left. The left wing tip touched the turning area at the runway threshold. The aircraft left the runway to the left and struck the ground violently. Extract from accident report for N700AR dated 13 May 2002 at Moulins, France.

- *5th event.* During an instruction flight, on short final, the student experienced difficulty in controlling the aeroplane in an area of turbulence. At the start of the flare, the aeroplane banked to the left with a high rate of descent. The instructor took over control of the aeroplane, increasing power, but the left wing struck the runway
  Summary of the report on the accident to N700GJ on 15 February 2003 at Aspen – United States.

- *6th event*. During the flare, the aeroplane bounced slightly, began to yaw then roll to the left despite the pilot's input on the rudder pedals. He decided to abort the landing and go around. The aeroplane then pitched up and the left wing struck the ground. The aeroplane left the runway.
  Summary of the report on the accident to N700VA on 24 October 2003 at River Tay - Scotland.

1.6 Demonstration Flight

In the context of the investigation of a loss of control[2] on final occurring on 6 December 2003 at Oxford (United Kingdom), a demonstration flight was performed by the AAIB with the manufacturer. This flight, conducted at times following procedures not recommended in the POH (for example, no corrective input on the rudder pedals after rapid application of thrust), highlighted:

- A tendency to start rolling to the left[3] during stall;
- A tendency to roll to the left, controllably, during go-around at speeds equal to or greater than 70 kt and from a fully reduced engine torque or adjusted to 20% ; the lower the speed, the more pronounced the rolling movement.

NB: During this flight, conditions could have been markedly different from the nominal operating conditions for the aeroplane and the circumstances encountered by pilots in accidents, such as proximity to the ground, poor weather conditions, fatigue, etc.

1.7 Partial Conclusion

The experience of this flight (see. 1.6) indicated that the six cases of loss of control do not appear to be directly explicable by unusual aerodynamic behaviour of the aircraft. The aircraft remained controllable within the certified flight envelope, particularly when close to stall speed.

Consequently the study looked into the operating conditions of the aircraft that could lead to such a loss of control.

[2] This event was not part of the loss of control cases as the technical investigation did not highlight a go-around leading to this loss of control.

[3] Movement to the left during a stall is a recognised phenomenon on single engine aircraft, even more strongly marked if the flight asymmetry is pronounced. The certification regulation accepts it and settles for specifying limits to this roll-off (FAR Part 23.201 (e) and (f)) and the TBM 700 complies with this regulation.

2 - ADDITIONAL INFORMATION

2.1 The TBM 700

Designed in the 1980s, the TBM 700 was intended for non-professional pilots needing to travel frequently over long distances. Such pilots were already using other aircraft (Socata TB 20, Cessna 310, etc.) for private journeys.

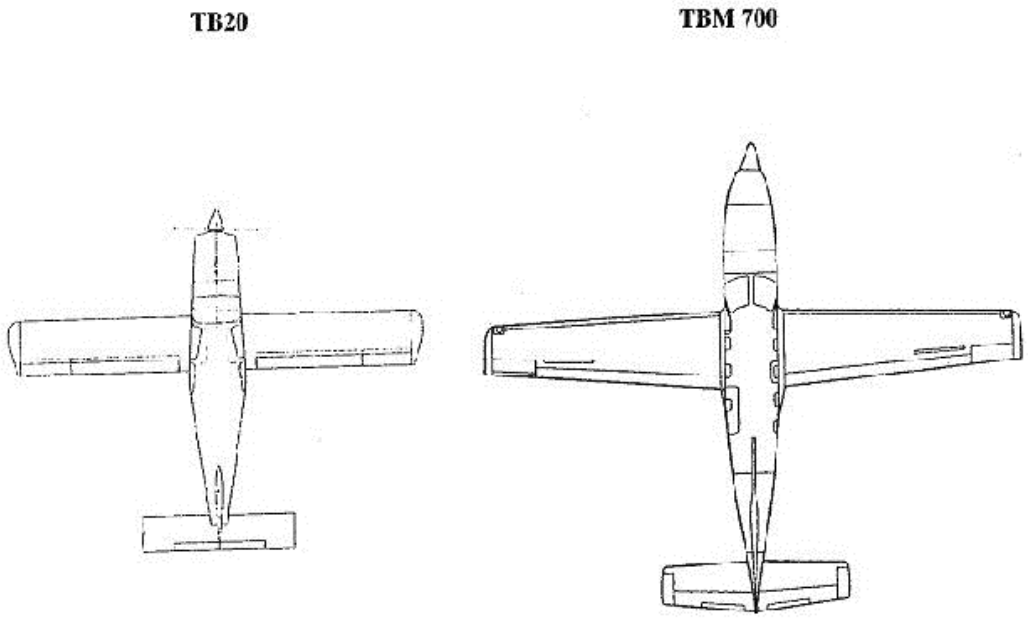
Most owners of TBM 700 aircraft undertook their VFR and then IFR pilot training on conventional single-engine piston aircraft. Many of them gained significant experience on such aircraft.

The TBM 700 is little used by air transport companies. Very few accidents have been reported in the context of commercial operations.

The French Ministry of Defence has a fleet of TBM 700 aircraft. Military use presents many analogies with public transportation in France: aircrew consisting of two qualified pilots whose main role is piloting the TBM 700, etc. No fatal accidents have occurred in this fleet.

2.2 Technical Specifications of the TBM 700

The views below represent a TB 20 and a TBM 700 on the same scale.



Spoilers are placed approximately two thirds of the way along the wings on the TBM 700. Their movements are linked to those of the ailerons. This aircraft is generally equipped with weather radar, the radome for which protrudes from the leading edge of the left wing.

The following table shows a comparison of the principal specifications of a TB 20, taken as an example of a widely used leisure aircraft, with those of a TBM 700.

