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Swiss Accident Investigation Board SAIB

Aviation Division

Final report No. 2148 by the Swiss Accident Investigation Board SAIB

On potential risks of ballistic parachute systems (BPS) in aircraft to rescue and investigation crews

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General notes on this report

This report contains the Swiss Accident Investigation Board (SAIB)'s final conclusions on the effects of fitting aircraft with ballistic parachute systems (BPS).

Under Art. 3.1 of the 10th edition of Annexe 13 (effective 18 November 2010) to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Aviation Law, the sole purpose of the investigations is to prevent accidents and serious incidents. Air accident investigations expressly exclude considering the circumstances and causes in legal terms: so it is not the purpose of this report to establish guilt or settle any liability issues.

These matters must be taken into consideration if using this report for any purpose other than to prevent accidents.

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1 Background

Preamble

This report is aimed at the supervisory authorities, manufacturers and rescue services. The implementation of certain recommendations and suggested procedures will be country-specific due to different local legal regulations.

The practicality and effectiveness of the proposed recommendations and procedures should be assessed by the specialists of the respective rescue and investigation organisations.

1.1 Introduction

Ballistic Recovery Systems Inc., or BRS, was founded in the USA in 1980.

This company manufactures recovery systems which were used mainly in ultralight aircraft to start with.

Ballistic Recovery Systems Inc. in collaboration with *Cirrus Design* developed the first ballistic parachute recovery system in 1998, fitted and approved in the USA as part of the Cirrus SR20 aircraft.

Today, there are several companies manufacturing recovery systems for different types of aircraft. These systems all work on the same principle.

1.2 Recovery systems in brief

With all these systems, in an emergency, a solid-fuel rocket can deploy a packed parachute mounted on or in an aircraft. When the parachute deploys, the aircraft and its occupants float down to earth (see section 2.1).

These recovery systems are called ballistic parachute systems.

In the report that follows, ballistic parachute systems are referred to as 'BPS' for short, and aircraft equipped with them as 'BPS aircraft'.

The rocket fuels used are explosives.

1.3 Manufacturers of BPS

There are around 20,000 ballistic parachute systems by different manufacturers in use worldwide (ICAO 2005).

There are eight manufacturers the SAIB is aware of:

• Pioneer Aerospace	www.pioneeraero.com
• *Second Chantz*	www.secondchantz.com
• *Advanced Ballistic Systems*	
• Galaxy	www.galaxy.lead-crm.eu
• GQ *Security*	www.skydiveky.com
• *Ballistic Recovery Systems* – BRS *Inc.*	www.brsparachutes.com
• Magnum *Ballistic Parachute*	www.magnumparachutes.com
• MVEN Ukrainian	MVEN Recovery System for Air Vehicles RSV Patrice-Lumumba-Str. 4 420141 Kazan, Russia

1.4 Accidents involving BPS aircraft in Switzerland

There have been three accidents investigated involving BPS aircraft in Switzerland to date:

- Accident in the Gotthard Pass involving Cirrus SR20 aircraft HB-KHA, 2 July 2006

  On 2 July 2006, pilot error resulted in Cirrus SR20 aircraft HB-KHA hitting the ground around 100 m below the head of the pass, in the Val Tremola area. The two occupants were seriously injured, but managed to escape from the wreckage of their own accord. The aircraft was destroyed, but did not catch fire.

  The aircraft owners rang the lead investigator, saying the aircraft was BPS-fitted: they said there was no risk of triggering the system provided no-one pulled the BPS release handle. A helicopter carried the aircraft away, unaware of the risk, and it was put in a hangar at Ambri airfield.

  It was not until 3 July that the lead investigator contacted Cirrus, the manufacturers. They told him not to touch the wreckage until a Cirrus specialist disarmed the BPS. This specialist arrived at Ambri airfield on 4 July.

- Accident involving Cirrus SR22 aircraft N467BD, Zurich Airport, 22 October 2008

  Four dead

  Soon after the accident was reported, the SAIB staff member on watch realised from the aircraft model that it was fitted with BPS. On consulting the emergency rescue forces, it was found this recovery system had very probably not been triggered, either during the flight or when the aircraft hit the ground. The rescue forces were not aware of the risks a still live BPS might involve at the time, but were told not to try deactivating it.

  As there were no specialists who could have disarmed the system on hand in Europe at the time, the aircraft manufacturers immediately sent an expert, who arrived in Zurich the following day. Meanwhile, the Airport fire brigade had recovered the aircraft, with its system still live, of their own accord. Salvaging the wreckage, which was near the final approach to runway 14, was at the Airport's own risk, and was done with the aim of clearing runway 14 so it could be used again as soon as possible. The aircraft manufacturer's expert then disarmed and dismantled the pyrotechnic BPS components from the salvaged wreckage.

- Accident of 6 August 2009, aircraft MCR-4S 2002 F-PEPU at Samedan.

  On 6 August 2009, at 14.14, a Dyn'Aero MCR-4S 2002 aircraft, F-PEPU, with a special airworthiness certificate for class 2 kit-built aircraft, took off from Samedan airport. The pilot failed to take off properly, and the aircraft hit the ground. It was equipped with BPS. To avoid the recovery system being set off by handling the wreckage, it had to be disarmed before any salvage or investigation work could start.

  Nothing was found in the wreckage indicating how to disarm the BPS. The instructions glued to the outside of the fuselage should have led to the BPS manufacturers in the USA being contacted, but no-one could be reached there.

The fuel tanks were damaged in the impact, and the AVGAS escaping as a result meant there was a fire and explosion risk at the scene of the accident. The wreckage could not be salvaged until the next morning.

1.5 Reasons behind the investigation

BPS contain explosives, as was said above.

SAIB has become aware of the safety precautions the manufacturers demand for handling a wreckage after an accident.

What SAIB class as a safety risk is that BPS cannot be disarmed with sufficient safety by rescue crews or fire fighters before rescuing the occupants. To date, in Switzerland, specialists from the manufacturer had to be called in for this purpose, which caused delays. This is out of line with current rescue procedures.

If the system is not disarmed fully or at all, this could put the lives of the occupants and/or emergency rescue services at risk when evacuating or recovering the wreckage.

1.6 Purpose of the investigation

SAIB has set itself the aim of analysing BPS and suggesting operating and rescue instructions in line with current rescue procedures.

1.7 Investigation report

Section 1 sets out the facts as the situation currently stands and the reasons for the investigations.

Section 2 looks at BPS, what their individual components do, the rockets used and the explosives they contain.

Section 3 sets out the precautionary measures to be taken in connection with BPS aircraft.

Section 4 lists the SAIB's recommendations to be followed in the event of an accident or fire involving BPS aircraft.

1.8 Aircraft and aircraft classes equipped with BPS

1.8.1 Register of BPS aircraft

The Federal Office of Civil Aviation (FOCA) in its capacity as regulating authority does not keep any register of BPS aircraft: that is to say, no-one knows which aircraft registered in Switzerland are fitted with BPS.

1.8.1.1 Cirrus SR 20 and SR 22

Aircraft of this type are fitted with a ballistic recovery system, the *Cirrus Airframe Parachute System* (CAPS), by the manufacturer.

The Cirrus SR22 flight manual states amongst other things:

“ Section 3

Emergency procedures

Spins

The SR22 is not approved for spins and has not been tested or certified for spin recovery characteristics.. The only approved and demonstrated method of spin recovery is activation of the Cirrus Airframe Parachute System (CAPS). (……) “

The BPS therefore forms part of the aircraft certification, and the aircraft must not fly without it.

1.8.1.2 Ecolight

In a circular of 5 November 2002, the Swiss Federal Department of the Environment, Transport, Energy and Communications announced it had decided to authorise *Ecolight* aircraft in Switzerland. This category does not include ultralight aircraft (ULA).

Switzerland's valid Ecolight standards allow for a simplified aircraft licence. In response, the licensing authorities have specified a maximum take-off weight for single-seaters of 300 kg and two-seaters of 450 kg, and allowed an additional all-in weight of 22.5 kg to carry a BPS.

1.8.1.3 Very Light Aircraft

The maximum weight allowed for *Very Light Aircraft* or VLA, is set at 750 kg. The licensing authorities have not allowed any additional weight to carry a BPS.

Many VLAs are *Ecolight* aircraft which meet VLA standards, however.

1.8.1.4 Cessna 172 and 182 models

One BPS manufacturer has had a *Supplement Type Certificate* or STC produced which allows Cessna 172s and 182s to be retrofitted with BPS. With these models, carrying a BPS is merely an additional safety feature, and is not part of the certification.

1.8.1.5 "Experimental class" aircraft

Some "experimental class" aircraft are equipped with BPS. Such aircraft are normally made by their owners, under the supervision of the appropriate authorities.

1.9 Documents used

1.9.1 Handling explosives – legal framework and guidelines

The SAIB has considered the following legal framework and guidelines for the present analysis:

- Swiss Federal explosives law 941.41
- Swiss explosives regulations 941.411
- Explosives record-keeping guidelines
- ICAO Doc 315 "*Hazards at Aircraft Accident Sites*"*:*

1.9.2 Documents

The descriptions and analyses this report contains are based amongst others on the documents and sources below:

• Armasuisse report: *Thermal behavior of BRS 440 and BRS 601 rockets:*	Annexe 1
• SAIB – Cirrus file memo of questions and answers, dating 1 February 2008:	Annexe 2
• *Safety Recommendation*, *National Transportation Safety Board* Report of 29 April 2004, Ref. A-04-36 through -41:	Annexe 3

• *BRS Ballistic Parachutes: Information for Emergency Personnel:*	Annexe 4
• *Aviation safety recommendations and advisory notices Output No R20040095 (Australian Transport Safety Bureau):*	Annexe 5
• Transportation Safety Board of Canada: Aviation reports – 2010 – A10O0101:	Annexe 6
• ICAO State letter "Rocket deploy parachute":	Annexe 7
• *Aerodrome Safety Circular – Transport Canada:*	Annexe 8

2 Scope of these investigations

For reasons of time and economy, SAIB has restricted itself to analysing the BPS made by *Ballistic Recovery Systems Inc.* when producing this report.

2.1 What are ballistic parachute systems?

BPS are emergency rescue systems which enable a whole aircraft with its occupants to be parachuted to the ground.

They comprise a parachute (packed), a rocket with trigger and firing systems and the connecting lines and carrier harness involved.

The parachute, carrier harness and some of the suspension lines are packed in or on the aircraft. The parachute is connected permanently to the suspension points on the aircraft structure via the carrier harness and suspension lines.

Suspension lines may be made of plastic or steel. They are often laminated or glued onto the surface of the fuselage, and are released from the fuselage structure as far as the actual suspension points themselves when the parachute opens.

The pilot releases the rescue parachute via a handle and the release cable. Pulling the handle fires a small solid-fuel rocket, which fires off from the aircraft with the parachute package on a short line. If the BPS is inside the fuselage, the rocket passes through the fuselage itself first, pulling the parachute package with it.

Where the rocket is fired from, and/or where the firing aperture is, varies from one aircraft type to another. The direction the rocket takes when fired may be up to 15° from the angle at which it was originally fitted.

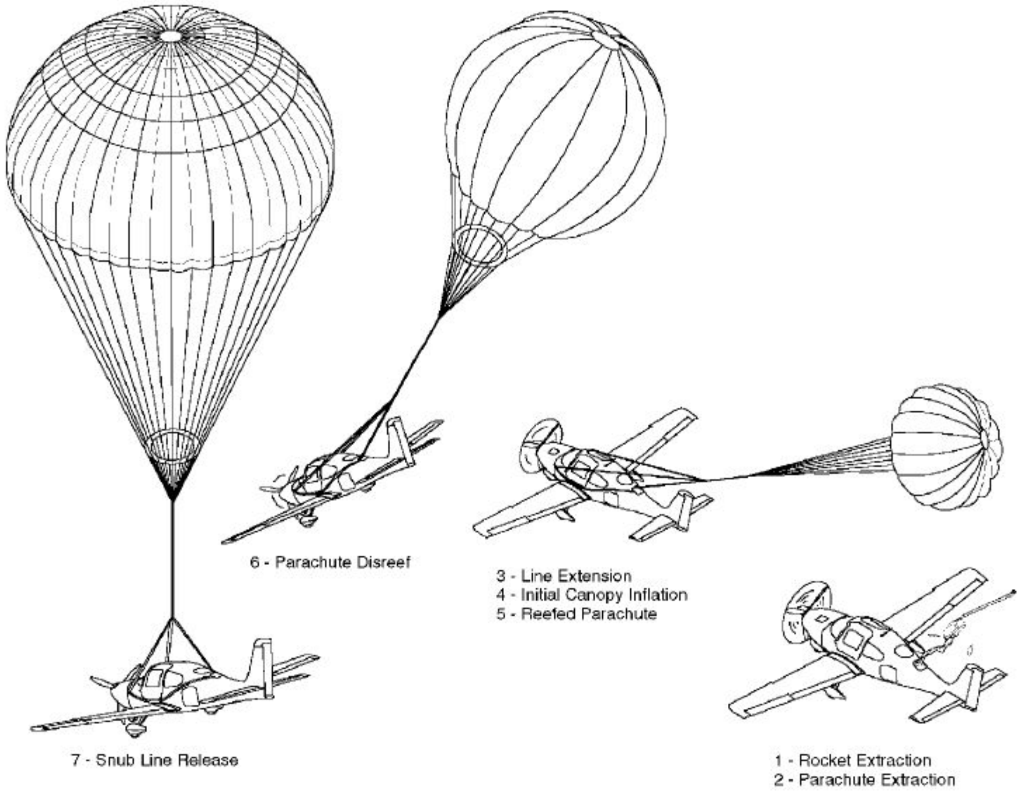


Fig. 1: Parachute opening – CAPS (*Cirrus Airframe Parachute System)*

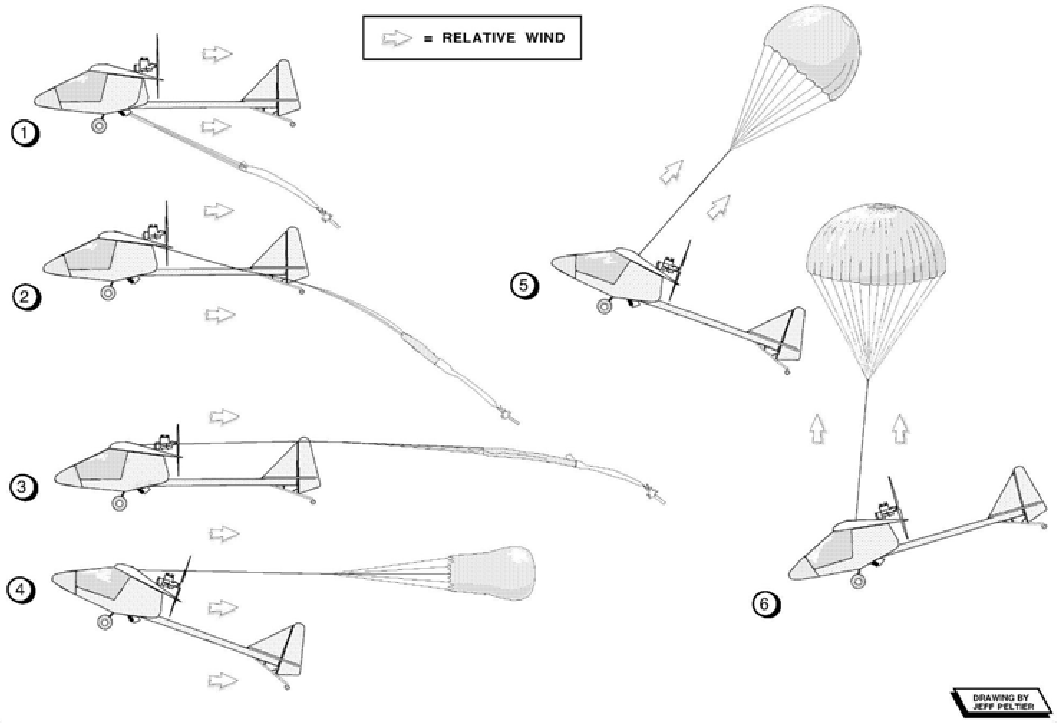


Fig. 2: BPS parachute opening in a VLA (Very light aircraft)

2.1.1 Rocket

The rocket consists of the guide tube, the primer mixture, primary booster material and the solid-fuel rocket. The solid-fuel rocket is often referred to as the rocket motor, and is the component which leaves the aircraft once ignited, taking the parachute pack tow line with it.

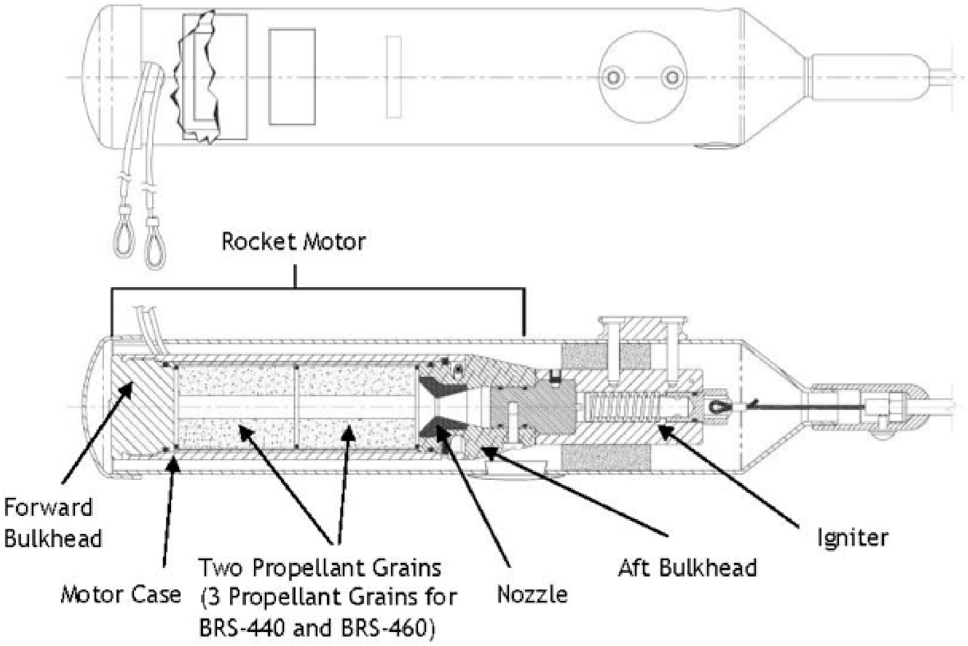


Fig. 3: Cross-sectional drawing of rocket

Both rocket motor and igniter unit contain explosives.