Specifications	TB 20	TBM 700
Engine type	Piston	Turbine
Maximum takeoff power	250 hp	700 hp
Maximum takeoff torque (engine T = resistant T)	681 NM	2,457 NM
Wingspan	9.77 m	12.56 m
Stall speed VS0 (landing configuration)	59 kt	53 to 65 kt
Recommended final approach speed (landing configuration)	75 kt	80 to 85 kt
Recommended takeoff speed	67 to 76 kt	77 to 90 kt
Maximum flight level used in IFR, order of magnitude	FL 120	FL 310
Indicated cruising speed, order of magnitude	135 kt	205 kt
Maximum operating speed (VMO)	150 kt	266 kt
Maximum true airspeed, order of magnitude	200 kt	320 kt
Maximum takeoff weight	1,400 kg	3,354 kg
Maximum landing weight	1,335 kg	3,186 kg
Pressurisation	no	yes

The maximum value for torque applied by the engine, or torque effect, is greater for the TBM 700 than for the TB 20.

For the torque during level flight at maximum power:

- On a TB 20, it is equivalent to that exerted by a load of about 30 kg applied in the centre of the left wing;
- On a TBM 700, it would correspond to a load of about 80 kg applied in the centre of the left wing.

These values apply however to cases of stabilised flights and cannot be directly transposed to phases of flight which, like a go-around, involve rapid variations in power settings.

Moreover, in the case of a piston engine, an input to increase power rapidly and significantly produces an almost immediate result. In the case of a turbo-prop, regulator mechanisms can delay the effects of this input. A firm but progressive use of the power lever cancels this delay. It is recommended in the POH, which in addition recommends:

"Before landing"

"The speed range the TBM 700 allows may sometimes lead some experienced pilots to make decelerated approaches with power on IDLE. This type of approach must be conducted sufficiently early in order to ensure a stabilised speed and a torque of not less than 10% before landing (in order to obtain immediately, if required, an increase in power)."

2.3 Different versions of the TBM

Since 1990, the TBM has been modernised. Successive versions and their major modifications are described below:

- TBM700 A :
  PRATT and WHITNEY Canada engine: PT6A 64 - 700 hp
  Classic electromechanical instrument Cockpit
- TBM700 B :
  EFIS Instruments for EADI (horizon) and EHSI (course indicator) only
  Enlarged motorised passenger door
- TBM700 C1 :
  Two GARMIN GNS 530 GPS
- TBM700 C2 :
  Extended maximum takeoff, landing and zero fuel weights.
- TBM700 N (commercial name : "TBM850"):
  PRATT and WHITNEY Canada engine: PT6A 66D – 850 hp
- TBM700 N equipped with GARMIN G1000 (commercial name : TBM850 G1000) :

2.4 Training regulations on the TBM 700

2.4.1 French regulations

2.4.1.1 Regulatory framework

Up until 1999, the 1981 order relating to certificates, licences and qualifications for non-professional pilots in civil aviation required that the holder of a certificate and a private aircraft pilot's licence should undertake a defined programme for the issue of a class C rating (turboprop). Running for about one week, the programme included ground courses, about five hours flying and an in-flight test.

The order of 29 March 1999 relating to the issuing of licences and ratings for members of aircraft flight crew (FCL 1, appendix 2), as well as the main additional or amending documents, comprise the standard regulations applicable in France.

2.4.1.2 TBM class rating

Piloting a TBM700 aircraft requires a class rating, in accordance with the FCL 1.215 (a) setting this requirement for all single pilot aircraft equipped with a turboprop. This rating groups together all the versions of the TBM. No training in their differences[4] is required in the regulations.

The conditions for obtaining a class rating are set by the FCL 1.240 (a) (3). No minimum flight training is specifically required. This training may be given statutorily by an FI or a CRI excluding FTO / TRTO, therefore following a non-approved programme.

A type rating may be required for specific single pilot single engine turboprop aircraft, according to certain criteria established by the FCL 1.220 (a). The list of aircraft type qualifications is set by a decree.

[4] Differences training must include a minimum of one flight with an instructor as well as theory classes. It must be mentioned in the log book.

2.4.1.3 High performance aircraft classification

Since publication of the order of 27 July 2006 modifying the FCL 1, the TBM 700 is classified as a High Performance Aircraft (FCL 1.221).

According to this order, the candidate for qualification in the TBM class must have completed at least two hundred flying hours[5]. He/she must also hold the ATPL (A) theory, or a valid ATPL (A) (or national pilot's licence), or a valid CPL (A)-IR (or national professional pilot's licence), or have taken an HPA training course.

[5]For single-engine aeroplanes, it is not necessary for these 200 h to have been flown as captain.

The aim of the HPA training is to provide the candidate with adequate general knowledge of the operation of aeroplanes flying at high speed and high altitude as well as aircraft systems. It must be approved by the Authority. It is taught by an approved FTO or TRTO organisation and is issued after taking and passing a written examination with multiple choice questions.

This training is generally done over 25 hours although no specific duration is imposed by the regulations. The Human Performance part includes aspects relating to basic physiology in flight and to the high altitude environment.

2.4.2 Overseas, for example in the United States

In the United States, the regulatory reference applicable for licences and ratings is the FAR (Federal Aviation Regulation) 61 of the CFR (Code of Federal Regulations).

In particular, FAR 61.31:

- Defines the aircraft for which a type rating is required;
- Defines additional training for "complex" aircraft (retractable landing gear, flaps and variable pitch propeller) (on the ground and in flight);
- Defines additional training for high performance aircraft (aircraft equipped with an engine with power of more than 200 hp) (on the ground and in flight);
- Defines additional training for pressurised aeroplanes capable of flying at high altitude (above 25,000 ft AMSL) (on the ground and in flight).

The TBM 700, whose weight is less than 12,500 lb, does not require type rating. It comes under the category of single engine land aeroplanes. For each of these three additional ratings mentioned above, for piloting TBM 700 no minimum duration is required. They must be issued by an instructor holding the desired qualification. Training programmes developed by the manufacturer may be used as basic training by schools and users.

The fact that the FAA does not have strict requirements for experience does not mean that the training for pilots holding an American licence is inadequate. In fact, most American insurance companies bind their members to training conditions that go beyond the minimum required by regulations. These conditions are however limited to American insured parties.

2.5 Training Programme for Issuing TBM Class Rating

2.5.1 The Manufacturer

Training for the issue of TBM 700 class rating has been carried out by SOCATA instructors since January 1990. The manufacturer has recognised only one other organisation dedicated to its clientele in the North America zone, based in Orlando, called "SIMCOM". The manufacturer included two training courses for pilots for each delivery of a new aeroplane.

The pilots can choose between training on the manufacturer's French site or on that of SIMCOM. Exceptionally, the manufacturer organised training in specific countries abroad at the client's request and in compliance with the local authorities.

Since 1990, the manufacturer requires that a candidate for training:

- Totals 500 flying hours as pilot flying and holds a valid instrument rating;
- Holds an HPA module or the ATPL theory.

After the training and passing the flight test, a class rating (EASA or other licence except FAA) or an attestation (FAA licence) is issued.

The training and renewal programme recommended by the manufacturer is recorded in the JOEB TBM700 report, approved by EASA.

Since 1991, the initial programme has changed according to the experience acquired and the new systems installed. In-flight training is all carried out on the aeroplane belonging to the client. No simulator is available in Europe.

Originally the training lasted three and a half days. One and a half days were devoted to theoretical training and two days to practical training, over four flights of a total duration of five hours.

Currently, the training course lasts eight days. A specific module, related to learning the integrated Garmin G1000 system must be carried out before the start of the theoretical training. The trainees' knowledge is checked at the beginning of the theoretical training. The duration of the ground classes has been extended to four days. The practical training also lasts four days during which seven flights are performed of a total duration of eight hours.

2.5.2 Other organisations or schools

Given the growing number of aircraft in service and second-hand sales, a number of class ratings are issued by organisations or schools without a connection with the manufacturer.

In this way a recognised FTO and TRTO French piloting school offers full training. As well as the additional HPA theoretical training, trainee instruction is divided into ten hours of theoretical classes, four hours of practical explanation and four hours of flight. A certificate is issued after passing a flight test.

2.6 Comment on In-flight Instruction

The basic essentials of in-flight instruction are carried out in VMC, in order to familiarise future pilots with handling the aircraft. Trainees are therefore rarely faced with very bad weather conditions. In addition, in-flight instruction is generally given as part of a continuous course, to which future pilots devote themselves full time.

The manufacturer raises trainees' awareness of the following normal and emergency procedures:

- Slow flight and stalls;
- Go-around on short final (VMC);
- Use of autopilot;
- Simulated engine failure in flight and after take-off;
- Loss of power (fuel control failure) simulated in flight and after take-off;
- Depressurisation in flight (simulated from FL280 upwards) – full procedure with use of oxygen masks;
- Electrical failure;
- Unexpected operation - trim runaway;
- Flight with loss of pilot display screen (PFD 1) – use in degraded mode;
- IFR Navigation at high altitudes;
- Flight in real or simulated icing conditions and use of various related systems;
- Instrument approaches in degraded mode (PFD 1 failure);
- Missed instrument approaches in normal and degraded modes (PFD 1 failure), in simulated IMC conditions.

3 - ANALYSIS OF SIX CASES OF LOSS OF CONTROL STUDIED

The first accident with loss of control with a roll to the left on final occurred in France in 1991. It involved a collision with the ground during a go-around at very low height at night in the fog (F-GLBC on 15 November 1991).

The pilot was surprised by the roll movement to the left caused when engine power increased. The left wing touched the runway and the aeroplane broke up. Following this accident, the BEA issued two recommendations:

- The first concerned the description of thin layers of fog;
- The second recommended that go-around exercises by instrument reference should appear explicitly in the TBM 700 pilot training programme.

Five other accidents occurring after 1991 had similarities with this event: loss of control of the aeroplane rolling to the left on final although the pilot was increasing engine power and speed was low.

The following analysis offers two factors to explain these six losses of control.

3.1 Phenomena Relating to Flight at Low Speed

Explanations relating to the mechanics of flight rely on the illustrations generally used for training of private pilots. They are not a reference for an in-depth analysis of the aerodynamic effects that occur.

The phenomena described are typical of all forward-mounted, single-engine aircraft. The extent of some of these phenomena depends on the weight of the aircraft and power of the engine.

3.1.1 Phenomena associated with a power increase on a single engine aircraft

When the aeroplane travels at a speed close to that recommended on final (for example 1.3 x Vso), the angle of attack remains significantly below i_{MAX} (fig. 1).

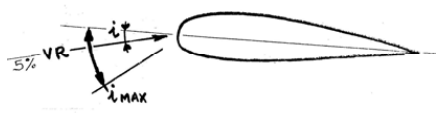


Fig. 1. diagram of the profile of the left wing, towards the wingtip, to the right of the aileron

When the pilot increases the power, the effect may be delayed a few seconds. When the engine actually delivers the expected power, the increase in spiral currents causes a yaw movement to the left. As the angle of attack is relatively high, the descending propeller blade, in other words the right-hand blade, exerts a greater pulling force than the rising blade. These two phenomena add to each other. The nose of the aircraft moves to the left, which causes sideslip to the right (fig. 2).