The rockets used vary in size, depending on the size, model and take-off weight of the aircraft concerned.

The rocket is mounted permanently in or on the aircraft: that is to say, it is bolted to the aircraft structure.

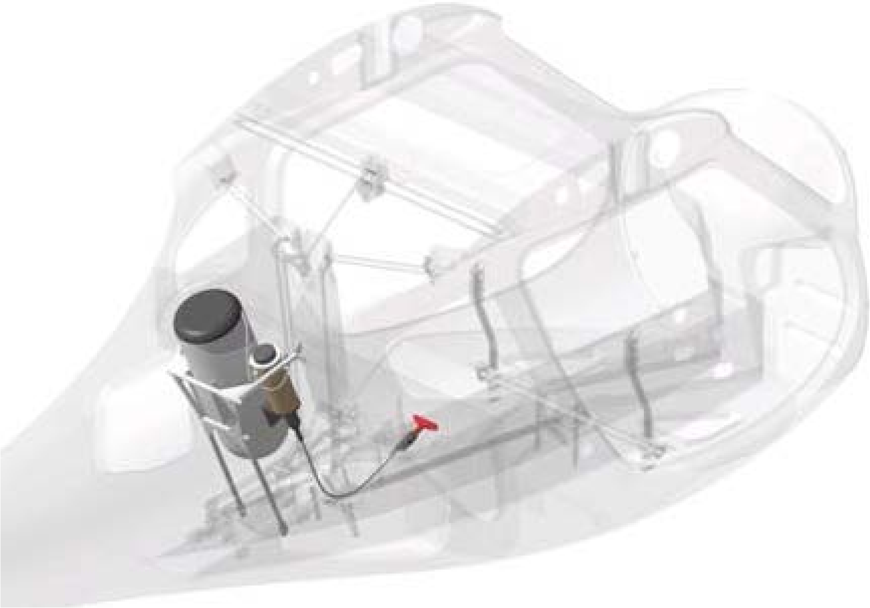


Fig. 4: Typical BPS installed

The flight manual states that the pilot must activate the BPS, i.e. the rocket, when preparing to take off, so they merely need to pull the handle to fire the rocket in an emergency.

Fig. 5: BPS release handle

The igniter unit and guide tube remain bolted to the structure once the rocket is fired.

2.1.2 Parachute

There are three main types of parachute packs BPS use:

a) Canister pack: the parachute is folded up tightly in a cylindrical container. The short rocket motor line connects to the parachute pack under the container cover. When the rocket is fired, the container cover comes off, and the rocket then pulls the parachute pack out of the container. The pack is weatherproofed.

Fig. 6: Parachute packed in canister

b) VLS pack: with a vertical launch system, the parachute is folded up into a trapezoidal square plastic container. With VLS systems too, the rectangular container cover comes off when the rocket is fired and the parachute is pulled out of the pack. The VLS system is only suitable if the rocket leaves the aircraft vertically; it is used mainly in aircraft in which the parachute pack is mounted outside the aircraft, such as on the wing, for example. The pack is weatherproofed.

Fig. 7: Parachute packed in rectangular container (VLS)

c) Soft pack: with packs like this, the parachute is folded up tightly in a rectangular bag with a Velcro seal. With this system, again, the Velcro seal opens when the rocket is fired, pulling the parachute pack out of the bag. Soft packs are not weatherproof.

Fig. 8: Parachute packed in bag with Velcro seal

Some BPS have a suspension line packed with the parachute with a line cutter with a small amount of explosive. This line cutter ensures that one of the suspension lines is lengthened some time after the parachute is launched, so the aircraft is suspended well balanced from the parachute.

2.1.3 Actuator and igniter unit

The igniter is triggered mechanically. The igniter consists of the plunger, a steel spring, a firing pin actuator to which the release cable is attached and two percussion cups. Each percussion cup has its own firing pin and primer which ignites the primary booster at the end of the igniter unit. In standby (normal) mode, the plunger and firing pin actuator are connected to one another by two small steel balls held in position by the inside wall of the igniter body.

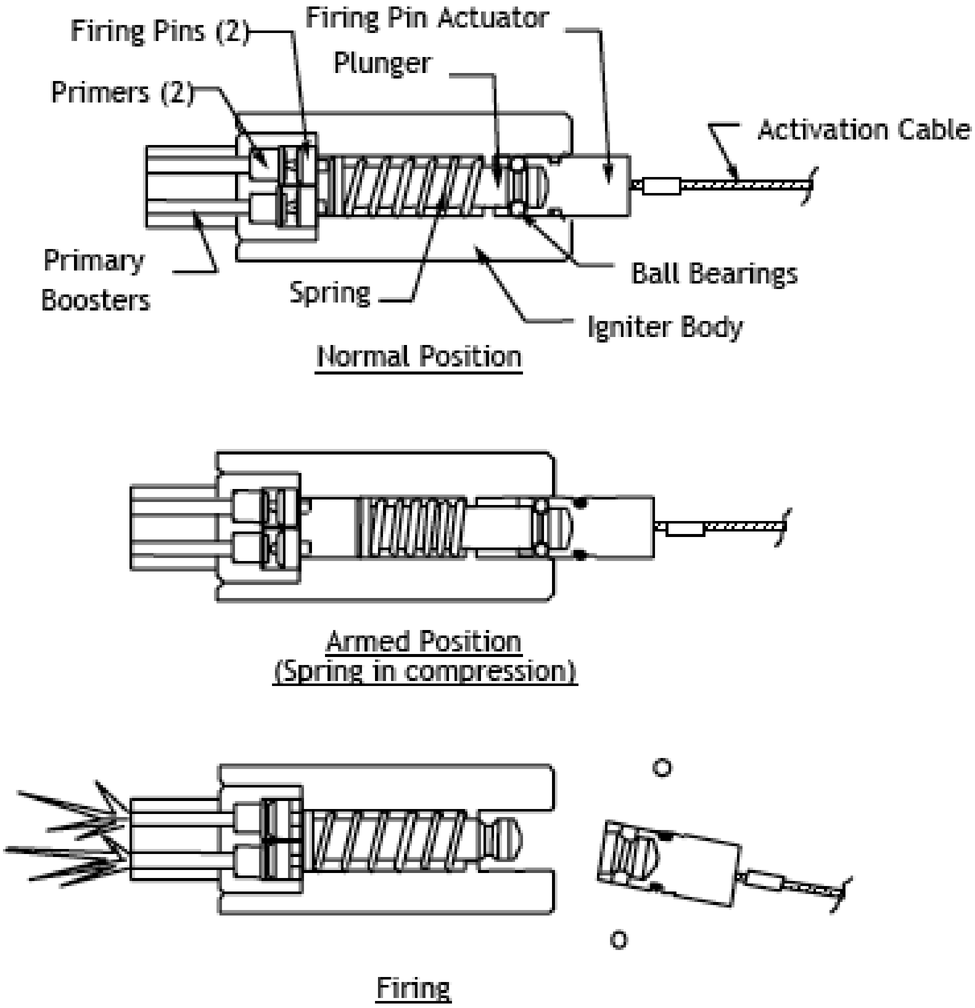


Fig. 9: How the release and igniter unit work

Pulling the release handle which is connected to the activation cable compresses the spring and cocks the plunger; the firing pin actuator is pulled out of the igniter body. Once the firing pin actuator has travelled approx. 13 mm, the steel balls fall out, releasing the pre-armed plunger.

The plunger strikes the two firing pins, which in turn ignite the primers and the primary boosters.

In the normal position, the firing pin is unarmed.

2.1.4 Rocket motor

These units may vary in size, but their structure and function are similar.

The rocket motor consists of a tube (usually metal) closed at its upper end containing the rocket fuel. At its lower end, the tube is partly sealed by a permanently mounted ring, which serves as a jet for the combustion gases. The bottom of the rocket motor rests on the igniter unit, which triggers firing the rocket through the jet (see diagram, actuator and igniter unit).

Fig. 10: Stripped down rocket motor

When it is ignited, the rocket motor fires out of the rocket guide tube, pulling the tow line and the parachute pack connected to it with it. The rocket guide tube and release/igniter unit remain in or on the aircraft.

Fig. 11: Rocket motor with release/igniter unit

2.2 Investigating the BPS rockets

SAIB has found that all investigations and reports in connection with accidents involving BPS aircraft to date focus mainly on the risks such recovery systems involve and state that extreme caution is required when handling them mechanically.

They say little about how the rockets behave thermally in the event of fire, or about how sensitive the explosives they contain are.

SAIB has therefore decided to commission studies into how the rockets (guide tube, igniter unit and rocket motor) behave thermally and how safe the explosives they contain are to handle.

Our studies covered two types of BPS rockets used by the company *Ballistic Recovery Systems Inc.*

The two types of rocket studied were as follows:

BRS 440	Suitable for aircraft up to 475 kg MTOM
Rocket dimensions, incl. igniter unit:	Diameter approx. 55 mm; length approx. 360 mm
Minimum burn time:	1.25 sec
Minimum thrust:	87 lbs; 386 Newton
Rocket motor dimensions:	Diameter approx. 45 mm; length approx. 250 mm
Rocket motor weight incl. casing:	Approx. 0.7 kg
Of which net explosive weight:	204.6 g

BRS 601	Suitable for aircraft up to 600 kg MTOM
Rocket dimensions, incl. igniter unit:	Diameter approx. 75 mm; length approx. 325 mm
Minimum burn time:	1.70 sec
Minimum thrust:	135 lbs; 600 Newton
Rocket motor dimensions:	Diameter approx. 64 mm; length approx. 175 mm
Rocket motor weight incl. casing:	Approx. 1 kg
Of which net explosive weight:	374.6 g

SAIB knows of systems in which the maximum rocket thrust is 1470 N.

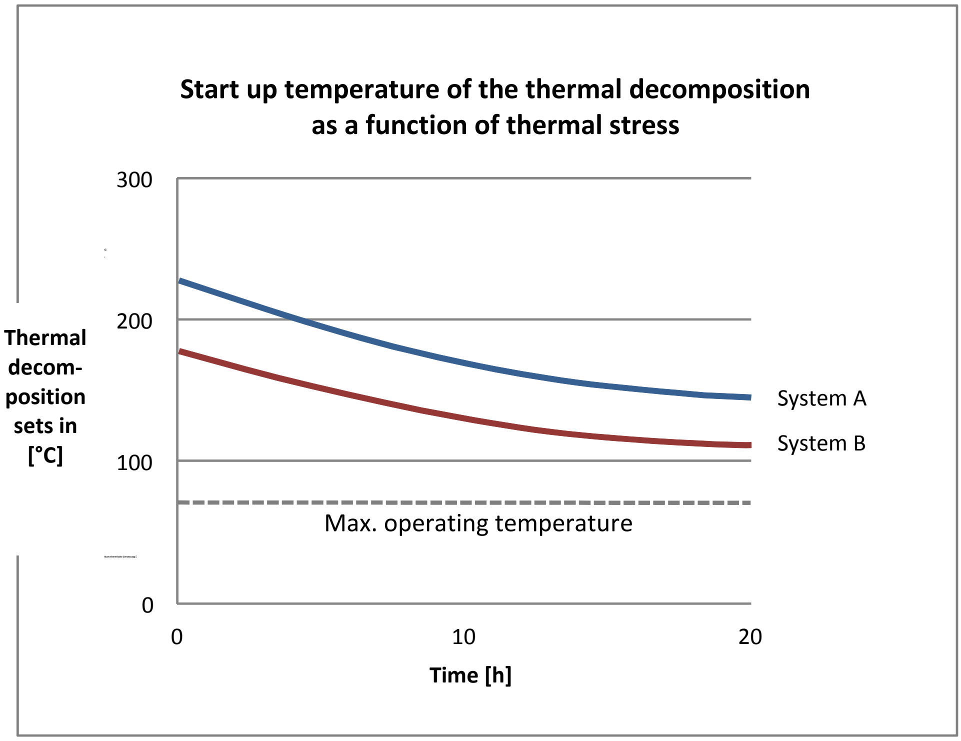
2.2.1 How explosives behave under heat: some basic notes

Maximum temperatures at which explosives may be stored and operated and their maximum shelf lives are stated by the manufacturers.

The maximum storage and/or operating temperature is typically 60-70 °C. If this temperature is exceeded briefly, that does not normally present any safety risks; but if the system is stored for any length of time (weeks or even months) at maximum temperature, or this is often exceeded, this accelerates the natural ageing of the explosives contained. This reduces their thermo-mechanical stability and so reduces their working life.

Explosives decompose when heated strongly, in a fire, for example, releasing energy in the process. The reaction temperature at which thermal decomposition sets in depends very much on what kinds of explosives are involved and how long they are exposed to thermal stresses for prior to the event. For commonly available rocket propellant powder, this reaction temperature is 180°-220 °C, depending on the components involved. If it is exposed to thermal stress for any length of time beforehand, such as some hours close to a fire, it is 60°-80 °C less.

If explosives inside a rocket motor have already started decomposing thermally once exposed to heat, they may go off suddenly of their own accord even if they are cooled from outside. This can happen anything up to more than an hour later, depending on what kind of rocket fuel is involved and what conditions are like on site.



Explosives age naturally in chemical and physical terms, which may make them unreliable and more dangerous to handle over time, which is why the manufacturers always state a specific guaranteed shelf time for explosive-based systems.

2.2.2 How rockets behave when the ambient temperature rises rapidly: simulating a fully developed fire (Fast Cook Off - FCO test)

This test involved exposing four complete rocket assemblies, i.e. guide tubes, igniter units and rocket motors, to a hot flame at approx. 1000 °C, resulting in the igniter units and the rocket motor inside the guide tubes heating up rapidly.

Both the BRS 440 rockets tested reacted violently after 129 and 145 sec. respectively, in that the rocket motors burned off fast and exploded. The primer mixture and the primary booster material in one rocket, failed to respond. Both rockets mounted on the test bench shot the rocket motor end caps off at high velocity. With one of the rockets tested, large quantities of unreacted rocket fuel were left behind.

Both the BRS 601 rockets tested reacted violently after 43 and 69 sec. respectively, by burning off fast and exploding. All the explosives in the igniter unit and rocket motor reacted completely. The force of the reaction tore the rocket motor being tested off its mountings, and it penetrated 2 mm thick aluminium target plate 2 m away.

The second rocket test results were comparable with those of the first.

2.2.3 How rockets behave when ambient temperatures rise slowly: simulating a fire in close proximity (Slow Cook Off - SCO test)

In this test, the rocket motor without the igniter unit or guide tube was heated slowly in an insulated container. Prior to the test, 14 g of rocket fuel was taken from the rocket motor for further testing; i.e. the rocket motor contained only 200 g of gross rocket fuel when tested, instead of the usual 214 g. For the purposes of the test, the rocket motor nozzle was sealed tight with a 10 mm thick aluminium disc to simulate plugging as the igniter unit would.

A heating rate of 15 °C per hour was used in this test.

In this experiment, the reaction occurred after heating for over 10 hours at 207 °C.

This reaction was an explosion, which burst the aluminium rocket motor casing into a number of flying fragments.

Fig. 12: Test results and fragments

2.2.4 DSC Analysis *(Differential Scanning Calorimetry)*

This test, conducted on small quantities of test material, was designed to study how these substances behave when heated, such as from what temperature explosives decompose thermally and how they react to heat.

The temperature at which thermal decomposition occurs and the thermal reaction sequence depend on the rate at which the explosive is heated.

The results of the DSC tests conducted were as follows:

1. The explosive (propellant) from the rocket motor studied was stable up to around 150 °C (heating rate of 15 °C per hour).

   Explosives subjected to ageing and those from other manufacturers may have lower limits of stability.

2. The rocket motor explosive had the lowest limit of stability of the materials studied (primer mixture, primary booster material and rocket motor explosive).
3. Compared with the rocket motor explosive, the stability limit of the primer mixture was around 40 °C higher and that of the primary booster was around 80 °C higher.

From the DSC test results, we can conclude as follows:

Unless a BPS rocket is heated to within range of the stability limit of the rocket fuel, spontaneous reactions, such as fast burn-off or explosion, can be ruled out.

It is still possible, however, that handling the firing pin mechanically, such as while rescuing people in an air accident, could fire the rocket accidentally.

2.2.5 Sensitivity to electrostatic discharge

This test involved studying the three explosives from the rocket motor, primary booster and igniter (primer mixture).

Loose test material was exposed to an electrostatic discharge, noting at what discharge level it started responding.

This test showed none of the three explosives studied is sensitive to electrostatic discharge from human bodies.

The minimum level at which they started reacting was measured with the igniter material at an electrostatic discharge of 560 mJ.

In practice, the average person is believed to give off 10 times less.

2.2.6 Sensitivity to friction and impact

These two tests were conducted on material from the rocket motor only.

In the friction test, loose material is rubbed between two rough surfaces under load. The load is increased in stages to find at what load the material starts responding.

The impact test involves hitting loose material with a firing pin. The impact energy is generated by dropping a weight. The impact energy is increased in stages, seeing at what energy level the initial reaction occurs.

The tests conducted showed initial reactions of 96 N in the friction test and 6 J in the impact test. From these test results, we can say the material studied is moderately sensitive to friction and impact.

The rocket fuel and primary booster material of the BRS 440 contain metallic magnesium powder. If these explosives are put out with water, this generates hydrogen, which can cause an explosive gas reaction.