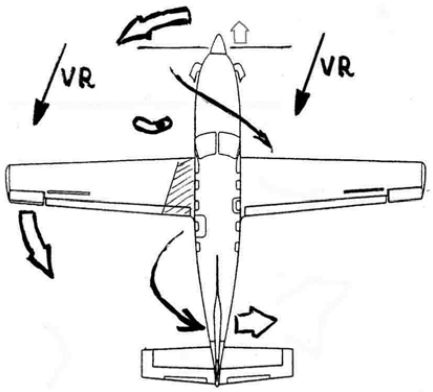
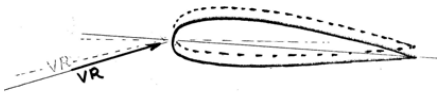
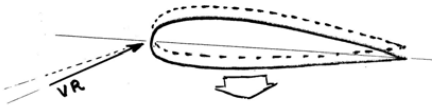
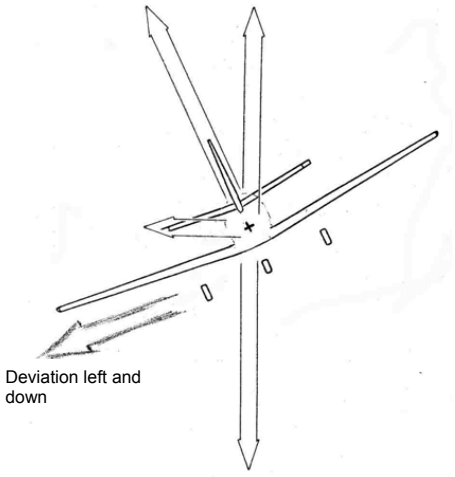


Fig. 2

Lift on the right wing increases and that on the left wing decreases. It sinks slightly, which causes a local increase in the angle of attack. At the same time the effect of an increase in power is to lift the nose of the aircraft, further increasing the angle of attack (fig. 3).	 Fig. 3
Finally, the increasing power intensifies the torque effect of the engine, which creates a roll to the left (see section 2.2). The left wing sinks again and, during this movement, the angle of attack of this wing also increases (fig. 4).	 Fig. 4
When the aircraft banks to the left, the flight path curves to the left. The vertical component of lift no longer balances the weight of the aircraft, which descends in the absence of pitch up input by the pilot (fig. 5).	 Fig. 5
Piloting inputs To counteract these movements of the aircraft, the pilot may tend to use the stick to roll to the right instead of acting mainly on the rudder pedals. The left aileron then pushed downward may not be enough to counteract the rolling movement of the aircraft. In parallel, lowering the trailing edge of the aileron modifies the wing profile and increases the angle of attack of this part of the wing (fig. 6). This action has the side-effect of increasing the drag on the left wing. The increase in angle of attack of the left wing can go as far as i_{MAX} and lead to a stall. Thus the pilot loses control of his/her aircraft as it banks strongly to the left with a significant nose-down attitude induced before touching the ground.	 Fig. 6

Some of these effects can appear amplified during a missed approach.

3.1.2 Comparison of the effect of flight control surfaces of a TBM 700 and a TB 20

The inputs necessary for the pilot to control the attitude of the aircraft depend on the effectiveness of the control surfaces. Here the analysis aims to compare this effectiveness between a fast single-engine turboprop aircraft such as the TBM 700 and a conventional single-engine piston aircraft such as the TB 20. The approach speeds considered were those recommended by the manufacturer.

On these two aircraft models, the flight controls are mechanically linked to the control surfaces. However, the roll control system of the TBM 700 is designed to use a combined movement of the ailerons and spoilers. An exact comparison of controllability characteristics at low speed may fall outside of the scope of this study.

However, the rate of roll depends on the aircraft's intrinsic moment inertia, therefore on its weight. The regulations take this into account to require that the effectiveness of the ailerons be demonstrated. The values of the rate of roll observed in the context of flights carried out are close to 20 °/s for the TBM700 and 30 °/s for the TB20, in the following conditions:

- Variation of tilt of -30° to +30°, using maximum travel of the controls;
- Landing configuration;
- Approach speed;
- Reduced power for a stabilised approach.

This difference of effectiveness in roll may surprise a pilot who mainly has experience on light single-engine piston aircraft, without necessarily encouraging him to adopt different behaviour at the controls.

3.1.3 Comparison of effort on the controls in roll between TBM700 B and N

The TBM design has not changed significantly during its development. Yet the number of losses of control in roll to the left during a go-around at low speed is higher for the A, B and C versions than for the N. The response in roll attitude of each of these two versions has therefore been measured in order to check if it is significantly different.

In-flight tests have been carried out in the following conditions:

- Installation of identical tests;
- Tilt variation from -45° to +45°, using the maximum travel at the controls;
- Cruise, approach and landing configurations;
- 150 kt, 100 kt, 85 kt speeds;
- Reduced power or power for level-off.

The results of these tests showed that the effort to make on the controls to counteract the loss of control in the roll axis were identical on the B and N versions despite a different weight. (loads between 10 and 14 daN in landing configuration).

3.1.4 Partial conclusion

It was not possible to link the accidents in the study with a lack of effectiveness of the ailerons or with the force to exert on the controls, according to the roll axis on some versions of the TBM 700.

3.2 Vestibular Disorientation in Flight

The paragraph that follows is taken from a BEA university paper relating to the Use of Flight Recording Data for Research into Spatial Disorientation in the Framework of Investigations at the BEA.

Spatial disorientation represents for the human the incapacity to correctly perceive position, attitude or movement in relation to the surface of the ground and to gravitational force. In flight it may take various forms, depending on the flight phase and the pilots' reaction faced with this type of situation. Spatial disorientation is the result of gaps in interpretation and integration of data, sometimes altered in specific conditions, coming from sensory receivers (eyes, the vestibular system, mainly proprioceptors) by the central nervous system which provides a perception of the situation. The responses to these perceptions depend on the personality, the physical and mental condition, and the experience of each person. They are limited by the features of the tasks to be performed by the pilots as well as by the environment in which these tasks must be performed.

In the absence of exterior visual references and without adequate monitoring of the aircraft instruments, perceptual illusions linked to the vestibular system may occur. Depending on the functional organs of the vestibular system which generate them, these illusions fall into two main categories.

3.2.1 Somatogyral illusions

Somatogyral illusion corresponds to an erroneous sensation of rotation (or absence of rotation) which comes from the non-perception of the scope or direction of a rotation by the semi-circular canals of the inner ear which are only sensitive to accelerations. Consequently, when a pilot engages in a manoeuvre including lasting rotation with little or no variation in speed (turn, barrel, spin, spiral) he places himself in conditions favourable to the appearance of this type of illusion. During such a manoeuvre, the data given by the semi-circular canals becomes progressively blurred during the first 20 seconds following the shutdown of angular acceleration. At that time, only the visual data, provided by the outside world or by the instrumentation, enables the pilot to notice the rotation. The illusion may persist for extended periods and the pilot continuing the control of his aircraft on instruments, is subject to a sensory conflict, causing tension and fatigue.

Somatogyral illusion of tilting (the leans) due to sensitivity of the semi-circular canals

A somatogyral illusion may occur when there is a difference between the real and perceived rotation speeds because of the sensitivity threshold of the semi-circular canals. This type of somatogyral illusion may occur when there is a rapid rolling movement followed by a slow return to the horizontal position. The first movement is perceived and the pilot has the non-erroneous sensation of leaning. However, the gradual return to horizontal is not perceived and the pilot continues to feel the first tilt, although it no longer exists. In this case as well, he will want to tilt the aircraft in order to stop this impression.

The Coriolis illusion

The Coriolis illusion occurs during a turn at constant speed while a pilot moves his head perpendicular to the aeroplane's plane of rotation. It is one of the most dangerous illusions experienced by pilots as it occurs suddenly and unexpectedly at a time when the pilot's attention is focused on another task. This illusion is even more dangerous in that it can occur more easily during takeoff or approach phases.

The effect of a simple movement of the head forwards during a turn at constant speed stimulates the semi-circular canals from the roll axis and yaw axis, producing a strange sensation of a change of angular speed in roll and yaw.

3.2.2 Somatogravic illusions

On the surface of the Earth, mankind is used to living in the Earth's gravity field, always constant, representing a stable vertical reference. During a flight, from the movements of the aircraft, the organism submits to forces of inertia and gravity. These forces consist of a gravito-inertial resultant force equivalent to a variation in intensity and/or direction of the gravity field vector. These forces may interfere with the perception of our body's orientation in relation to the pull of gravity. In this way, when an aeroplane is subject to linear or radial acceleration (or deceleration) for several seconds, the inner ear is unable to distinguish gravitational acceleration from other accelerations. For example, acceleration of the aeroplane may give the same impression as a rear tilt, in other words, a perception of aircraft in climb. The vertical reference taken into account by the pilot's central nervous system is no longer the terrestrial force of gravity but the resulting force of gravitational inertia, the sum of the force of gravity and the forces of inertia. Somatogravic illusion leads therefore to the wrong perception of the orientation of the body in space. In go-around or takeoff phases in conditions of reduced visibility, during acceleration of the aeroplane, a pilot may try to counteract his perception of climb by lowering the nose of the aircraft until the dive counterbalances the apparent pitch up caused by the acceleration, which may terminate in an impact with the ground.

3.2.3 Cases in this study

Two thirds of the events studied occurred in conditions of poor visibility. The effects associated with the increase in power on a single-engine, during a go-around, are of a kind to cause one or a combination of several of the sensory illusions described above. In the absence of recorded flight data, it is not possible to determine if one or more of the inputs on the flight controls were made by the pilot in reaction to a sensory illusion.

3.3 Operating Conditions of the TBM 700

Very few accidents are recorded for professional operating organisations. So, in this section, the analysis deals with loss of control close to the ground occurring with private or professional pilots using the aircraft for a personal purpose.

The initial training of private pilots (club) is less in-depth than that of professionals. Recurrent training, such as check rides with an instructor, is less frequent. A professional pilot generally receives consistent initial training and regular recurrent training sessions. When he/she works in a commercial enterprise, the operating standards, such as operational limitations and criteria of use of aircraft (dual controls) constitute mental reference points and tools for the prevention of accidents. Private users operate their aircraft as a means of transport with the associated limitations. By virtue of their social function, these users often have less time to perfect their skills.

Their aviation experience is counted as flying hours, sometimes considerable, on various types of aircraft. However, the background of their real experience with turbine-powered aeroplanes is difficult to assess as most of the flights are carried out using the autopilot. Therefore, the number of flying hours may not be a good indicator of the number of missed approaches or landings (without autopilot) carried out in marginal weather conditions.

When a professional pilot uses an aeroplane privately, he does not necessarily take into account the same operating standards.

The professional pilots involved in accidents sometimes held instructor qualifications and were accompanying a private pilot. Investigations were unable to clarify their role on board.

3.4 Confronting an Unusual Situation

The hours of instruction given at the time of qualifying on fast mono-turboprop aircraft include basic piloting sessions with missed approaches. However, flying activity generally comprises long flights carried out with autopilot, during which pilots do not consolidate this know-how.

Consequently, when the pilot is confronted with a sudden and unusual situation, he may tend to react by virtue of what he learned and practised during his initial training on a single-engine piston aircraft. Thus, when he increases power in a single-engine turboprop aircraft at low speed, the pilot may be surprised by the delayed onset and intensity of engine torque. Under these conditions, unsuitable inputs to correct the trajectory on final approach or to miss an approach may lead to a loss of control following the sequence described in 3.1.

In landing or missed approach phases, control of the flight path requires physical and mental readiness. In addition, an unfamiliar environment or unexpected weather conditions require the further use of significant mental and psychomotor resources. The pilot's workload during an approach is therefore often significant. Yet in a large number of the accidents studied, the pilots had carried out a long exhausting flight, sometimes following a hard day's work. Fatigue probably reduced their performance level and may have led to difficulties in correctly interpreting an unusual situation, in making and executing the appropriate decision, in controlling flight parameters on final approach, and in making the necessary corrections on the controls at the right time.

Although this is true of the end of any flight, it is more evident in the context of using a fast aircraft over long distances to meet personal obligations. This specific context and the possible consequences on the pilot's performance are not always mentioned explicitly in training or skill maintenance programmes, especially for private pilots. The HPA training programme does not cover this point.

4 - CONCLUSION

Since the TBM 700 came into service, the annual accident rate per flying hour has been reduced by a factor of ten.

Before 2003, six accidents occurred during approach phases (landing or missed approach) during which the pilot lost control of the aircraft, generally rolling to the left, when workload was high.