3 Safety precautions recommended for BPS aircraft

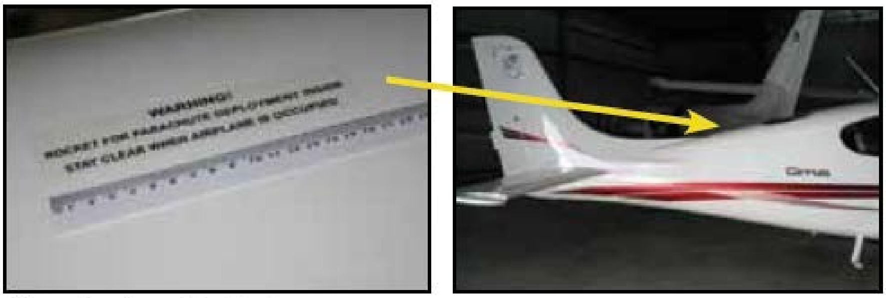
The recommendations in this report are aimed at the supervisory authorities, manufacturers and rescue services.

The situational feasibility and effectiveness of these recommendations and procedures have to be assessed by the specialists of the organisations concerned.

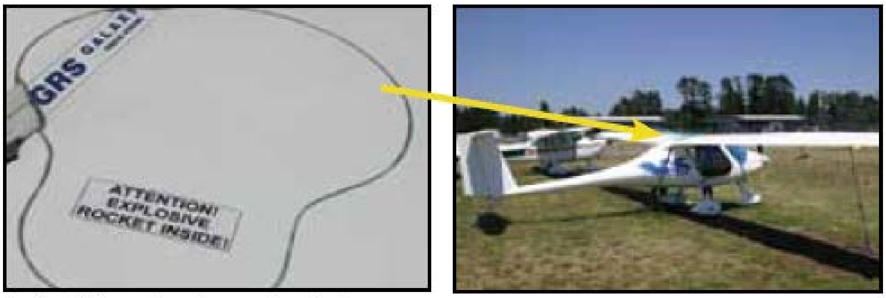
3.1 Identifying BPS aircraft

3.1.1 Safety deficit

BPS aircraft are currently identified by a small triangular decal about 40 mm long on a side. This decal warns of the risks a BPS can involve, and tells emergency rescue crews to call the telephone number in the USA printed on the decal before starting rescue work on the wreckage.



Cirrus aircraft warning decal



Pipistrel Virus aircraft warning decal

Fig. 13: Current BPS aircraft IDs

3.1.2 Safety recommendation no. 444

Above all, BPS aircraft should be clearly and uniquely identifiable as such. The aircraft must be marked by a large triangular hazard warning decal approx. 40 cm on a side on the fuselage. This decal warns in prominent colours that the aircraft has a BPS installed in or on it which may put rescue workers at risk, and that, before starting rescue work, they must call REGA's telephone number printed on the decal which will tell them how to proceed. Other precautions required are:

- The location of the rocket firing aperture must be indicated on the aircraft shell.
- The shell must be marked in such manner that rescue workers can see where they can cut the fuselage open.

If they are in any doubt as to whether a given aircraft has a BPS on board, rescue workers must assume it has.

3.2 BPS aircraft in review

3.2.1 Safety deficit

When air accidents are reported today, there is no straightforward way of knowing whether BPS-equipped aircraft are involved.

3.2.2 Safety recommendation no. 445

The Federal Office of Civil Aviation (FOCA)'s website should add to the details displayed in the section on aircraft registration whether an aircraft is equipped with BPS or not.

If an accident is reported, SAIB/REGA staff could then check whether BPS-equipped aircraft are involved in the accident and highlight the risks they present right from when they pass on the accident report.

3.3 Temperature monitoring BPS aircraft

3.3.1 Safety deficit

BPS rockets exposed to slowly rising temperatures (SCO) may explode, as section 2.2.3 shows.

The same applies if an aircraft is exposed to heat close to a fire.

3.3.2 Safety recommendation no. 446

3.3.2.1 BPS rocket

BPS rockets must be fitted with heat indicators as close to the rocket motor as possible (e.g. Telatemp). These heat indicators change colour if they exceed a given temperature.

Checking the heat indicators must be included in aircraft ground checklists, for example.

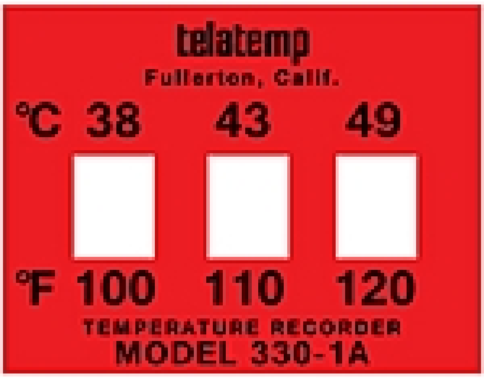


Fig. 14: Telatemp temperature sensor strip

3.4 Shelf life check

BPS components have a limited shelf life.

This shelf life is something BPS manufacturers need to specify, allowing for storage and/or working temperatures also. This must be stated in maintenance documents as well.

Explosives exposed to temperatures in excess of the maximum permitted storage or operating temperature for any length of time age faster, making them more unstable (section 2.2.1).

3.4.1 Safety deficit

Residual shelf lives are currently not checked systematically; nor are any checks made to see whether maximum permitted storage/working temperatures are observed.

3.4.2 Safety recommendation no. 447

Checking the residual shelf life of a BPS must be included in aircraft checklists and/or maintenance schedules and in aircraft documents, allowing for whether maximum permitted storage/working temperatures are exceeded for any significant length of time.

3.5 Protecting BPS against being triggered accidentally

In BPS-equipped aircraft, the recovery system release mechanism is triggered by a handle and the release cable. The handle has to be pulled for approx. 13 mm to trigger the system. As an extra safety precaution, if an aircraft is not in use, the crew puts a pin in the handle to prevent accidental activation.

3.5.1 Safety deficit

The release mechanism handle is mounted in the aircraft cockpit. The release cable transmits releasing the recovery system to the igniter unit. The rocket and igniter unit are often mounted immediately behind the seats.

Rescue teams may pull this release cable accidentally and so set off the rocket, even if the handle is secured in place. This risk is even greater if the release mechanism was set under tension when the aircraft hit the ground.

Aircraft makers Cirrus suggest, in the event of an accident, that special pliers (Felco) be used to cut through the release cable as close to the igniter unit as possible.

The NTSB's report says even using special pliers to cut the release cable could be risky if the release cable is tugged slightly while cutting it.

3.5.2 Safety recommendation no. 448

BPS manufacturers should check whether a cutout system could be used to separate the igniter unit from the rocket.

3.6 BPS aircraft in hangars

If an aircraft hangar burns, there is a great risk that BPS aircraft will explode. The thermal tests show such aircraft may be life-threatening as far as the fire brigade is concerned.

3.6.1 Safety deficit

As things now stand, neither airfield managers nor their fire brigades know whether they have any BPS aircraft on their hands, and if so where.

3.6.2 Safety recommendation no. 449

3.6.2.1 Hangar plans

There must be a plan of the aircraft hangars at an airfield, in its control tower and/or the fire brigade crew rooms, which clearly marks the presence of any BPS aircraft.

3.6.2.2 Identifying hangars and monitoring temperatures

Hangars, which have BPS aircraft, must be identified clearly, so the callout crew can respond accordingly if a hangar fire breaks out.

Hangars must have maximum thermometers, so supervisors can check what temperatures have been reached.

3.7 Training

3.7.1 Crew training

3.7.1.1 Safety deficit

As the accident examples in section 1 show, aircraft pilots and owners had no idea what hazards BPS could involve.

3.7.1.2 Safety recommendation no. 450

The Federal Office of Civil Aviation should ensure that pilot training programmes include details of how BPS work.

3.7.2 Training emergency response and rescue crews

3.7.2.1 Safety deficit

As the accident examples in section 1.4 show, rescue/fire brigade crews did not take any safety precautions when working. Crews were neither informed nor trained.

The manufacturer’s suggestion if an accident occurs, to call a hotline number in the USA and ask to speak to a specialist, is impracticable. In an aircraft accident, those inside may be badly injured, and rescue crews have to be able to complete their work within a useful time.

3.7.2.2 Safety recommendation no. 451

All rescue services are to be trained on the potential risks of BPS.

For this, it is essential to distinguish between:

1. Training airport emergency response crews
2. Cantonal police, emergency ambulances and fire-fighters
3. Cantonal disposal crews via cantonal police
4. Search and Rescue (SAR) crews

4 What to do if there is an accident or fire involving BPS aircraft

The procedures in this report are aimed at the supervisory authorities, manufacturers and rescue services.

The situational feasibility and effectiveness of these recommendations and procedures have to be assessed by the specialists of the organisations concerned.

If an accident or a fire occurs in which BPS aircraft are involved, the rocket launch area MUST always be considered unsafe and/or hazardous. Safety and rescue services must avoid this area when approaching an aircraft.

4.1 Hangar fire

In this section, we assume there are no people to be rescued. Unlike with an air accident, this is not about rescuing people, but putting the fire out and clearing the area.

4.1.1 Safety deficit

Hangar fires can involve extreme temperatures in places. In that event, it is conceivable that aircraft which are not involved directly in the fire, but are fitted with BPS, would be exposed to heat. Such radiated heat may cause a BPS rocket to explode, as we explained in section 2.2.3 (SCO).

The emergency team leader to reach the scene of a fire must draw their team's attention to the potential hazards involved in dealing with BPS and repeat the risks.

As well as the usual safety precautions involved in connection with the various fuels and structural aircraft materials and the risk of the hangar collapsing, a number of other safety precautions are required, as follows:

- Check what temperatures have been reached in the hangar via the max. thermometer (see section 3.6.2.2)
- If there is no max. thermometer, the emergency leader can use the state of the aircraft in the hangar to estimate what temperatures have been reached.
- If temperatures reached were not estimated accurately or measured, it must be assumed that they were above 90 °C; procedures as set out in section 4.1.2.2 have to be followed.
- Keeping a safe distance from the aircraft concerned
- Ensure you have enough extinguishing materials and coolant; attention must be paid to the fact that rocket fuels and primary booster material may contain metallic magnesium powder. If this comes into contact with water, it produces hydrogen gas, which will act as an accelerant (explosion risk).

If you cannot estimate or measure the reached temperatures reliably, you must assume they have been over 90 °C, and proceed accordingly, as in section 4.1.2.2.

4.1.2 Safety recommendation no. 452

4.1.2.1 If the temperatures reached are less than 90 °C

If the temperatures the max. thermometer is showing are less than 90 °C, or it is safe to assume no temperatures in excess of 90 °C have been reached, the heat indicators on the rockets have to be checked taking appropriate precautions. If the heat indicators confirm no temperatures over 90 °C have been reached, the emergency services can switch to standard normal operating procedures.

4.1.2.2 If the temperatures reached are in excess of 90 °C

If temperatures in excess of 90 °C have been reached, or if it is assumed that high temperatures have been reached, the emergency team leader must assume there is a risk of the rocket exploding.

The emergency team leader must ensure that all parties involved remain at a safe distance, that the area of risk is cordoned off and that a disposal specialist is called in.

4.2 If a BPS aircraft is involved in an accident and then catches fire

4.2.1 Safety deficit

Rescue teams are currently unaware that, if a BPS aircraft is involved in an accident and catches fire, the BPS rocket may explode as a result of heat exposure. As we saw in section 2.2.3, if a rocket explodes, that could lead to flying metal fragments which could put the rescue teams' lives at risk. The US Federal Aviation Administration suggests keeping a safe radius of 300 ft (approx. 100 m) around a wreckage during recovery operations.

4.2.2 Safety recommendation no. 453

Aircraft involved in accidents which catch fire must be cooled intensively from a safe distance. That could prevent BPS rockets exploding as rescue teams approach wreckages.

4.3 If BPS aircraft are involved in accidents but do not then catch fire

4.3.1 Safety deficit

There is a major risk that rescuers trying to rescue those inside an aircraft may pull the handle or release cable accidentally, setting off the rocket and firing the parachute from the wreckage. That could result in rescue team members being hit by flying objects or the rocket's exhaust gases setting the wreckage on fire.

The solution suggested of blocking the release handle with a safety bolt is inadequate. The release cable could be under tension somewhere in the cabin or baggage compartment, pre-arming the firing unit firing pin; and relaxing the cable suddenly could cause the rocket to fire.

Splitting the release cable could be dangerous, as the FAA and NTSB documents state.

The same applies when servicing and repairing BPS aircraft as it is quite conceivable that a mechanic could set off a rocket by accident.

4.3.2 Safety recommendation no. 454

4.3.2.1 Blocking the release cable

One possibility would be to block the release cable as close to the igniter unit as possible. This could be done using crimp pliers, for example, crimping the release cable to the cable sheath and so blocking it.

4.3.2.2 Safety cover over rocket

Investigations should be made to see if a safety cover can be made, from a strong shielding material such as Kevlar, for example, which could then be put over the rocket before starting to work on an aircraft or wreckage. This would work rather like body armour: if the rocket went off accidentally, the safety cover would contain it.

4.4 Salvaging wreckages after accidents

Appropriate precautions and measures must be taken when salvaging the wreckage of a BPS aircraft in which the BPS is still live. If the wreckage is unstable mechanically, handling it may tension the BPS release cable and possibly set off the rocket.

A disposal squad must therefore be called in as a preliminary precaution when salvaging wreckage in which the BPS may be live.

Payerne, 27 August 2012 Swiss Accident Investigation Board

This final report was approved by the management of the Swiss Accident Investigation Board SAIB (Art. 3 para. 4g of the Ordinance on the Organisation of the Swiss Accident Investigation Board of 23 March 2011).

Berne, 11 June 2013

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armasuisse
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Annex 1

RESTRICTED

Final report - Analysis

Thermal behavior of BRS 440 and BRS 601 rockets

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Thun, 18-Oct-11

Summary

Small aircraft ballistic recovery systems are nowadays worldwide used and therefore it is crucial that the first responder teams know all possible hazards which can occur after an air crash. During the investigation of first accidents with aircrafts equipped with such systems, the Swiss federal bureau for air crash investigation (BFU) observed a leak of information especially concerning the thermal behavior of such ballistic rockets. On request and order of BFU, we have performed the present study which covers the investigation of the thermal behavior of two types of small aircraft ballistic recovery rockets and the sensitivity tests of the energetic materials contained therein.

The results show that these rocket motors can react violently in particularly in a slow cook off scenario with rapid ejection of individual heavy fragments. It is also possible that open energetic substances can remain at the place. First responder teams should know these hazards and should be trained to apply the corresponding counteractive measures.

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List of abbreviations

Abbreviation	Text
A	Pre-exponential factor
α	Reaction progress
AKTS	Advanced Kinetics and Technology Solutions Inc., CH-Sierre
AP	Ammonium Perchlorate
BFU	Swiss federal bureau for air crash investigation
BRS	Ballistic Recovery Systems, Inc
BP	Black Powder
DSC	Differential Scanning Calorimetry
Ea	Activation energy
FCO	Fast Cook-off
HTPB	Hydroxyl Terminated PolyButadiene
Mg	Magnesium
SCO	Slow Cook-off
STANAG	Standardization agreement
UVEK	Department of Environment, Transport, Energy and Communications
WTE	Science and Technology, Explosives, Effect and Protection
WTT	Science and Technology, Test Center

1 Introduction

1.1 Initial situation

The present investigation was performed on request and order from the BFU (Swiss federal bureau for air crash investigation) which belongs to the UVEK. By end of 2008 they informed us for the first time about safety concerns with Airplane Parachute Systems which contains energetic materials and which are increasingly deployed in Switzerland. In case of an air crash of a plane equipped with such a parachute system, reactive parts can remain in unsafe condition and the rescue teams needs to know all possible hazards to react appropriately. Especially in case of a fire the BFU is actually not documented enough about possible dangers from the different components and energetic substances involved.

The BFU purchased from the manufacturer 3 rockets BRS 440 and 2 rockets BRS 601 for the tests.

1.2 Purpose of assignment

The purpose of this study is to analyze the effects of direct thermal load and heat radiation which occurs during a fire on the BRS 440 and BRS 601 rockets and to determine the handling safety of the different energetic materials involved. Thereby the temporal development and the violence of reaction are of main interest.

1.3 Assigning organization and supporting services

This study was performed by armasuisse, Science and Technology according to the order from BFU, Nr. 2000013052, from June 21st 2001. The SCO and FCO were performed by WTT and all other analysis by WTE. The investigation is based on different documents which we got from BFU [1,2,3,4,5]

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2 Execution of the analysis

2.1 Procedure

The FCO and SCO experiments were performed at the Sprengbunker, laboratory II, by Mr. Martin-Karl Rolli and Mr. Beat Grünig.

The dismantling was done at Anlage Thierachern and in laboratory II by Mr. Jörg Mathieu and Mr. Robert Aegerter.

The analyses were carried out at the Labor II. Mr. Bruno Haas was in charge of the handling safety tests and Mr. Alexandre Sarbach for the DSC, thermal simulation and data treatment.

2.2 Test objects

BRS 440 rocket 1-3	Rocket:	SN T2B44-BFU-Schweiz2, BAM-PT2-0187, DAeC BN07/90, 06/2011
	Igniter:	Part Nr. 008403-01 Rev E, Lot# BRS11C-228, SN BRS440-1260
BRS 601 rocket 1-2	Rocket:	SN 6403 P/N 008418-01 Rev A 04/2011, Lot# BRS11C-044
	Igniter:	Part Nr. 008403-01 Rev E, Lot# BRS11C-230, SN 6404

2.3 Measuring methods and equipments

2.3.1 Fast Cook-off test (FCO)

For the FCO we have used an internal set-up based on STANAG 4240 [6]. The rocket was fixed in the center of a mobile aluminum pipe structure with two metal straps. A type J bimetal temperature probe was placed 1 cm above the rocket to measure the test temperature. The structure with the mounted rocket can then be pulled over 6 gas burners (2 series of 3 in parallel) to ensure a very fast heating rate (a few seconds) to reach a temperature of 1000℃ and maintain it till the reaction has taken place. Axially to the rocket in 2 m distance were placed two Aluminum witness plates (100x100cm) of 2 mm thickness.