To prevent such accidents, training could be extended into various areas, such as:

- Aircraft use at low speed;
- Deterioration in the level of pilot performance at the end of a flight, as much for private pilots as for professionals;
- Raising pilot awareness of managing personal resources.

List of appendices

Appendix 1

List of the 36 TBM accidents between 1991 and 2010

Appendix 2

HPA programme and extracts from FCL 1

Appendix 1

List of 36 TBM accidents between 1991 and 2010

- Injuries: F for Fatalities, In for Injured.
- Flight rules: V for VFR, I for IFR, Y for IFR then VFR, CIR for circle to land.

Date	Registration	State of Occurrence	Injuries	Flight Rules	Brief Description	Type of Event	Pilot's Licences	Pilot's Experience	Final Report
02/08/1991	F-GJTS	France	None	VFR	Stall, hard landing on an altiport. Tailwind: 5 kt.	Loss of control on arrival	CPL(A)	2,100 h of which 206 on type	
15/11/1991	F-GLBC	France	2 In	IFR	Loss of control on left bank during go-around in area of light fog, at night. Runway 09, wind 080° / 8 kt.	Loss of control on left bank	PPL(A)	1,100 h of which 24 in the previous 3 months	
22/08/1992	N339W	United States	2 In	IFR	Left wing struck runway during landing.	Loss of control on arrival	Pilot in left seat : American PPL Pilot in right seat : American CPL + instructor qualification	Pilot in right seat : 246 h	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20001211X15455&key=1
10/12/1992	F-GLBD	United Kingdom	None	VFR	Loss of control on left bank during go-around, during a demonstration flight, on approach at night. Runway 20, wind 230° / 5 kt.	Loss of control on left bank	Pilot in left seat : PPL Pilot in right seat : unknown	Pilot in left seat : 100 h	http://www.aaib.gov.uk/publications/bulletins/february_1993/socata_tbm_700_f_glbd.cfm
02/04/1993	OE-EDU	Germany	6 F	VFR	Collision with terrain in unfavourable meteorological conditions.	Other	ATPL(A)	unknown	
07/12/1995	OE-EHG	Germany	1 In	IFR	Loss of control on short final, at night, in unfavourable meteorological conditions. Runway 08, wind 100° / 20 kt.	Loss of control on arrival	Pilot in left seat : PPL(A) Pilot in right seat : CPL(A)	Pilot in left seat : 255 h of which 6 on type Pilot in right seat : 1,900 h of which 400 on type	
29/03/1996	N292RG	United States	None	VFR	Landing with gear up.	Other	American CPL	1,126 h of which 218 on type	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20001208X05389&key=1
26/04/1996	JA8896	Japan	6 F	IFR	Collision with terrain during instrument approach.	Other	unknown	unknown	
10/05/1996	N345RD	Denmark	None	IFR	Retraction of left MLG during landing.	Other	PPL	1,660 h of which 900 on type	
13/03/1998	N345RD	United States	4 In	IFR, CIR	Loss of control during approach, at night. Visibility 2,000 m, ceiling 1,700 ft.	Loss of control on arrival	American CPL	2,088 h of which 1 200 on type, 54 h on type in the previous 3 months	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20001211X09714&key=1
04/08/1998	N69BS	United States	4 F	IFR, CIR	Loss of control during approach in unfavourable meteorological conditions. Mist and low ceiling.	Loss of control on arrival	American PPL	3,150 h	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20001211X10911&key=1
13/03/1999	N700SP	United States	None	IFR	Landing with landing gear retracted.	Other	American PPL	1,680 h of which 207 on type	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20001205X00383&key=1
15/12/2000	N45PM	United States	None	IFR	Loss of control on left bank during a go-around, in unfavourable meteorological conditions, at night. Visibility 3,000 m, ceiling 200 ft, wind calm.	Loss of control on left bank	American PPL	1,430 of which 54 on type, all in the previous 3 months	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20001220X45451&key=1

26/03/2001	N300WC	United States	1 F	IFR	Loss of control during initial climb, collision with terrain.	Other	American PPL	1,024 h of which 136 on type, 37 h on type in the previous 3 months	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20010328X00660&key=1
13/05/2002	N700AR	France	None	VFR	Loss of control on left bank during a go-around, collision with terrain. Runway 08, wind 130° / 10 kt.	Loss of control on left bank	PPL	2 ,100 h of which 35 on type, 70h in the previous 3 months	
15/02/2003	N700GJ	United States	None	IFR	Loss of control on left bank during a go-around, collision with terrain, turbulent conditions, under instruction.	Loss of control on left bank	Pilot in right seat: American ATPL, instructor qualification. Pilot in left seat : American PPL	Pilot in right seat : 23 592 h of which 445 on type, 87 on type in the previous 3 months	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20030221X00244&key=1
13/02/2003	N700VA	United Kingdom	1 In	N/A	Uncommanded aircraft movement at the ramp, pilot injured on ground.	Other	American ATPL	4,437 h of which 75 on type	http://www.aaib.gov.uk/publications/bulletins/august_2003/socata_023413.cfm
01/03/2003	N700PP	United States	3 F	IFR	Loss of control on final in unfavourable meteorological conditions, collision with terrain. Visibility 1200 m, ceiling 300 ft. Runway 17, wind 140° / 5 kt.	Loss of control on arrival	Pilot in left seat : American PPL Pilot in right seat : American ATPL	Pilot in left seat : 730 h	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20030310X00310&key=1
24/04/2003	N705QD	United States	1 F	VFR	Disconnection of the engine thrust control during approach, engine cut, collision with terrain before runway, fire.	Other	American ATPL	10,000 H of which 408 on type	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20030429X00591&key=1
24/10/2003	N700VA	United Kingdom	None	VFR	Bounce during landing, go-around, loss of control in bank to the left, collision with terrain.	Loss of control on left bank	British CPL	3,170 h of which 65 on type, 41 h in the previous 3 months	http://www.aaib.gov.uk/publications/bulletins/february_2004/tbm_027213.cfm
06/12/2003	N700QD	United States	None	IFR	Fuselage icing, emergency landing just after takeoff.	Other	American ATPL	6,500 h of which 2,000 on type, 210 h on type in the previous 3 months	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20031209X02013&key=1
06/12/2003	N30LT	United Kingdom	3 F	VFR	Loss of control on final, collision with terrain. Runway 01, wind 030° / 16 kt.	Loss of control on arrival	American CPL	1,573 h of which 500 on type	http://www.aaib.gov.uk/publications/bulletins/may_2005/socata_tbm_700b__n30lt.cfm
27/12/2005	N198X	United States	2 In	VFR	Difficulties for trainee to maintain zero bank, late takeover of controls by the instructor, right wing struck runway	Loss of control on arrival	Pilot in right seat: American ATPL, instructor qualification.	6,296 h of which 2 921 on type	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20060120X00108&key=1
07/01/2006	N22WZ	United States	None	unknown	Hard landing.	Other	unknown	unknown	
04/02/2006	N755PG	United States	None	VFR	Hard landing.	Other	American CPL	1,560 h of which 86 on type	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20060309X00280&key=1