2.3.2 Slow Cook-off test (SCO)

For the SCO we have used an internal set-up based on STANAG 4328 [7]. At the surface of the rocket we attached with metal straps three type J bimetal temperature probes. The rocket was inserted in the center of a spiral heating element which was placed in the center of a 26 cm long brick cylinder with an external diameter of 17cm and a wall thickness of 1.5 cm. All this setup was isolated with several layers of glass-wool.

The data acquisition was done with the Data Acquisition d'Agilent [8] (Switch Unit 34970A) and a programmable Temperature Controller (REX-P48/96 series) from RKC instrument Inc. [9]. We have used the Agilent BenchLink Data Logger 3 software version 3.10.00.

2.3.3 Differential scanning calorimetry (DSC)

The DSC [10] measurements were performed on a DSC1 from Mettler-Toledo driven by the software STARe version 9.30. The samples were placed in a high pressure 40 µl gold plated crucible. N_2 50 (at 150 ml/min.) was used as purge gas and Ar 60 (at 30 ml/min.) as measuring gas.

2.3.4 Friction, impact and electrostatic tests

The handling safety tests were performed according STANAG [11-13]. For the friction and impact test we have used the standard apparatus from Julius Peters, D-Berlin. For the electrostatic discharge we have used an apparatus developed by armasuisse.

2.4 Data treatment and simulation

The data were treated with the CALISTO [14] software version 1.088 developed by AKTS. The numerical simulations were performed with the AKTS-Thermo kinetics [15] software version 3.25 from AKTS.

3 Results

3.1 Dismantling of a BRS 440 rocket

According to the producer, the energetic substances used in BRS 440 and BRS 601 are identical. To isolate these substances from the system, the BRS 440 rocket Nr. 1 was dismantled completely. From this rocket we got three different energetic materials:

• rocket motor (HTPB/AP/Mg)	three cylinders, 71.3 g each
• primary booster (BP/Mg)	160mg
• primer mixture (composition unknown)	300mg

Fig. 1: Main components of the BRS 440 rocket; the 3 gray cylinders at the top of the rightmost picture compose the rocket motor.

Fig. 2: Detail of the igniter of the BRS 440 rocket. The primary booster charge is contained in two firing channels under an aluminum foil (glued to the base of the igniter; left picture). The picture in the middle shows the two percussion cups in the igniter housing and the two firing pins beside. The rightmost picture shows one of the two percussion cups and the housing cut by a diamond wire saw.

The active parts in the BRS are mechanically well protected and sealed properly. This is of great importance as Magnesium (Mg) reacts with humidity by the time under production of hazardous hydrogen gas.

3.2 Fast Cook-off test

The description of the test samples and results for the FCO experiments are listed in the following table:

Test Nr. / Rocket	Mean Temp. [℃]	Time to Reaction [s]	Type of Reaction[1]	Remarks
V01/ BRS 440 Nr. 2	1045	145	Type V-IV Fast burning towards deflagration	End cap was axially ejected out of the rocket casing with high velocity. The main part of HTPB cylinder of the rocket motor did not react. Both percussion cups of the Igniter did not react.
V03/ BRS 440 Nr. 3	1085	129	Type V-IV Fast burning towards deflagration	The end cap was axially ejected out of the rocket casing with high velocity. One wire cut and the second wire almost cut. No unreacted rocket motor parts left. Igniter including primary booster remained unreacted.
V02/ BRS 601 Nr. 1	1050	43	Type V-IV Fast burning towards deflagration	The rocket was axially ejected apart from the fixation and penetrated the 2 mm thick aluminum witness plate (see Fig. 7). The outer casing of the rocket was ejected to the opposite witness plate which resulted in a crack into the plate. All parts of the rocket motor and igniter did react.
V04/ BRS 601 Nr. 2	1065	69	Type V-IV Fast burning towards deflagration	The rocket remained onto the support but shifted the whole test equipment about 1.5 m in the direction of the base of the rocket. All parts of the rocket motor and igniter did react.

Table 1: Summary of the FCO experiments

Fig. 3: FCO set-up; respectively for the BRS 440 (left) and the BRS 601 (right).

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[1] Sample pictures for Type of Reaction see Annex 7.1

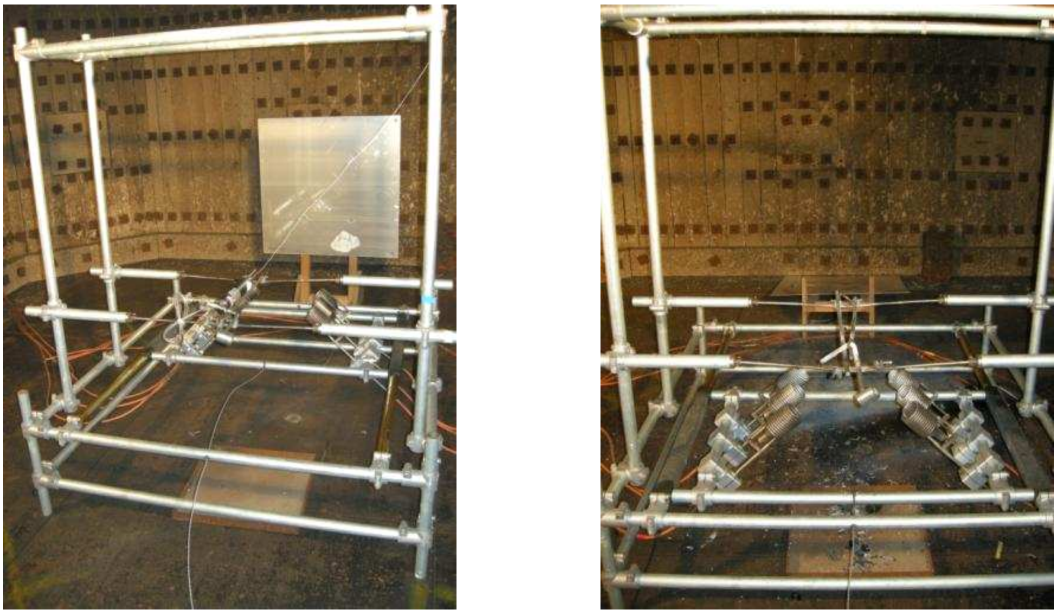


Fig. 4: FCO test V01 of BRS 440; before (left) and after the test (right).

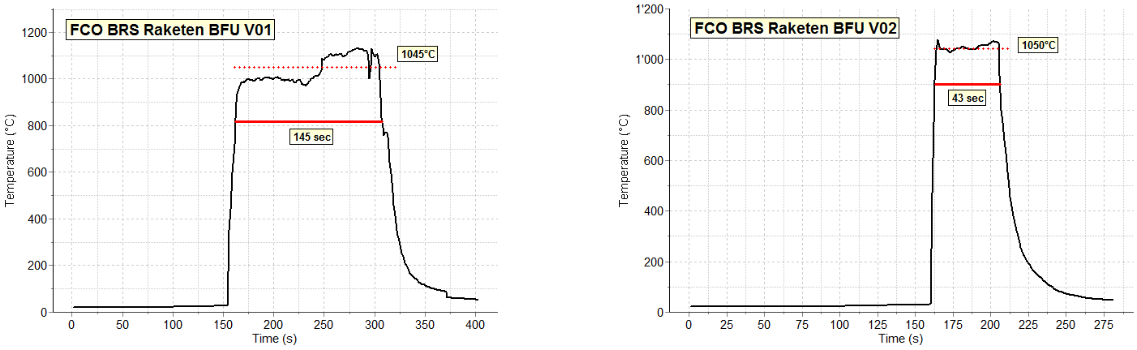


Fig. 5: FCO curves respectively for the BRS 440 (left) and the BRS 601 (right).

Fig. 6: FCO results for the BRS 440 respectively for test V01 (left) and test V03 (right).

Fig. 7: FCO results for the BRS 601 respectively test V02 (left) and the test V04 (right).

3.3 Slow Cook-off test

Only one type of BRS rocket was left to perform an indicative SCO experiment; BRS 440 Nr. 1 which was used for dismantling. The test was performed without Igniter (used for analytical tests) and with an aluminum disc of 1 cm thickness for confinement towards the rocket nozzle. The first HTPB cylinder of the rocket motor weighted 57.3 g instead of 71.3 g. We have chosen a heating rate of 15°C/h for this experiment which corresponds to a realistic heating rate for the thermal radiation of a fire in the vicinity.

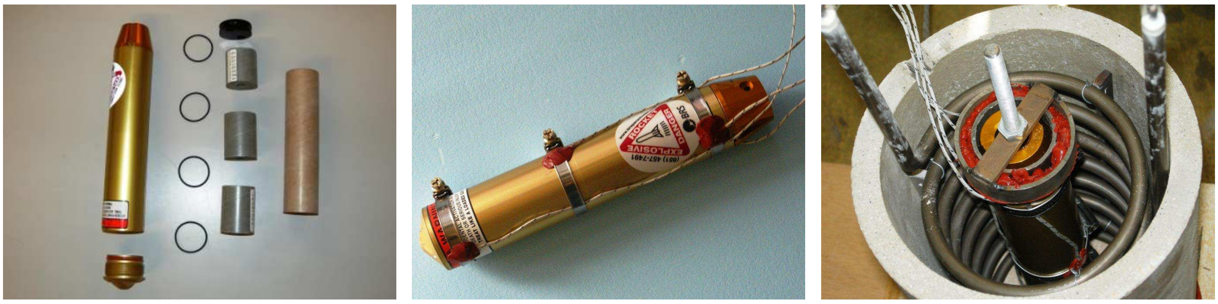


Fig. 8: Arrangement of the BRS 440 rocket for the SCO test; respectively rocket with probes and in position in the brick cylinder.

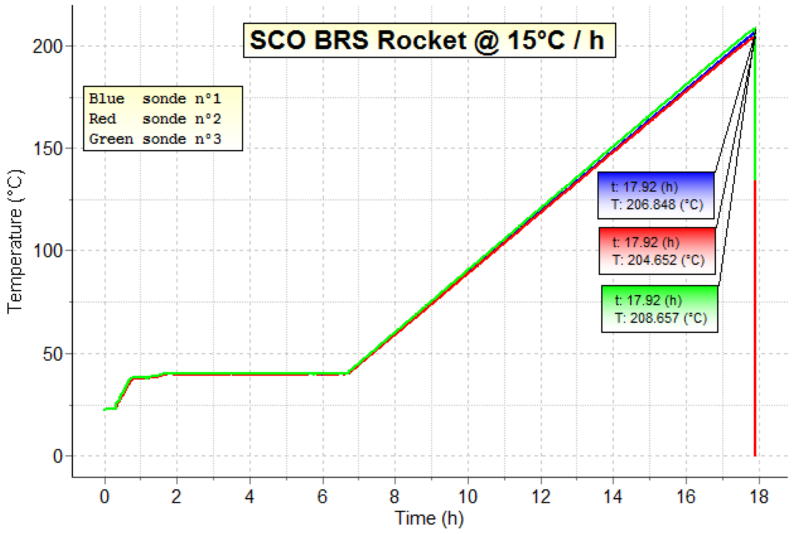


Fig. 9: SCO heating curves for the BRS 440 rocket at 15℃ per hour.

The violent reaction corresponds to a type IV – III started after 18 hours at a temperature of around 207℃. The differences in temperature between the three probes originate most probably by the geometry of the rocket and the heating system which is not fully symmetrically.

Fig. 10: SCO of the BRS 440 rocket; respectively before and after test and the fragments.

3.4 Friction, impact and electrostatic discharge tests

The mass of the primary booster and the primer mixture left for these tests was only about 100-200 mg; this wasn't enough to perform all three tests. The electrostatic discharge test was favored as this test represents the main danger for such mixtures in case of a breakup of the protecting casings.

For each test, two values were reported; the first where the first reaction occurred and the value of no reaction i.e. where it begin to be safe (6 repetitions for each level).

Samples		Sensitivity test		
		Electrostatic discharge [J]	Impact [J]	Friction [N]
rocket motor	No reaction	>5.6	5	80
	First reaction	>5.6	6	96
primary booster	No reaction	1.0	n.a.	n.a.
	First reaction	1.8		
primer mixture	No reaction	0.1	n.a.	n.a.
	First reaction	0.6		

Table 2: Handling safety test results.

All three substances are not sensitive towards electrostatic discharge. The HTPB (rocket motor) shows a moderate sensitivity towards mechanical load (impact, friction).

3.5 Differential scanning calorimetry and simulations

For each DSC measurement we have used samples about 1 mg. The following figure summarizes the DSC of the 3 samples i.e. the rocket motor, the primary booster and the primer mixture of the igniter.

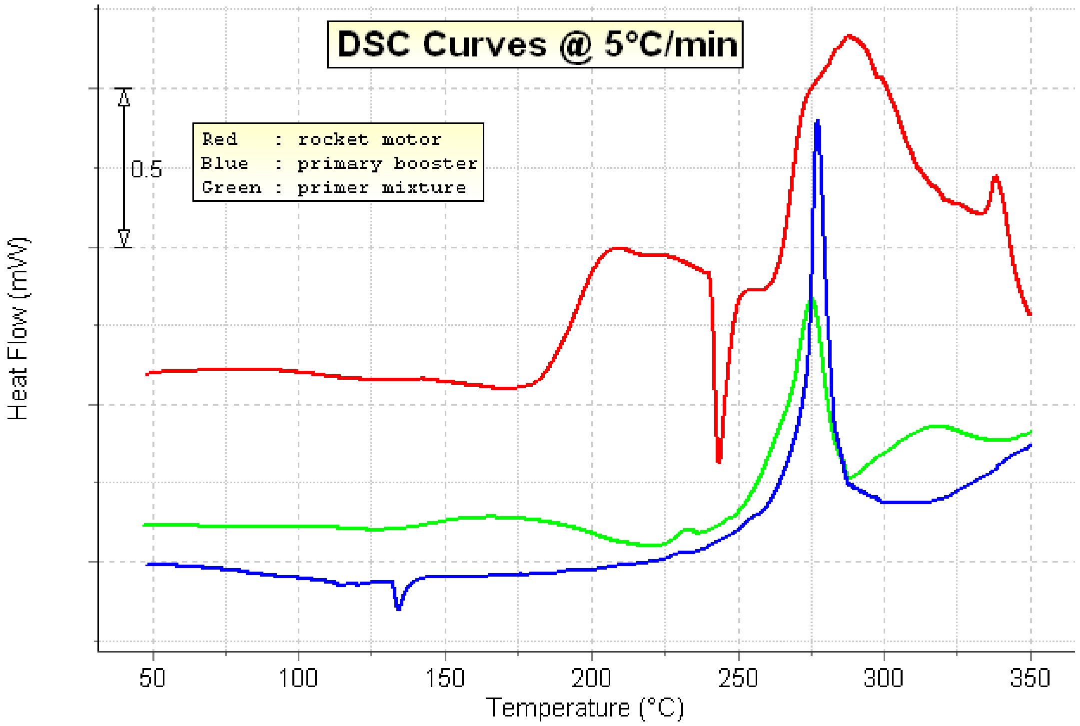


Fig. 11: DSC curves of the rocket motor, the primary booster and the primer mixture with a heating rate of 5℃ per minute.

3.5.1 Simulations

The practical application of the kinetic evaluation of the thermally induced decomposition reactions requires two main stages:

(1) determination of the kinetic parameters of the investigated process, namely the values of the activation energy Ea, the preexponential factor A and the form of the f(α) function depending on the reaction model.

(2) application of obtained kinetic triplet (A, Ea and f(α)) for the prediction of the reaction course under arbitrarily chosen temperature profiles. This issue is of great importance in investigating of materials aging i.e. the time and temperature dependent decay of material properties occurring often even at ambient temperatures.

Commonly applied kinetics evaluation methods such as ASTM E1641-07 [16], ASTM E698-05 [17] or NATO stability test procedure [18] are all based on the first order kinetic model; therefore the peculiarities of other models expressed by the form of the f(α) function are not taken into considerations. The models of the thermal decomposition reactions can be divided into three main types (see e.g. [19]) depending on the shape of the α-time dependence in isothermal conditions:

- decelerating, when the maximal reaction rate is observed at the beginning of the reaction

- accelerating, when the reaction rate increases during reaction course, and

- sigmoidal, characterized by the long induction period ; the maximal reaction rate occurs somewhere between the beginning and the end of the decomposition.

A full kinetic analysis of a solid state reaction has at least three major stages:

(1) Experimental collection of data

(2) Computation of kinetic parameters using the data from stage 1

(3) Prediction of the reaction progress for required temperature profiles applying determined kinetic parameters.

Experimental collection of data

The 3 samples, rocket motor, primary booster and primer mixture were measured with the DSC at different heating rates. The reproducibility of the DSC curves is not as good due to the high inhomogeneity of the samples, in particular of the rocket motor, if we have to work in the milligram domain.

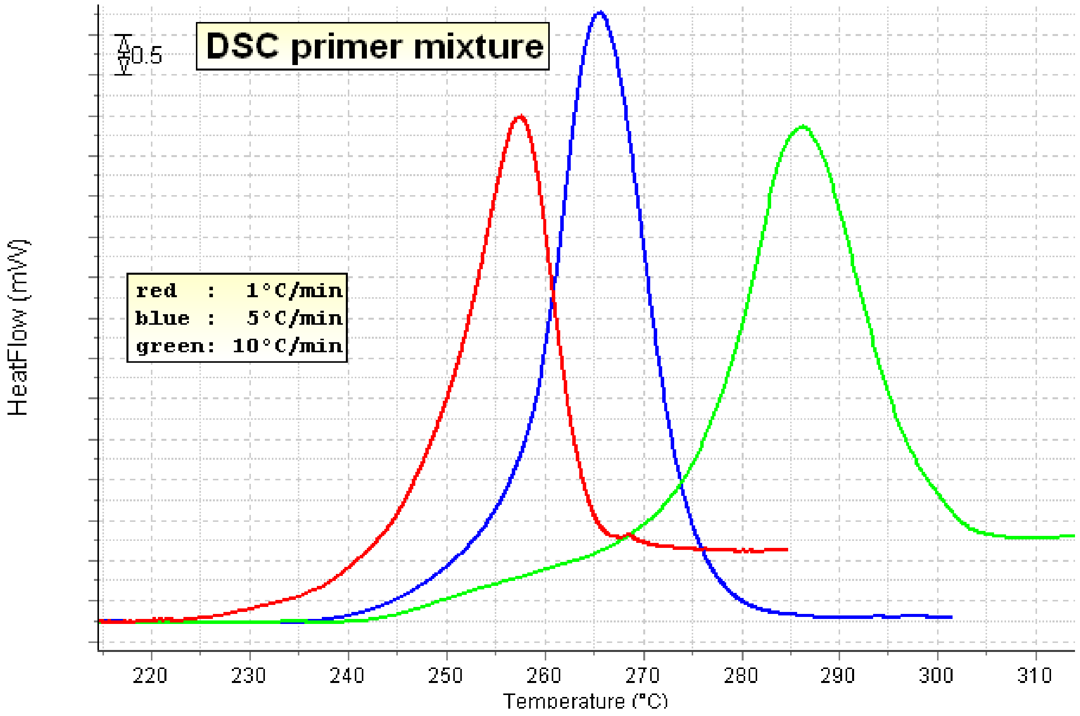


Fig. 12: Typical DSC curves of the primer mixture at different heating rates of 1, 5 and 10℃ per minute.

Computation of kinetic parameters

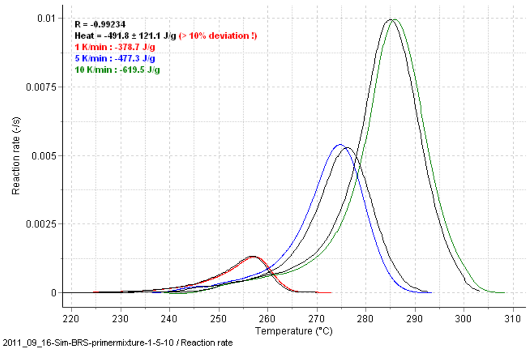
The kinetic parameters can be evaluated by the isoconversional method. This is a numerical method which involves determination of temperatures corresponding to certain, arbitrarily chosen values of the conversion extent α recorded in the experiments carried out at e.g. different heating rates β. Isoconversional methods are based on the so called isoconversional principle saying that the reaction rate dα/dt at constant reaction progress α is only a function of temperature and that the temperature dependence is contained only in the Arrhenius expression. These methods can be applied for determination of the activation energy (or dependence Ea on α) without assuming the explicit form of f(α).

The thermo analytical data set usually contains:

- the relationship between specific conversion, α_i and temperatures for different heating rates (non-isothermal mode).

- the relationship between specific conversion, α_i, and time for different temperatures (isothermal mode).

Commonly applied are the following three isoconversional methods known as: Friedman [20], Ozawa-Flynn-Wall [21-22] and the ASTM E698 analysis [17].



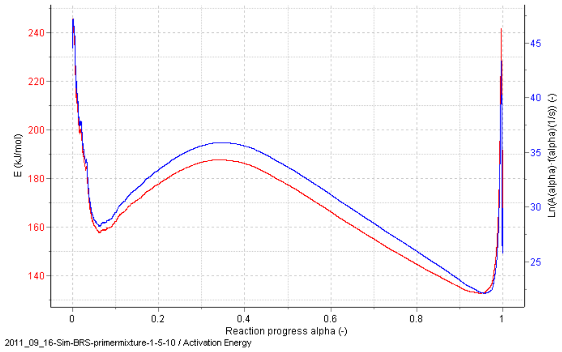


Fig. 13: Typical reaction progress kinetic results based on DSC curves with several heating rates of 1, 5 and 10℃ per minute.

Fig. 14: Typical activation energy and pre exponential factor calculation.

Prediction of the reaction progress for required temperature profile

Kinetic parameters calculated from non-isothermal experiments allow prediction of the reaction progress at any temperature mode: isothermal, non-isothermal and intermediate intervals in the heating rate.

We have chosen the stepwise mode to simulate what happens in a SCO experiment at 15℃ per hour.

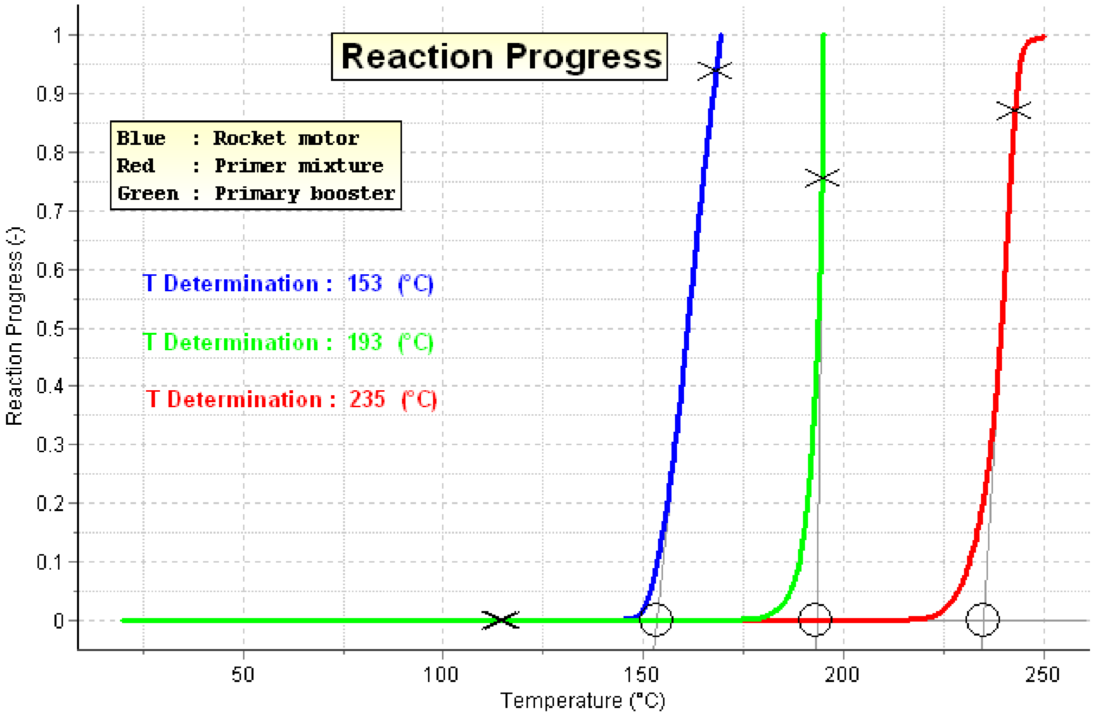


Fig. 15: Prediction of the reaction progress under adiabatical condition for a heating rate of 15℃ per hour; the blue curve represents the rocket motor, the green curve the primary booster and the red curve the primer mixture.

4 Assessment

From the dismantling of the rocket BRS 440 we got three explosives components; the rocket motor, the primary booster and the primer mixture. All three components are not very sensitive to electrostatic discharge; which is the major concern especially for open pyrotechnic compositions. Due to the small available quantity of the primary booster and the primer mixture, it was not possible to perform the friction and impact tests on them. The HTPB rocket motor propellant shows a moderate sensitive to friction and impact. This result implies that one can manipulate remaining open explosives from BRS if one avoid stronger mechanical load.

The fast cook-off experiments have shown that the BRS 440 rocket could support during 145 to 129 seconds an average temperature of 1050℃ and the BRS 601 rocket could support the same temperature during 43 to 69 seconds. For both systems we observed a reaction of type V-IV (burning towards deflagration) with some pieces up to several hundred grams which will be ejected much more than 15 meter away.

The slow cook-off experiment with a heating rate of 15℃ per hour has shown a quite violent reaction of type IV – III at 207℃. This reaction can be classified as strong deflagration towards explosion. This SCO was performed with the rocket motor without primary booster and percussion cups with primer mixture as no igniter was left for this test.

The DSC experiments have shown that for a heating rate of 5℃ per minute, the rocket motor is the sample which shows first an exothermic reaction at 180℃ (cf. fig. 11). In comparison the primary booster and the primer mixture seem to be thermodynamically more stable.

For the thermodynamical simulations we had to make a compromise due to the high inhomogeneity of the sample in the milligram domain. This was especially the case for the HTPB rocket motor. For the simulation we could use only the first exothermic peak (up to 220℃) instead of the full spectrum as for the other two substances. Figure 15 shows the reaction progress of the three samples in an adiabatically configuration. Although that this condition does not totally fulfill to the SCO test set-up, it is reasonable to assume that with a heating rate of 15℃ per hour, the rocket motor will probably react first.

5 Conclusions

The present experiments have shown that the BRS rockets directly in a fire (FCO scenario) or in presence of irradiative heat (SCO scenario) can react with fast burning to deflagration reaction up to explosion. It is to expect that in most cases of a reaction of the rocket, the wires and belts between the parachute and airplane will hold back the main rocket case parts. So the safety distance for these parts will be within this defined radius formed by the length of wires and belts. The present investigation has shown that at least one heavy piece (end cap of approx. 88 g) of the BRS 440 will be ejected and one or more even heavier pieces from BRS 601 will be ejected over much bigger distances than the above mentioned scenario.

The observations during these tests have revealed that the connection wires could be damaged at some stage in the fire and eventually malfunction when the motor reacts.

Especially for BRS 440, one has also to take into account that unreacted open parts of the HTPB rocket motor could remain after a FCO scenario. There were left also unreacted parts of the igniter in these tests but we do not have enough knowledge of the installation of the systems in the aircraft to state if this also could happen in a real situation.

If a rocket motor is exposed to a fire or to irradiative heat, one has to consider that the thermal decomposition inside the massive casing can still go on for several minutes up to hours and can still lead to a violent reaction. Therefore one should wait (depending on the situation) and allowing the cooling down of the components before to approach and manipulate them.

For the first responder teams, it is very important to be aware of the potential hazards from such active rescue systems, especially in case of direct or indirect fire. Nevertheless they have to keep in mind that the system can also accidently be ignited by the movement of parts or the whole airplane after an air crash (i.e. release by pulling the activation wire).

Due to the natural aging of the energetic materials in the BRS, the shelf life time given from the producer has to be respected and the parts have to be changed at the given time intervals.

This investigation is based only on tests with 5 BRS systems in total whereas only one SCO test with BRS 440 was performed. To confirm the present conclusions and collect additional information i.e. SCO behavior of BRS 601 or the energy of ejected debris from FCO tests, a second test series including velocity measurement by aid of a high speed video system could be performed.

6 Release

Thun, 18.10.2011

Task leader	Reporter
J. Mathi	A. Sarbach
Jörg Mathieu WTE Explosives specialist	Alexandre Sarbach WTE Scientific project leader
armasuisse Science and Technology	armasuisse Science and Technology

Approved

Folly Patrick

Patrick Folly
Head WTE

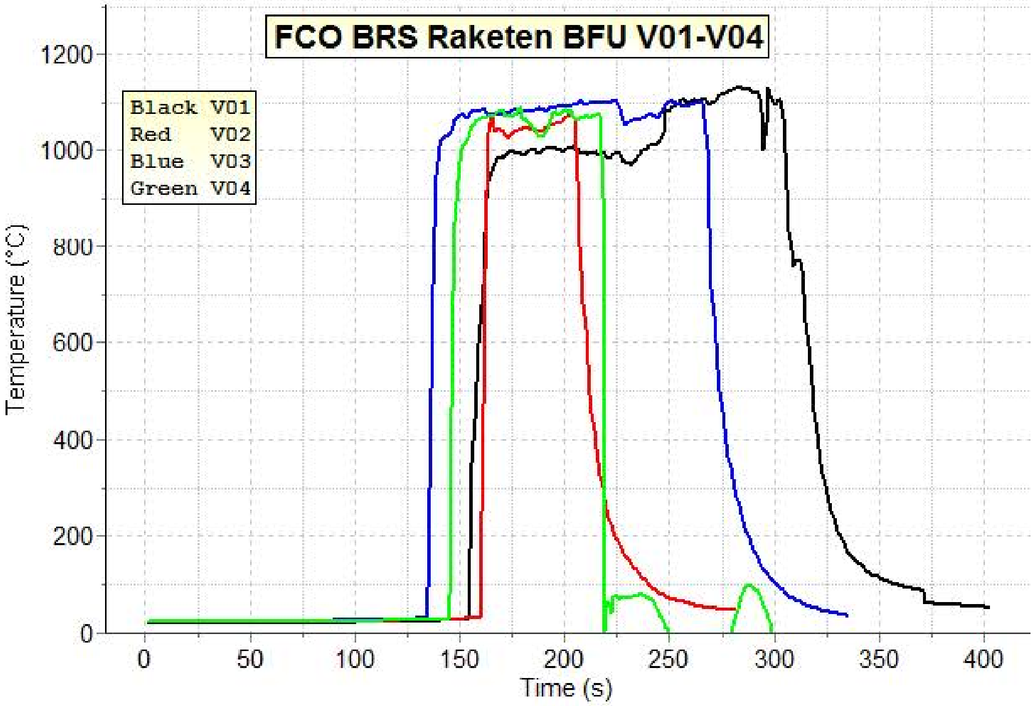
armasuisse
Science and Technology

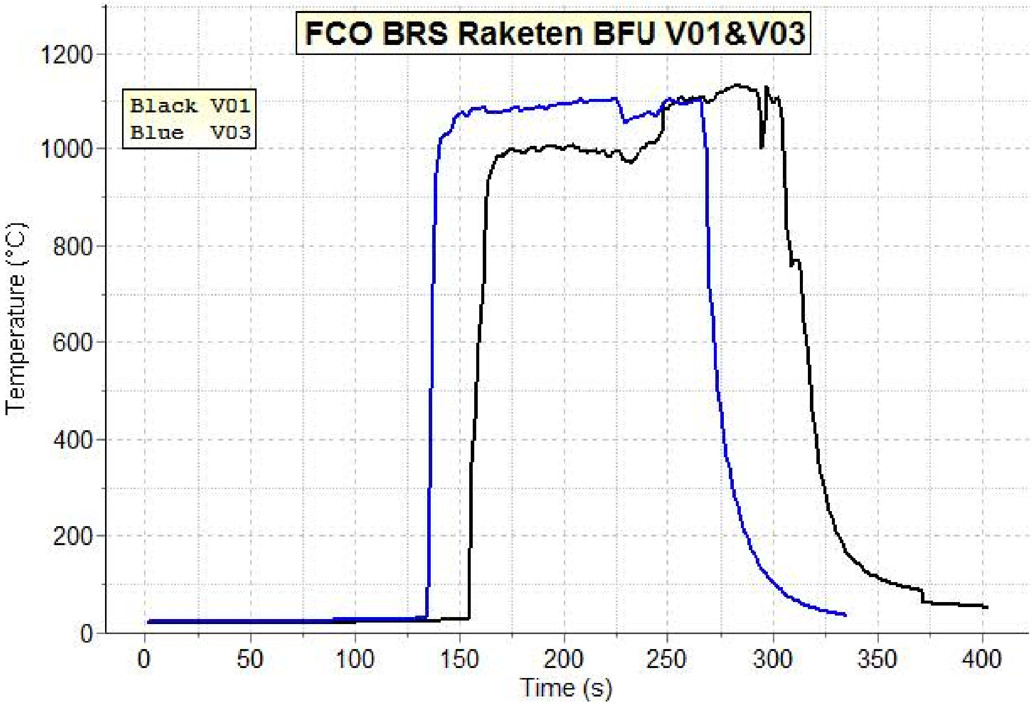
7 Annex

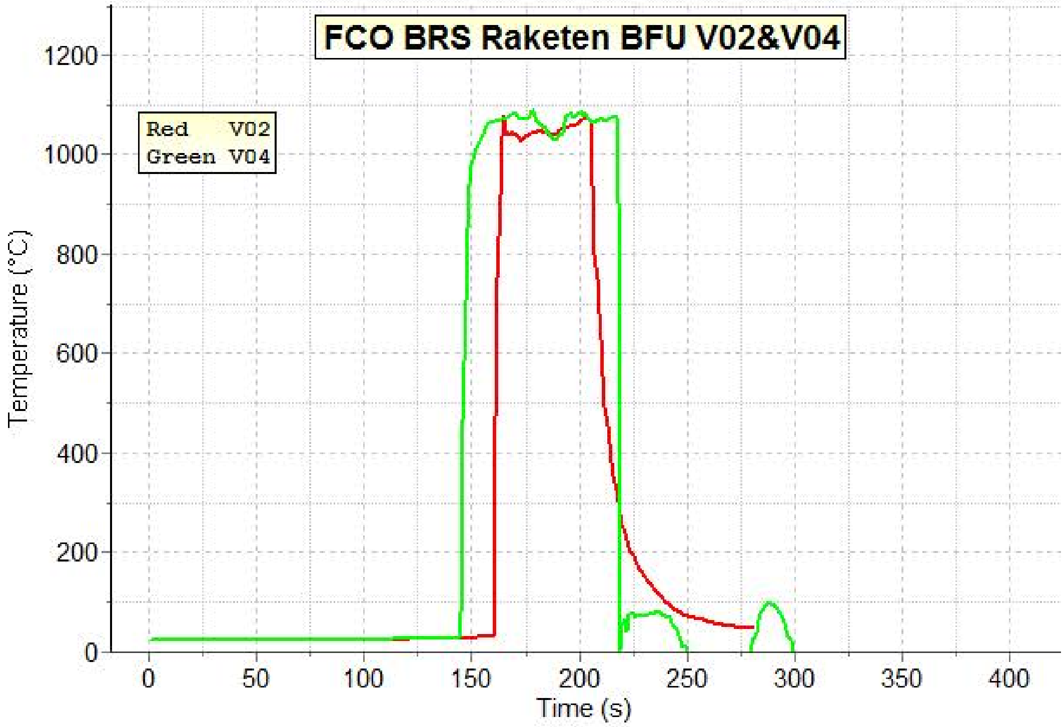
7.1 Type of reaction according MIL-STD 2105 B