02/02/2007	N944CA	United States	3 F	IFR	Loss of control during a missed approach in unfavourable meteorological conditions, at night. Visibility 1,600 m, ceiling 200 ft. Runway 05, wind 160° / 4 kt.	Loss of control on arrival	Pilot in right seat: American CPL, instructor qualification. Pilot in left seat: American PPL.	Pilot in right seat : 1,700 h Pilot in left seat : 300 h	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20070212X00169&key=1
04/09/2007	F-GTJM	France	None	unknown	Abnormal display of landing gear position during takeoff, nose gear retraction during landing.	Other	PPL(A)	1,428 of which 898 on type	www.bea.aero/docspa/2007/f-jm070904/pdf/f-jm070904.pdf
27/03/2008	N700GY	United Kingdom	None	unknown	Retraction of nose gear during landing.	Other	ATPL(A)	17,400 h of which 150 on type	http://www.aaib.gov.uk/publications/bulletins/may_2009/eads_socata_tbm_700c1__n700gy.cfm
03/06/2008	N849MA	United States	1 F and 2 In	IFR	Takeoff with tailwind, stall, collision with terrain.	Other	American PPL	5,688 h of which 4138 on type	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20080611X00836&key=1
15/07/2008	N484RJ	United States	1 F	IFR	Loss of control during an "S" manœuvre on final approach, collision with terrain.	Loss of control on arrival	American PPL	975 h of which 44 on type and 4 in the previous 24 h, all on type.	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20080720X01084&key=1
22/12/2008	N70LR	United States	None	VFR	Landing with landing gear retracted.	Other	American CPL	5,510 h of which 525 on type	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20090105X93800&key=1
29/08/2009	N715V	United States	None	VFR	Loss of control on short final, hard landing and right wing struck runway.	Loss of control on arrival	American PPL	1,233 h of which 458 on type	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20090831X41405&key=1
13/12/2009	N850MT	United States	None	VFR	Loss of control during a go-around at night, in unfavourable meteorological conditions, collision with trees.	Loss of control on arrival	American PPL	1,738 h of which 1,098 on type and 41 in the previous 3 months	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20091214X94945&key=1
27/01/2010	N850VM	United States	None	VFR	Landing with landing gear retracted.	Other	American PPL	3,079 h of which 50 on type	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20100204X61041&key=1
01/03/2010	N700ZR	United States	1 In	VFR	Swing to the left during landing run, go-around without full application of thrust, loss of control in flight, collision with terrain.	Loss of control on arrival	American ATPL, instructor qualification	4,215 h of which 1 240 on type	http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20100302X80100&key=1
23/05/2010	N750AB	United States	None	VFR	Loss of power in cruise, runway overrun during landing.	Other	unknown	unknown	Preliminary report: http://www.ntsb.gov/aviationquery/brief.aspx?ev_id=20100524X75523&key=1

Appendix 2

HPA programme and extracts from FCL 1

Extract from the decree of 29 March 1999, FCL 1, applicable as of 31 December 2007 (Appendix 1 to FCL 1.251)

FCL 1.215 Class ratings (A)

(a) Divisions.

Class ratings shall be established for single-pilot aeroplanes not requiring a type rating as follows:

(1) all single-engine piston aeroplanes (land);
(2) all single-engine piston aeroplanes (sea);
(3) all touring motor gliders;
(4) each manufacturer of single-engine turbo-prop aeroplanes (land);
(5) each manufacturer of single-engine turbo-prop aeroplanes (sea);
(6) all multi-engine piston aeroplanes (land); and
(7) all multi-engine piston aeroplanes (sea).

(b) Listings:

Class ratings for aeroplanes will be issued according with the associated administrative procedures accepted by the JAA.

In order to change to another type or variant of the aeroplane within one class rating, differences or familiarisation training is required.

[...]

FCL 1.220 Type ratings (A)

(a) Criteria.

For the establishment of type ratings for aeroplanes other than those included in JAR–FCL 1.215, all of the following shall be considered:

(1) airworthiness type certificate;
(2) handling characteristics;
(3) certificated minimum flight crew complements;
(4) level of technology.

(b) Divisions.

Type ratings for aeroplanes shall be established for:

(1) each type of multi-pilot aeroplane; or
(2) each type of single-pilot multi-engine aeroplane fitted with turbo-prop or turbojet engines; or
(3) each type of single-pilot single-engine aeroplane fitted with a turbojet engine; or
(4) any other type of aeroplane if considered necessary.

(c) Listing:

Type ratings for aeroplanes will be issued in accordance with the associated administrative procedures accepted by the JAA. In order to change to another variant of the aeroplane within one type rating, differences or familiarisation training is required.

FCL 1.221 High performance single pilot aeroplanes

(Modified by decree of 27 July 2006)

(a) Criteria.