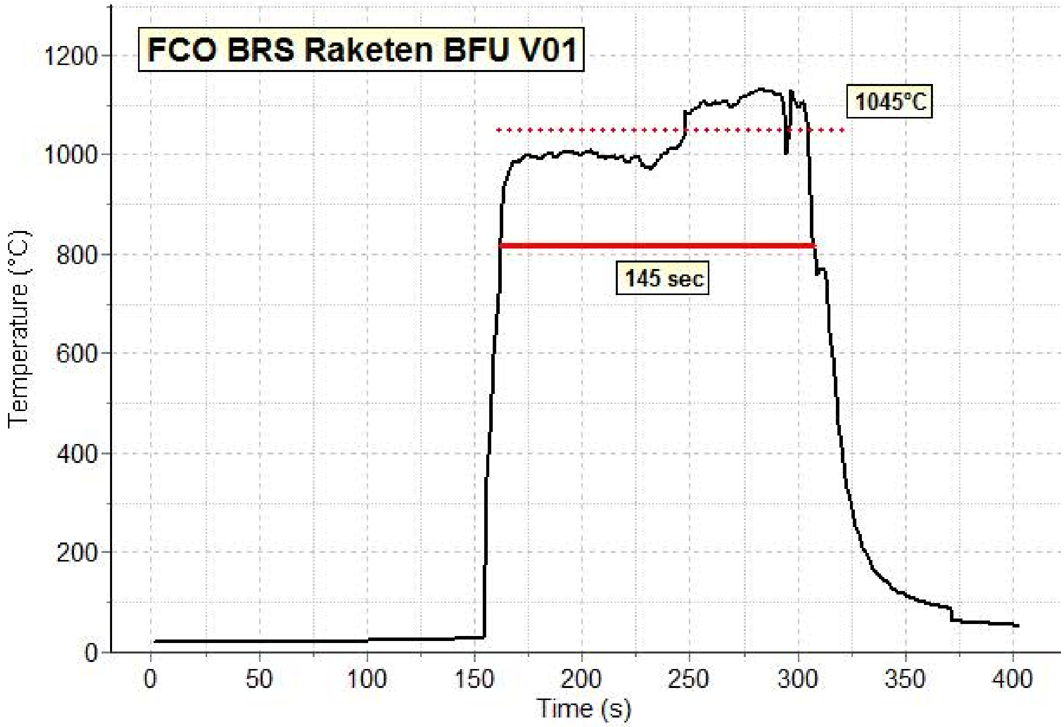
7.2 Measurement protocols

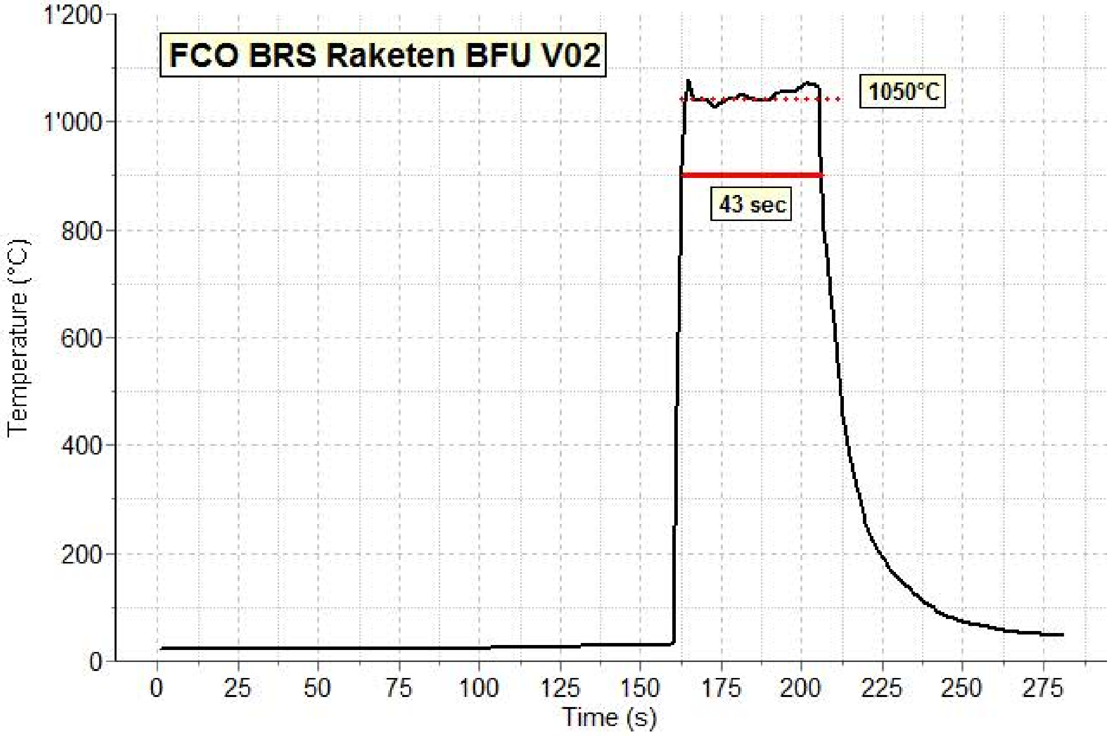
7.2.1 FCO

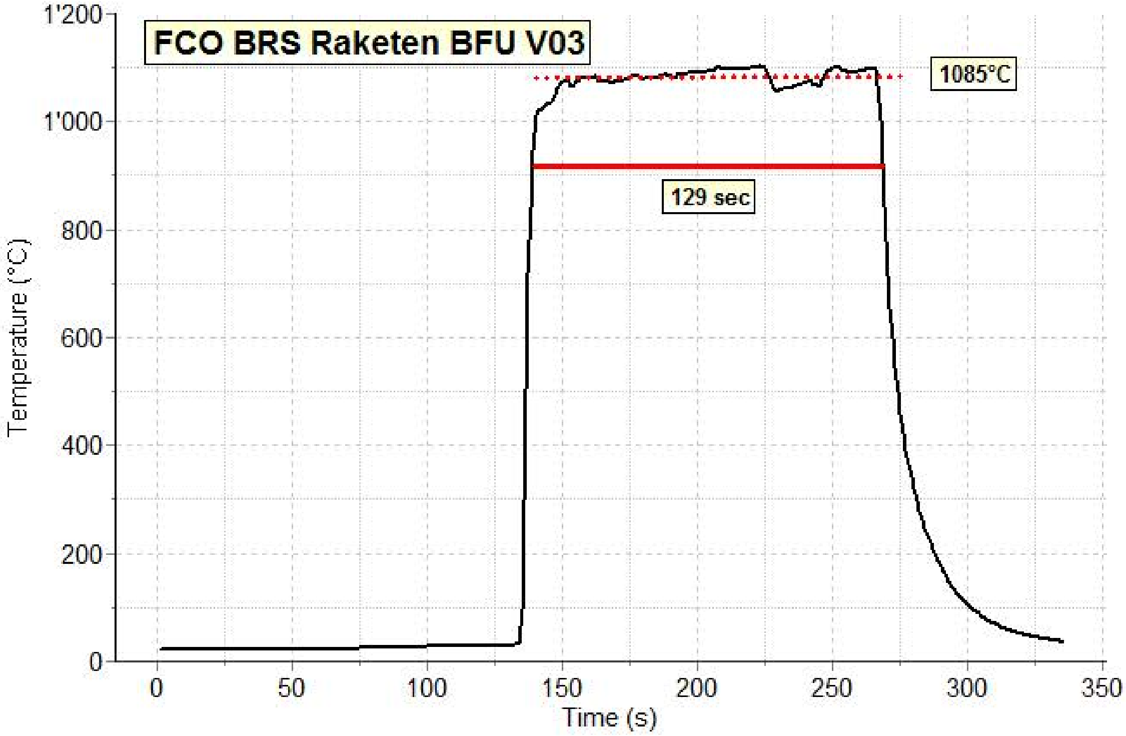


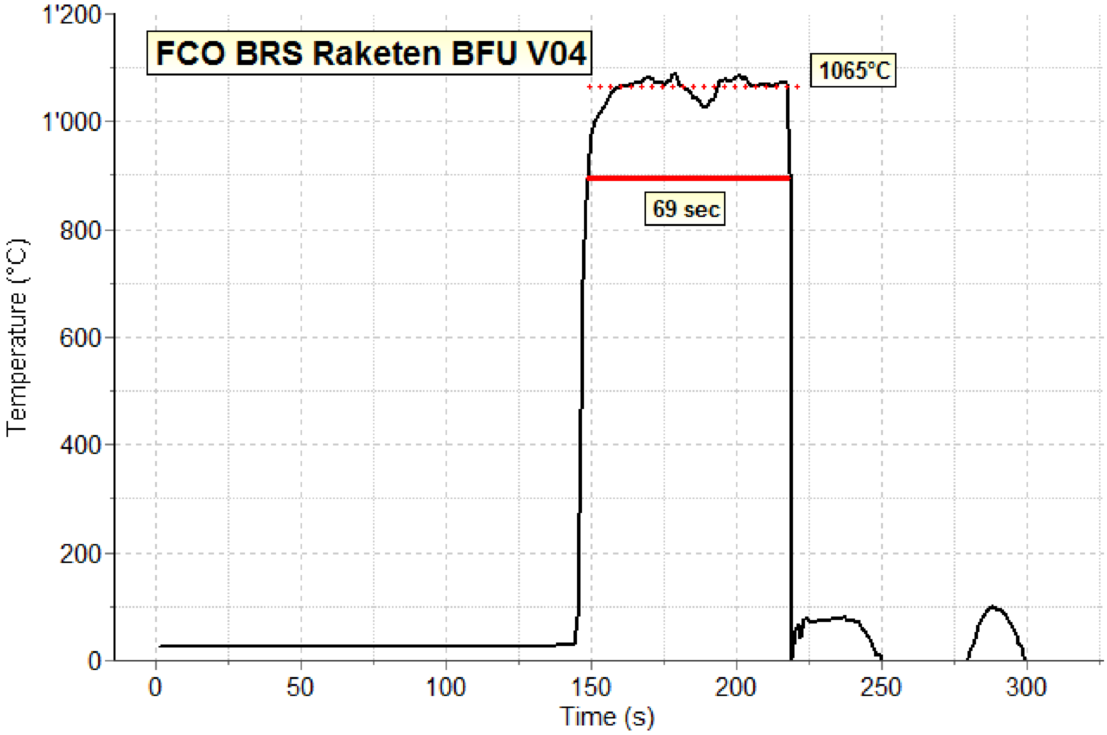



FCO BRS Raketen BFU V02&V04
Red V02
Green V04
Temperature (°C)
0
200
400
600
800
1000
1200
Time (s)
0
50
100
150
200
250
300
350
400

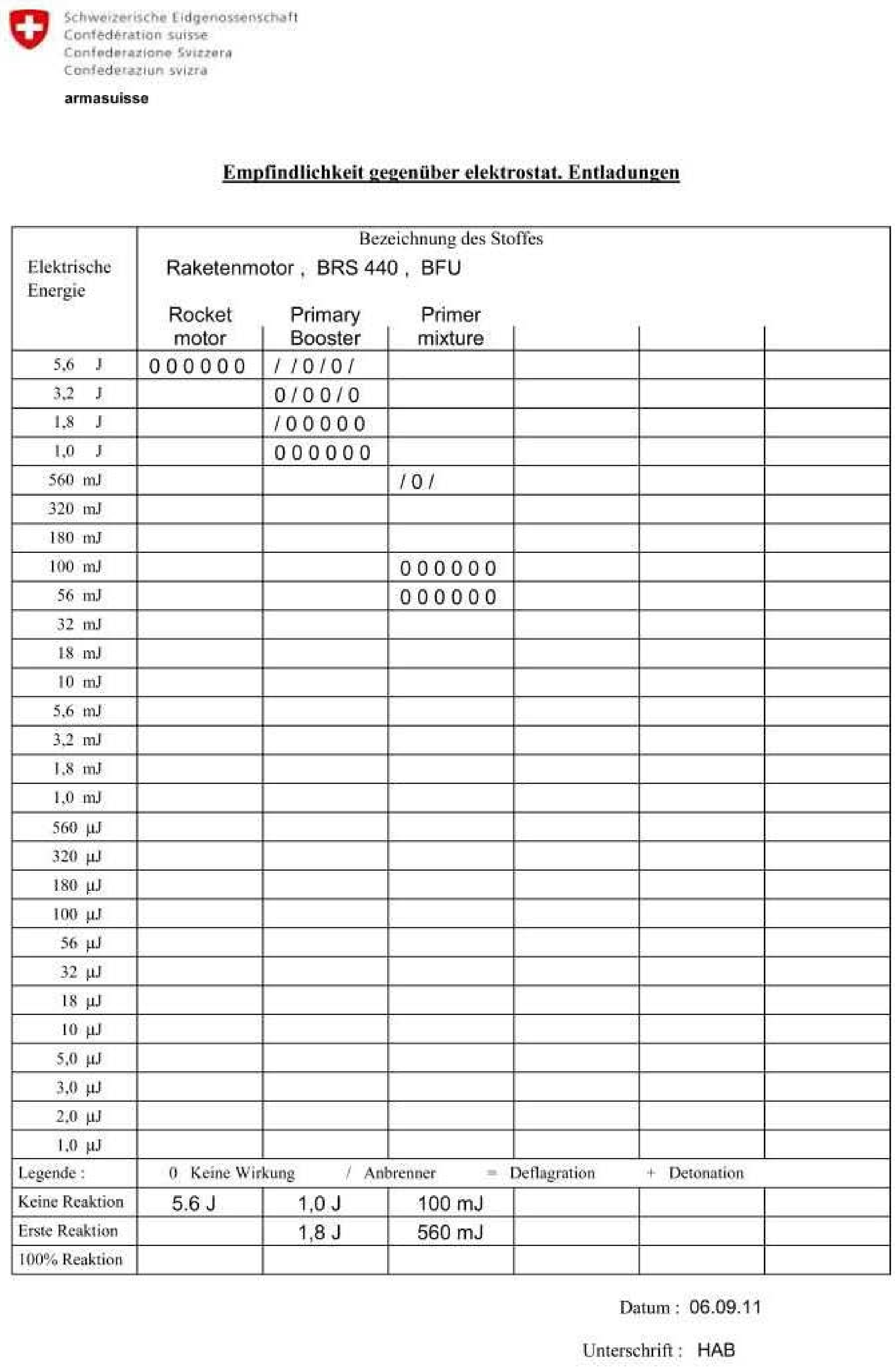

FCO BRS Raketen BFU V01
1045°C
145 sec
Temperature (°C)
0
200
400
600
800
1000
1200
Time (s)
0
50
100
150
200
250
300
350
400


FCO BRS Raketen BFU V02
1050°C
43 sec
Temperature (°C)
1'200
1'000
800
600
400
200
0
0
25
50
75
100
125
150
175
200
225
250
275
Time (s)


FCO BRS Raketen BFU V03
1085°C
129 sec
Temperature (°C)
1'200
1'000
800
600
400
200
0
0
50
100
150
200
250
300
350
Time (s)


FCO BRS Raketen BFU V04
1065°C
69 sec
Temperature (°C)
1'200
1'000
800
600
400
200
0
Time (s)
0
50
100
150
200
250
300

7.2.2 Impact, friction and electrostatic discharge



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

armasuisse

Empfindlichkeit gegenüber elektrostat. Entladungen

Elektrische Energie	Bezeichnung des Stoffes Raketenmotor , BRS 440 , BFU					
	Rocket motor	Primary Booster	Primer mixture			
5,6 J	0 0 0 0 0 0	/ / 0 / 0 /				
3,2 J		0 / 0 0 / 0				
1,8 J		/ 0 0 0 0 0				
1,0 J		0 0 0 0 0 0				
560 mJ			/ 0 /			
320 mJ						
180 mJ						
100 mJ			0 0 0 0 0 0			
56 mJ			0 0 0 0 0 0			
32 mJ						
18 mJ						
10 mJ						
5,6 mJ						
3,2 mJ						
1,8 mJ						
1,0 mJ						
560 µJ						
320 µJ						
180 µJ						
100 µJ						
56 µJ						
32 µJ						
18 µJ						
10 µJ						
5,0 µJ						
3,0 µJ						
2,0 µJ						
1,0 µJ						
Legende :	0 Keine Wirkung / Anbrenner = Deflagration + Detonation					
Keine Reaktion	5.6 J	1,0 J	100 mJ			
Erste Reaktion		1,8 J	560 mJ			
100% Reaktion						

Datum : 06.09.11

Unterschrift : HAB

Empfindlichkeit gegenüber Reibung

Methode nach Peters , BAM Reibapparat

Belastung		Bezeichnung des Stoffes Raketenmotor , BRS 440 , BFU					
[Kg]	[N]	Rocket motor					
36,0	360						
32,4	324						
28,8	288						
25,2	252						
24,0	240						
21,6	216						
19,2	192						
18,0	180						
16,0	160	0 0 0 / 0 /					
14,4	144	/ 0 0 0 0 /					
12,0	120	0 0 0 0 / 0					
9,6	96	0 / 0 0 0 0					
8,0	80	0 0 0 0 0 0					
6,0	60						
4,0	40						
2,0	20						
1,0	10						
0,5	5						
Legende :		O Keine Wirkung / Anbrenner = Deflagration + Detonation					
Keine Reaktion		8,0 Kg 80N					
Erste Reaktion		9,6 Kg 96N					
100% Reaktion							

Datum : 16.08.11

Unterschrift : HAB

Schweizerische Eidgenossenschaft
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Empfindlichkeit gegenüber Schlag

Methode nach Koenen und Ide, BAM Fallapparat

Fallgewicht		2 Kg					
Volumen		$10mm^3$					
Höhe [cm]	Energie [J]	Bezeichnung des Stoffes Raketenmotor , BRS 440 , BFU Rocket motor					
100							
95							
90							
85							
80							
75							
70							
65							
60							
55							
50							
45							
40	8	0 / 0 / 0 /					
35	7	0 0 /0 0 0					
30	6	0 0 0 0 0 /					
25	5	0 0 0 0 0 0					
20							
15							
10							
5							
Legende :		O Keine Wirkung / Anbrenner = Deflagration + Detonation					
Keine Reaktion		25cm 5 J					
Erste Reaktion		30cm 6 J					
100% Reaktion							

Datum : 16.08.11

Unterschrift : HAB

Schweizerische Eidgenossenschaft
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Büro für Flugunfalluntersuchungen BFU

Aktennotiz

Datum: 1. Februar 2008
Für: ovj
Kopien an:

Safety and Certification BRS Systeme

In Deinem Auftrag habe ich im November an Cirrus, BRS und das NTSB die folgende Anfrage gesandt:

> *Dear Sir, Madam,*
>
> *With reference to investigations carried out by our office on Cirrus aircraft and in view of other aircraft being equipped with Ballistic recovery systems in the future, we have the following questions and statements, which we like you to answer or give a statement:*
>
> *- During the certification process of the aircraft, was there carried out a evaluation of the possibility of an unintentional activation of the Ballistic recovery system during an accident, especially in the case of a "flip-over" ?*
>
> *- What is the danger of a unintentional activation of the Ballistic recovery system during the first intervention of the rescue personnel when recovering injured persons ?*
>
> *- We consider it not always possible to wait for manufacturer's personnel to be available at the accident site. What advise could and should be given to the various intervention services (police, fire and rescue personnel)*
>
> *- In view of the hazard of the Ballistic recovery systems, we consider the markings size and format insufficient. There should be used or introduced a more standardized and recognized placard despite the designers resistance against such a requirement.*
>
> *We are very much interested in your return of information on our request.*
>
> *Christian Gerber*
> *Investigator*
> *Swiss Aircraft Accident Investigation Bureau*
>
> *Christian Gerber BFU*

Ich habe dann die folgenden Antworten erhalten:

NTSB:

Keine Antwort

Cirrus:

I am in receipt of your inquiry about ballistically deployed parachutes on aircraft in general and on Cirrus Aircraft specifically, and thank you for it. I am very pleased to be able to address your concerns pertaining to our system and advise you that we have personnel here at Cirrus Design in our Air Safety Department that are specialists in this very issue. Furthermore, we have invested an appreciable amount of resources in making sure that investigators and "First Responders" clearly understand the particular issues or concerns about ballistically deployed safety devices on aircraft. We typically are invited to give a presentation to a group of appropriate individuals (investigators/responders) and send one of our senior staff personnel to educate the group on our system (and general information on non-Cirrus systems - but are similar in nature. i.e.. ultralights, light-sport aircraft, LSA, and the like). This typically includes demonstrations by use of actual components (inert) that can be easily and safely handled to learn more about the systems involved. As you no doubt are aware, we have thousands of these systems in the market to date, and we are pleased to assure you and your colleagues that we have never had any inadvertent in-flight deployments. Rest assured, we have complied with the stringent regulations of our Federal Aviation Administration (FAA) throughout the certification processes and we have a very robust system that has now been responsible for saving over 20 individuals in life-threatening situations, without any fatalities being reported as a result of the use of the system! Furthermore, this life saving technology, and the training we provide though our team here at Cirrus was recognized last year at the ISASI conference in Texas for our diligent and thorough effort to enhance safety and training of these systems to Air Safety related organizations around the world.

I would be most pleased to respond through our Air Safety Department professionals answers to your specific questions, though I might suggest that we try to arrange a symposium of some type to incorporate the appropriate safety personnel in Switzerland, or at least your region. We would be more than happy to have our staff present to give you a thorough briefing of this important system. Furthermore, this is of particular importance as other aircraft manufacturers are now announcing their intentions to use ballistic systems on their products as well, and our information will give you a wonderful perspective on how these systems function and what you and your colleagues need to know when becoming involved with any investigation(s) in the field involving aircraft with these components on board.

I might also add that we receive calls with some regularity regarding this question and we welcome the chance to continue to bring this important training information to fellow safety personnel often. If you cannot support a cost-sharing effort to bring our team there, we will be happy to do so at our expense. Our primary interest is in assuring that safety standards are appropriately in place when dealing with any aircraft incident, whether it is a Cirrus aircraft or another system. I truly believe you will find this training information to be of a very high quality and worth the investment of the time required to host our trainer. My internal team will be happy to give you a reference, if you so desire, from either the FAA or the NTSB that can attest to the value of this training effort. In this day and age, it is information that is essential for you and your team to understand and to assure the safety of the entire team you work with.

I trust this long email is of some value to you and encourage you to follow up with me, or my Air Safety Department at your convenience to get this effort scheduled at our collective first opportunity. Our trainer remains very busy with his schedule so I would encourage a conversation at your earliest convenience to build this effort into his schedule.

Please feel free to contact me at your convenience as well to answer any specific questions you may have. I am copying my Director and the Director of Air Safety Training so they too can watch for your return inquiry. In the mean time I remain,

Yours very truly, William T. King Vice President Business Administration

In der Folge meldete sich noch der Cirrus Vertreter aus Deutschland per Telephon. Allerdings sprach er nur über die Möglichkeiten, wie das BRS System bei Cirrus Flugzeugen nach einem Unfalkl desaktiviert werden könne.

Untenstehend seine Info

Hallo Herr Gerber,

vielleicht ergibt sich ja einmal ein persönlicher Kontakt.

Im Anhang sehen Sie 3 Fotos, wie Sie den Raketenauslösezug finden und „in Selbsthilfe“ mittels einer kleinen Drahtschere (ein Seitenschneider ist vielleicht nicht geeignet, da das Kabel kein massiver Draht sondern verdrillt ist) entschärfen können.

Herzliche Grüße

Jan-Peter Fischer

CIRRUS Deutschland
Cirrus Deutschland GmbH & Co. KG (AG Potsdam HRA 3822 B)
Cirrus Deutschland Maintenance GmbH & Co. KG (AG Potsdam HRA 3736 P)
Komplemetärin: Cirrus Deutschland Verwaltungs GmbH
Geschäftsführer: Jan-Peter Fischer
jpf@cirrusdeutschland.de

✉ Flugplatz C4, D-14959 Schönhagen

Phone +49 (0) 33731 7064-0
Fax +49 (0) 33731 7064-15
Mobile +49 (0) 172 730 7576

Beule in Gepäckraum, Abdeckung entfernen

Kabelzug sichtbar

Kabelzug hier durchtrennen

BRS:

The VP of engineering for BRS is Frank Hoffmann. He is responsible for the engineering details of our system. I will send him a copy via email. Our BRS air safety person is Gregg Ellsworth. We know about the BRS systems.

Regarding the Certification of Cirrus and that evaluation that data is available directly from Cirrus (Mike Bush is the safety officer I suggest you contact, Cirrus has developed a first responder DVD that addresses your issue Mike is at 218-727-2737)

The size and marking of the BRS systems is something that can be addressed, thank you for your questions.

Stand 01. Feb 2008

National Transportation Safety Board
Washington, D.C. 20594

Safety Recommendation

Date: April 29, 2004

In reply refer to: A-04-36 through -41

Honorable Marion C. Blakey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

Mr. James M. Shannon
President and Chief Executive Officer
National Fire Protection Association
1 Batterymarch Park
Quincy, Massachusetts 02269

Mr. Garry Briese
Executive Director
International Association of Fire Chiefs
4025 Fair Ridge Drive
Fairfax, Virginia 22033-2868

On June 16, 2001, about 1438 central daylight time, a Cirrus Design SR22, equipped with an undeployed ballistic parachute system,[1] was destroyed while landing on runway 20 at the Springfield-Branson Regional Airport (SGF), in Springfield, Missouri. The airplane touched down 1,000 to 1,500 feet beyond the approach end of the runway, bounced several times, and veered off the left side of the runway. The airplane then crossed a sod area, a taxiway, and another sod area before impacting a disabled aircraft used for airport rescue and firefighting (ARFF) training. The private pilot and the passenger in the rear seat received minor injuries; the passenger in the left front seat was seriously injured. Visual meteorological conditions prevailed at the time of the accident. The personal flight was operated under the provisions of 14 *Code of Federal Regulations* (CFR) Part 91.[2]

---

[1] The ballistic parachute device installed in the accident airplane was a Cirrus Airplane Parachute System (CAPS), components of which are manufactured by Ballistic Recovery Systems, Inc. (BRS). According to Cirrus, CAPS is "a safety system designed to lower the entire aircraft to the ground in extreme emergencies."

[2] The description for this accident, CHI01FA169, can be found on the National Transportation Safety Board's Web site at <http://www.ntsb.gov>.

ARFF personnel arrived at the scene about 2 minutes after the airplane crashed. A firefighter who responded to the scene was later interviewed by the National Transportation Safety Board and stated that emergency workers, at first, did not notice the warning labels on either side of the aft fuselage indicating that the airplane was equipped with a rocket for parachute deployment. However, during fire suppression activities, another worker who recognized the airplane make and model alerted other firefighters to the potential hazard. After the accident, the Assistant Director of Aviation for SGF wrote a letter to the Safety Board investigator-in-charge (IIC) of the accident investigation, expressing concern that existing warning labels on Cirrus airplanes do not provide emergency workers with sufficient notice that "a possible hazardous device [is] located on the aircraft."

CAPS has been installed on all SR20 and SR22 airplanes (Cirrus has delivered about 1,000 to date).[3] In addition, since 1993, BRS (the manufacturer of CAPS components) has installed similar ballistic parachute systems in about 30 Cessna 150 and 172 airplanes under supplemental type certificates (STC).[4] CAPS has been deployed in at least one emergency involving a Cirrus SR22, possibly saving the pilot's life;[5] however, as was the case in the June 16, 2001, accident at SGF, the devices are not always deployed before an aircraft accident. Therefore, as a result of a proliferation of ballistic parachute devices in the general aviation fleet, emergency workers who respond to aircraft accidents are increasingly likely to encounter unfired ballistic parachute systems that could discharge during rescue and recover operations.

CAPS uses a solid-fuel rocket (stored in a compartment in the aft fuselage of Cirrus airplanes) to deploy a 55-pound parachute that allows the airplane to descend in a level attitude at about 26 feet per second. To activate the system, a pilot pulls an overhead handle in the cockpit (after removing a metal pin that secures the handle in a stowed position). The aluminum CAPS rocket, which weighs 1 pound 6 ounces, contains 1 pound of propellant, fires for 1.2 seconds, and accelerates to over 100 miles per hour in the first tenth of a second. It produces peak thrust of about 300 pounds. Under normal conditions, CAPS is well secured and is not prone to accidental firing. The rocket will only fire if the activation handle in the cockpit is pulled with sufficient force (about 35 pounds for Cirrus airplanes[6]). However, the system can be less predictable if an airplane has been in an accident. BRS addresses this safety issue in a publication for emergency workers (available on the company's Internet site), titled "Rocket-Deployed Parachutes on Civilian Aircraft May Pose Hazard to Emergency Personnel." The BRS publication advises that merely moving a damaged airplane could cause the rocket to fire and states the following:

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[3] CAPS is part of the type design approved in the initial type certification of Cirrus SR20 and SR22 airplanes, which were first delivered to customers in 1999. Under the Federal Aviation Administration's (FAA) equivalent level of safety certification policy, described in 14 CFR Section 21.21(b)(1), Cirrus was allowed to forgo spin recovery testing (described in Section 23.221) for its airplanes based on the demonstrated capabilities of CAPS.

[4] BRS has also manufactured about 3,000 ballistic parachute systems installed in experimental and homebuilt airplanes and about 10,000 installed in ultralight aircraft since 1981. Cirrus and Cessna airplanes are the only FAA-certificated aircraft with ballistic parachute systems installed.

[5] The description for this accident, FTW03LA005, can be found on the Safety Board's Web site at <http://www.ntsb.gov>.

[6] BRS does not have data regarding the pull force required to activate the system in other airplane models.

> Should the sections of an airplane be broken apart, the activating housing [a shaft that houses the cable that links the firing handle to the parachute] may become stretched tight. If the parts separate enough, the unit could be detonated even with the blast handle still secured by its safety pin.

Using rescue tools to extricate airplane occupants could also cause the rocket to fire. The activation cable (between the handle in the cockpit and a firing mechanism that ignites the rocket) need only be pulled forward 1/2 inch, with a force of about 35 pounds to activate the rocket. By comparison, hydraulic rescue tools are capable of applying as much as 18,000 pounds of force per square inch to cut or spread aircraft structures. In addition, crimping or snagging the activation cable could move it far enough forward to activate the rocket.

The BRS publication also includes detailed instructions for disabling BRS ballistic parachute units. These instructions direct emergency workers to identify and locate the activation handle, the rocket motor, and the metal housing protecting the cable that stretches from the handle to the rocket activation tube, noting that these components may have shifted during the accident sequence and may not be in their original locations. The instructions then direct emergency workers to cut the activation cable where it attaches to the launch tube, while avoiding the departure end of the rocket, to prevent the rocket's firing mechanism from being activated.

Emergency workers who move or cut airplane wreckage without determining the existence of a ballistic parachute system or who disregard the positioning of the rocket motor as they work with the wreckage risk death or serious injury. The Safety Board considers it critical to these workers' safety that they be able to quickly identify aircraft with these systems installed and take action to ensure that the systems are not accidentally deployed. Training that specifically addresses the hazards of ballistic parachute systems, as well as effective warning labels and markings, would greatly aid emergency workers in the safe completion of their activities.

Emergency Worker Training for the Identification and Disabling of Ballistic Parachute Systems

Current Federal Aviation Administration (FAA) regulations[7] and guidance[8] for ARFF training do not require or recommend training on the hazards associated with ballistic parachute systems. Safety Board informal communications with firefighters at three Part 139-certificated airports suggest that there is little awareness among some ARFF units regarding the hazards of ballistic parachute devices. Anecdotal evidence from Board investigators who have responded to accidents involving ballistic parachute-equipped airplanes supports the stated lack of awareness.

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[7] Title 14 CFR 139.319(j)(2) requires that ARFF personnel at land airports serving certain air carriers be trained in many general areas, including aircraft familiarization, rescue and firefighting personnel safety, emergency aircraft evacuation assistance, and adapting and using structural rescue and firefighting equipment for aircraft rescue and firefighting.

[8] Advisory Circular 150/5210-17, "Programs for Training of Aircraft Rescue and Firefighting Personnel," contains additional information on recommended training subtopics, such as identifying the hazards associated with aircraft and aircraft systems.

The Safety Board's investigation also revealed a lack of any national training guidelines for non-airport emergency personnel on this subject. Although the National Fire Protection Association (NFPA) publishes nationally recognized training standards for non-airport firefighting organizations (in addition to voluntary training standards[9] for ARFF personnel that complement FAA regulations and guidelines), these standards do not address the hazards associated with ballistic parachute systems either. As discussed earlier, the BRS publication about this safety issue is available on the Internet, but there has been no national effort to distribute this information to firefighters or other emergency responders.

To maintain their safety and the safety of any aircraft accident survivors, emergency personnel need to be trained to quickly identify aircraft containing ballistic parachute systems, determine whether the system needs to be disabled, and proceed accordingly. Therefore, the Safety Board believes that the FAA should revise training guidelines for Part 139-certificated airports to ensure that ARFF crews receive training in the recognition and disabling of aircraft ballistic parachute systems during emergency operations. The Safety Board also believes that the FAA should distribute a safety bulletin to all Part 139-certificated airports to raise awareness among ARFF crews regarding the hazards associated with ballistic parachute devices during general aviation rescue and firefighting operations.

Because many first responders to aircraft accidents are non-airport firefighters and to ensure that this population is informed of this safety issue, the Safety Board believes that the NFPA and the International Association of Fire Chiefs should, in cooperation with BRS and Cirrus Design, develop and distribute a safety bulletin to your membership to raise awareness among non-airport fire/rescue organizations regarding the hazards associated with ballistic parachute devices during general aviation rescue and firefighting operations. The Board also believes that the NFPA should update existing firefighter training standards for non-airport firefighting organizations to include information on the recognition and disabling of ballistic parachute systems.

Design for Disabling Ballistic Parachute Systems

In its instructions for disabling ballistic parachute systems, BRS "strongly recommends" using a Felco brand C.16 circular cutting tool (part number 39601-63-00) to cut the activation cable in its protective housing. The company's instructions stress that using the appropriate tool is important because any twisting during the cutting process (such as might occur with standard bolt cutters) could pinch the cable, possibly pulling it far enough to cause the rocket to fire. The instructions state that the ballistic parachute system is relatively safe after the activation cable has been cut, and emergency workers can more safely remove accident victims from the wreckage. After victims have been removed, BRS recommends taking the additional safety step of removing the rocket's fuel and firing the rocket igniters to render the rocket completely incapable of firing.

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[9] Relevant NFPA guidelines include the following: (1) *Recommended Practice for the Recurring Proficiency Training of Aircraft Rescue and Fire Fighting Services.* (1999). Standard 405. Quincy, Massachusetts: National Fire Protection Association. (2) *Guide for Aircraft Rescue and Fire Fighting Operations.* (2002). Standard 402. Quincy, Massachusetts: National Fire Protection Association. (3) *Standard for Aircraft Rescue and Fire Fighting Services at Airports.* (1998). Standard 403. Quincy, Massachusetts: National Fire Protection Association.

The Safety Board notes two shortcomings of BRS' disabling instructions. First, the instructions appear to have been designed with ultralight aircraft in mind. Although ballistic parachute systems are clearly visible on most ultralight aircraft, they are highly concealed on general aviation airplanes, especially the Cirrus models. There are no external markings on Cirrus airplanes revealing the location of CAPS components or identifying the rocket's exit path. The activation cable, which must be cut to disable the system, is concealed under materials inside the aft baggage compartment, with no exterior markings identifying its location. Second, the Felco tool recommended for cutting the activation cable inside its housing is not standard firefighting equipment. Airport firefighters contacted by Safety Board staff at three airports were unfamiliar with the Felco C.16, and one fire official at a major airport stated that firefighters typically carry more common types of bolt and cable cutters.[10] Because of the difficulty in locating the necessary components and the need for a special cutting tool, it is likely that firefighters or emergency workers would have difficulty disabling the ballistic parachute systems that are currently being factory-installed in general aviation airplanes. Therefore, the Safety Board believes that the FAA should develop standards for the design and installation of ballistic parachute systems in future general aviation aircraft to enable emergency responders to quickly and safely disable the system using only common firefighting tools and examine the feasibility of retrofitting aircraft that currently have ballistic parachute systems installed with a system that complies with the new design and installation standards.