For the establishment of a class or type rating of a single-pilot aeroplane designated as high performance, all the following shall be considered:

(1) type of power plant;

(2) provision and capabilities of airframe systems;

(3) cabin pressurisation;

(4) capabilities of navigation systems;

(5) performance both airfield and en route;

(6) handling characteristics.

(b) Listings.

Aeroplanes designated as high performance shall be listed as such in the associated administrative procedures within the relevant class or type rating list using the annotation HPA.

FCL 1.240 Type and class ratings – Requirements

(Modified by decree of 30 November 2004)

(a) General:

[…]

(3) An applicant for a class rating for a class of aeroplanes shall comply with the requirements set out in JAR–FCL 1.260, 1.261(a), (b) and (c) and 1.262(a), and if applicable FCL 1.251;

[…]

(end of amendment of 30 November 2004)

[…]

FCL 1.251 Type, class ratings for single pilot high performance aeroplanes – Conditions

(See Appendix 1 to FCL 1.251)

(a) Pre-requisite conditions for training:

An applicant for a first type or class rating for a single-pilot high performance aeroplane (HPA) shall:

(1) have at least 200 hours total flying experience;

(2) have met the requirements of FCL 1.255 or 1.260, as appropriate; and

(3) (i) hold a certificate of satisfactory completion of a pre-entry approved course in accordance with Appendix 1 to FCL 1.251 to be conducted by a FTO or a TRTO; or

have passed at least the ATPL(A) theoretical knowledge examinations in accordance with FCL 1.285; or

hold a valid ICAO ATPL(A) or CPL/IR with theoretical knowledge credit for ATPL(A);

(b) The holder of a licence issued by a JAA Member State which includes a class or type rating for a high performance single pilot aeroplane shall be credited with the theoretical knowledge requirement of paragraph (a)(3) above when that rating is transferred to a FCL licence issued by the State.

Appendix 1 to FCL 1.251
Course of additional theoretical knowledge for a class or type rating for high performance single-pilot aeroplane

High performance aeroplane training
1 The aim of the theoretical knowledge course is to provide the applicant with sufficient knowledge of those aspects of the operation of aeroplanes capable of operating at high speeds and altitudes, and the aircraft systems necessary for such operation.

[…]

Course syllabus

(5) There is no mandatory minimum or maximum duration of the theoretical knowledge instruction, which may be conducted by distance learning. The subjects to be covered in the course and written examination are shown in the accompanying table. The knowledge objectives are those defined for the ATPL (A).
Syllabus content is a general indication of areas to be covered and examination content should cover all subject numbers irrespective of their relevance to any specific type or class of aeroplane.
[…]

Subject reference	Programme content
021 00 00 01	*AIRFRAME and SYSTEMS, ELECTRICITY, MOTORISATION, EMERGENCY EQUIPMENT - AIRCRAFT*
021 02 02 01 *to* *021 02 02 03*	*General remarks - alternating current* *Generators* *Distribution of alternating power*
021 01 08 03	*Pressurisation (piston engines - air conditioning systems)*
021 01 09 04	*Pressurisation (turbojet and turbo-propeller aircraft - air conditioning systems)*
021 03 01 06 *021 03 01 07* *021 03 01 08* *021 03 01 09*	*Piston engines - engine performance* *Power increasing systems (supercharging/turbo)* *Fuel* *Mixture*
021 03 02 00 *to* *021 03 04 09*	*Turbine engines*
021 04 05 00	*Oxygen equipment aboard the aircraft*
032 02 00 00	*MULTI-ENGINED AIRCRAFT - PERFORMANCE CLASS B*
032 02 01 00 *to* *032 02 04 01*	*Performance of uncertified multi-engine aircraft according to CS-25 conditions*
040 02 00 00	*HUMAN PERFORMANCE*
040 02 01 00 *to* *040 02 01 03*	*Basics of physiology in flight* *and* *the high altitude environment*
050 00 00 00	*METEOROLOGY - WINDS AND DANGEROUS PHENOMENA IN FLIGHT*
050 02 07 00 *to* *050 02 08 01*	*Jet-streams* *Clear air turbulence* *Stationary waves*
050 09 01 00 *to* *050 09 04 05*	*Dangerous in-flight phenomena* *Icing and turbulence* *Storms*
062 02 00 00	*ELEMENTARY PRINCIPLES OF RADAR*
062 02 01 00 *to* *062 02 05 00*	*Elementary principles of radar* *On-board weather radar* *Secondary surveillance radar*
081 00 00 00	*AIRCRAFT - PRINCIPLES OF FLIGHT*
081 02 01 00 *to* *081 02 03 02*	*Transonic aerodynamics* *Mach number / shock waves* *Buffeting margin / lift ceiling*

FCL 1.261 Type and class ratings – Knowledge and flight instruction

[…]

(a) Theoretical knowledge instruction and checking requirements

(1) An applicant for a class or type rating for single- or multi-engine aeroplanes shall have completed the required theoretical knowledge instruction (see Appendix 1 to FCL 1.261(a) and demonstrated the level of knowledge required for the safe operation of the applicable aeroplane type.

[…]

(b) Flight instruction

(1) An applicant for a class/type rating for single-engine and multi-engine single-pilot aeroplanes shall have completed a course of flight instruction related to the class/type rating skill test

[…]

(c) Conduct of training courses

(1) Training courses for the above purpose shall be conducted by a FTO or a TRTO. Training courses may also be conducted by a facility or a sub-contracted facility provided by an operator or a manufacturer or, in special circumstances, by an individually authorised instructor.

(2) Such courses shall be approved by the Authority) and such facilities shall meet the relevant requirements of Appendix 2 to FCL 1.055, as determined by the Authority. For Zero Flight time Training (ZFTT) see Appendix 1 to FCL 1.261 (c)(2)).

(3) Notwithstanding paragraphs (c) (1) and (2) above, training courses for a single engine aeroplane class rating or touring motor glider class rating may be conducted by an FI or a CRI.

[…]

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