Deficiencies of Current Exterior Warning Labels

The type certificate for Cirrus SR20 and SR22 airplanes and the STC for after-market installation of BRS units in Cessna airplanes require that warning labels for the units be affixed to the exterior of these airplanes (labels should be affixed to the aft fuselage on Cirrus airplanes and to the rear window on Cessna 172s[11], for example). However, there are no general FAA requirements or standards pertaining to the design of such labels. Cirrus designed the labels used on its aircraft and BRS designed the labels that are provided with aftermarket ballistic parachute installation kits. As shown in figures 1 and 2, the warning labels designed by Cirrus and those designed by BRS are very dissimilar.

The Safety Board identified several shortcomings with both companies' warning labels. According to the American National Standards Institute's (ANSI) 2002 *American National Standard for Product Safety Signs and Labels* (ANSI Z535.4),[12] warning labels should be subdivided into three panels. The first panel should contain an appropriate signal word,

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[10] Personal communication with Lieutenant/FAA Training Specialist, Chicago Fire Department, O'Hare International Airport, August 23, 2002.

[11] The Cessna 172 STC also requires that a label be affixed to the parachute canister, located inside the baggage compartment.

[12] This standard, first published by the National Electrical Manufacturers Association in 1992, provides guidelines for the design of safety signs and labels for application to products and is completely voluntary. For standards to be ANSI-approved, the standards developer must meet ANSI requirements for due process, consensus, and other criteria. A laboratory study conducted by Michael S. Wogalter, Ph.D., at North Carolina State University in 2002 found that warning labels consistent with the ANSI standard were better noticed, more often read, and produced greater understanding and compliance [Wogalter, M.S. (2002). Guidelines for Warning Design: Do they matter? Paper presented at the 46th Annual Meeting of the Human Factors and Ergonomics Society, Baltimore, Maryland.]

accompanied by a safety alert symbol,[13] that advises readers of the hazard and is written in black letters against an orange background. The second panel should contain a message that informs readers of the consequences of not taking precautions to avoid the hazard and provides instructions for avoiding the hazard.[14] ANSI Z535.4 also states that the message panel should be legible from a minimum safe viewing distance. Finally, the third panel should contain a safety pictorial that rapidly conveys information about the nature and consequences of the hazard to people who do not or cannot read the message panel.

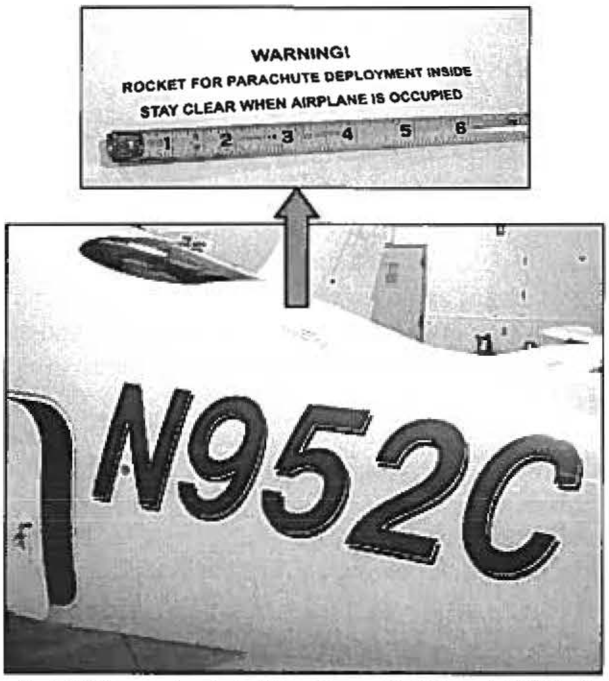

Figure 1. CAPS warning label for Cirrus SR20 and SR22 airplanes

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[13] According to the ANSI standard, the signal word "warning" is used to indicate a hazard which, if not avoided, could result in death or serious injury. The ANSI standard safety alert symbol is an exclamation point surrounded by an equilateral triangle.

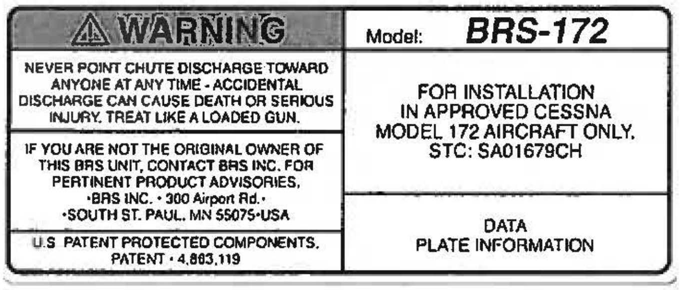
[14] According to a 1996 study on the effectiveness of signs and labels, failing to provide information about hazard consequences reduces the likelihood of compliance with recommended safety precautions. [Wogalter, M.S., and Laughery, K.R. (1996). WARNING! Sign and label effectiveness. *Current Directions in Psychological Science*, 5, 33-36.]

Label Affixed to Aircraft Rear Window

WARNING

This aircraft is equipped with a ballistic parachute recovery system.
Rocket motor is installed under cover. Remain clear. Factory sealed unit,
do not open or disassemble. See Airplane Flight Manual Supplement or BRS
Operators Manual for inspection procedures.

Label Affixed to Parachute Canister



WARNING

NEVER POINT CHUTE DISCHARGE TOWARD
ANYONE AT ANY TIME - ACCIDENTAL
DISCHARGE CAN CAUSE DEATH OR SERIOUS
INJURY. TREAT LIKE A LOADED GUN.

IF YOU ARE NOT THE ORIGINAL OWNER OF
THIS BRS UNIT, CONTACT BRS INC. FOR
PERTINENT PRODUCT ADVISORIES.
•BRS INC. • 300 Airport Rd.•
•SOUTH ST. PAUL, MN 55075•USA

U.S PATENT PROTECTED COMPONENTS.
PATENT • 4,863,119

Model: *BRS-172*

FOR INSTALLATION
IN APPROVED CESSNA
MODEL 172 AIRCRAFT ONLY.
STC: SA01679CH

DATA
PLATE INFORMATION

Figure 2. BRS Warning Labels for the Cessna 172

As shown in figure 1, the Cirrus warning label does not use the panel format. Although it contains an appropriate signal word (in this case, "warning"), it does not contain a safety alert symbol, nor does it use the recommended orange background. The label also lacks a message panel that provides information regarding steps that emergency workers can take to avoid the hazard and that explains the potential consequences of failing to avoid the hazard (in this case, that a person struck by the rocket or flying debris or exposed to the blast during an accidental firing could be killed or seriously injured). Although the Cirrus label instructs those outside the airplane to "stay clear when [the] airplane is occupied," there are no markings showing the exit point of the CAPS rocket, or otherwise indicating unsafe areas outside the airplane. Moreover, the instruction to stay clear is not useful information for emergency workers who may need to rescue trapped occupants. It does not explain that moving or cutting the wreckage after an accident could cause the rocket to fire and does not point emergency workers to the appropriate location to cut the activation cable if they need to disable the ballistic parachute system. In addition, the text size on the current Cirrus label does not allow personnel to identify the hazard from a safe viewing distance. The largest letters (in the word "warning") are 1/4 inch high, which requires the reader to get quite close to the rocket exit point to read the label. Furthermore, the label lacks a safety pictorial that warns those who do not or cannot read the written message. Finally, Cirrus does not currently affix any warning label to the rocket canister, which would increase the difficulty of identifying this component if it were to become displaced from its normal position during a crash.

The BRS-designed labels are superior to the Cirrus warning label in some respects. For example, both labels feature an ANSI-style safety alert symbol and the signal word "warning" in black letters against an orange background, as recommended by ANSI Z535.4.[15] In addition, on the canister label, the signal word and safety alert symbol are presented in their own panel, as

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[15] BRS referred to a 1991 version of ANSI Z535.4 when designing its warning labels.

recommended by ANSI Z535.4. The canister label also describes the potential consequences of failing to avoid the hazard and provides specific information on how to avoid the hazard. Although the BRS warning labels are an improvement over the Cirrus label, they also have shortcomings. Like the Cirrus warning label, the message panel on the BRS label intended for use on the aircraft exterior contains small lettering that would be difficult to read from a distance. Also like the Cirrus label, the BRS exterior label provides the reader with an instruction to "remain clear," a safety precaution that may not be specific enough to be useful to emergency workers. Information for avoiding the hazard, which is included on the canister label, would not be seen easily from outside the aircraft. Like the Cirrus label, the BRS labels do not provide a safety pictorial illustrating the nature of the hazard and hazard consequences.

The Safety Board is concerned that current warning labels and exterior markings on general aviation airplanes containing ballistic parachute systems are poorly designed. The Board notes that BRS and Cirrus pioneered the development of ballistic parachute systems for general aviation airplanes and, therefore, possess considerable expertise regarding the hazards of these systems. Furthermore, the Board notes that the FAA's ARFF working group has considerable expertise regarding the training and working practices of airport rescue personnel, as does the NFPA with regard to non-airport rescue personnel. Therefore, the Safety Board believes that the FAA should work with BRS, Cirrus Design, the NFPA, and the ARFF working group to establish design requirements for warning labels and exterior markings for airplanes equipped with ballistic parachute systems that meet the ANSI guidelines for conspicuity, coloration, visibility, and content.

Therefore, the National Transportation Safety Board makes the following recommendations:

—To the Federal Aviation Administration:

> Revise training guidelines for 14 *Code of Federal Regulations* Part 139-certificated airports to ensure that airport rescue and firefighting crews receive training in the recognition and disabling of aircraft ballistic parachute systems during emergency operations. (A-04-36)
>
> Distribute a safety bulletin to all 14 *Code of Federal Regulations* Part 139-certificated airports to raise awareness among airport rescue and firefighting crews regarding the hazards associated with ballistic parachute devices during general aviation rescue and firefighting operations. (A-04-37)
>
> Develop standards for the design and installation of ballistic parachute systems in future general aviation aircraft to enable emergency responders to quickly and safely disable the system using only common firefighting tools and examine the feasibility of retrofitting aircraft that currently have ballistic parachute systems installed with a system that complies with the new design and installation standards. (A-04-38)

> Work with Ballistic Recovery Systems, Inc., Cirrus Design, the National Fire Protection Association, and the airport rescue firefighting working group to establish design requirements for warning labels and exterior markings for airplanes equipped with ballistic parachute systems that meet the American National Standards Institute's guidelines (ANSI Z535.4) for conspicuity, coloration, visibility, and content. (A-04-39)

—To the National Fire Protection Association and the International Association of Fire Chiefs:

> In cooperation with Ballistic Recovery Systems, Inc., and Cirrus Design, develop and distribute a safety bulletin to your membership to raise awareness among non-airport fire/rescue organizations crews regarding the hazards associated with ballistic parachute devices during general aviation rescue and firefighting operations. (A-04-40)

—To the National Fire Protection Association:

> Update existing firefighter training standards for non-airport firefighting organizations to include information on the recognition and disabling of ballistic parachute systems. (A-04-41)

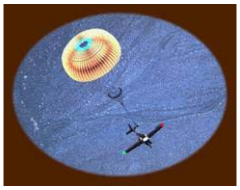
Please refer to Safety Recommendations A-04-36 through -41 in your reply. If you need additional information, you may call (202) 314-6177.

Chairman ENGLEMAN CONNERS, Vice Chairman ROSENKER, and Members GOGLIA, CARMODY, and HEALING concurred in these recommendations.

Original Signed

By: Ellen Engleman Conners
Chairman

Annex 4



BRS Ballistic Parachutes:

Information for Emergency Personnel

Airplane crashes are rather rare events, thankfully. This helps illustrate that aircraft, whether commercial airliners, general aviation aircraft or recreational sport planes, are quite safe when flown by competent pilots.

However, the rare nature of these crashes also means that those who arrive first at the scene of an accident (rescue workers, investigating officers, fire fighters, and other safety personnel) may be overwhelmed or not recognize the parts of the aircraft particularly well.

One potential hazard rescue workers may encounter is an unfired, rocket-deployed emergency parachute system (sometimes called a **ballistic parachute**). While these devices are intended to save lives, they have the potential to cause injuries or even death to rescue workers.

An emergency call takes you to the scene of an aircraft accident. Victims inside may be injured. You want to act quickly but people at the scene warn you about a rocket-deployed parachute installed on this airplane. The pilot did not activate the safety device and now you may find yourself working on or near the airplane with its ballistic device still ready to fire. You want to help the victims, but you don't want to harm yourself or others around you. Perhaps the occupants escaped without serious injury and may be out of the plane, but the wreckage must be dealt with and a damaged aircraft with a ballistically-deployed parachute can be lethal. What do you do?

In the hope of preventing a secondary tragedy, this document attempts to address the safety questions facing emergency personnel.

SUMMARY... But Please Read the Entire Article

The following summary provides the minimum steps to disarm a BRS rocket motor:

1. **Locate** the BRS parachute system by finding the parachute pack (see photo of container types). NOTE: Keep in mind that a badly broken apart airplane *may* have already put the activating housing into a stretched state that could be close to firing.
2. **Identify** the rocket motor launch tube (photos inside). Note where the activating housing attaches to the base of the launch tube.
3. **Cut** the activating housing at the base of the launch tube using a Felco-brand cutter (identified within) or equivalent.
4. **Remove** the still-live rocket motor to a secure place and contact BRS for further directions about permanently disabling it.

What Does "Ballistic" Mean?

The term ballistic in this context has nothing to do with guns or ammunition. Instead it refers to a means of extracting a parachute. For Ballistic Recovery Systems (BRS) today, this means a **rocket-deployed** emergency parachute system.

Used as intended, these BRS-brand emergency parachute systems have saved over 175 lives. More correctly stated - they save lives if used. However, the pilot must elect to deploy the system, completely different than, say, an airbag which deploys automatically when certain conditions develop. Because the pilot (or his passenger) must pull the activating handle, sometimes the units are not used.

The pilot may have felt he could rescue the plane from its predicament. Or he may have been unable to deploy for physical or other reasons, such as being at very low altitude. Regardless of why a ballistic parachute was not used, the fact remains for safety personnel that when handling an accident where a BRS unit was not deployed, a potentially dangerous device now confronts them.

How Dangerous Are They?

The rocket motors are ignited by pulling an activation handle in the cockpit. They then accelerate to over 100 mph in the first tenth of a second after ignition. While the total firing period is only one second, someone in the path of an escaping rocket could be seriously injured or killed. These are powerful rockets (about 1½-2 inches diameter and 8-10 inches long) that work very efficiently. At left is a test of a Cirrus system showing the 55 pound parachute pack being pulled by the rocket motor. This is a fraction of a second after ignition.

The danger to safety personnel may now be more obvious. A rescue worker who disregards the position of the ballistic parachute system, or who moves the aircraft without determining the existence of a ballistic parachute system may put him or herself in considerable jeopardy. BRS has worked with NTSB and FAA personnel, as well as rescue personnel throughout the country and around the world. We have assembled this information for safety personnel to disarm these systems, but caution is required.

COMPONENT DESCRIPTION/INSTALLATION DIAGRAMS

A BRS unit is comprised of four major elements: Activation Handle, Activation Cable or *Housing*, Rocket Motor Assembly and Parachute Container.

The first thing emergency people may see is a red firing handle. This will be located near the seats, as it obviously must be close to the pilot. The red firing handle will connect to the activation housing, the flexible cable that links the firing handle to the igniter.

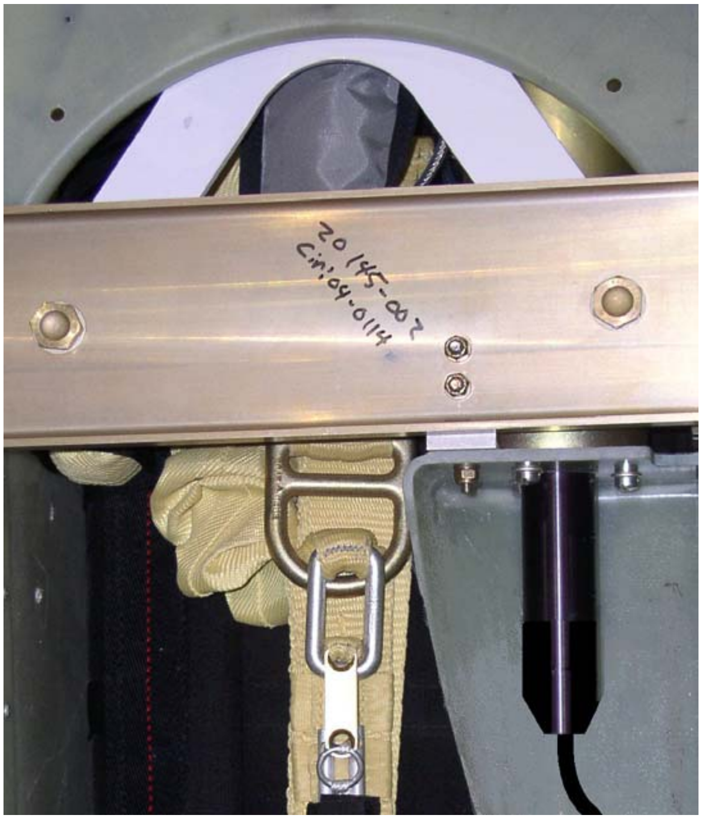
In the picture below, see that each handle is secured with a safety pin. This is to remain with the handle until the aircraft departs for flight, at which time the pilot should then remove the pin. **A first step for emergency personnel is to place some type of 3/16 inch pin or rod into the handle holder.** This provides some measure of security as you proceed to further disarm the system.

PARACHUTE CONTAINERS

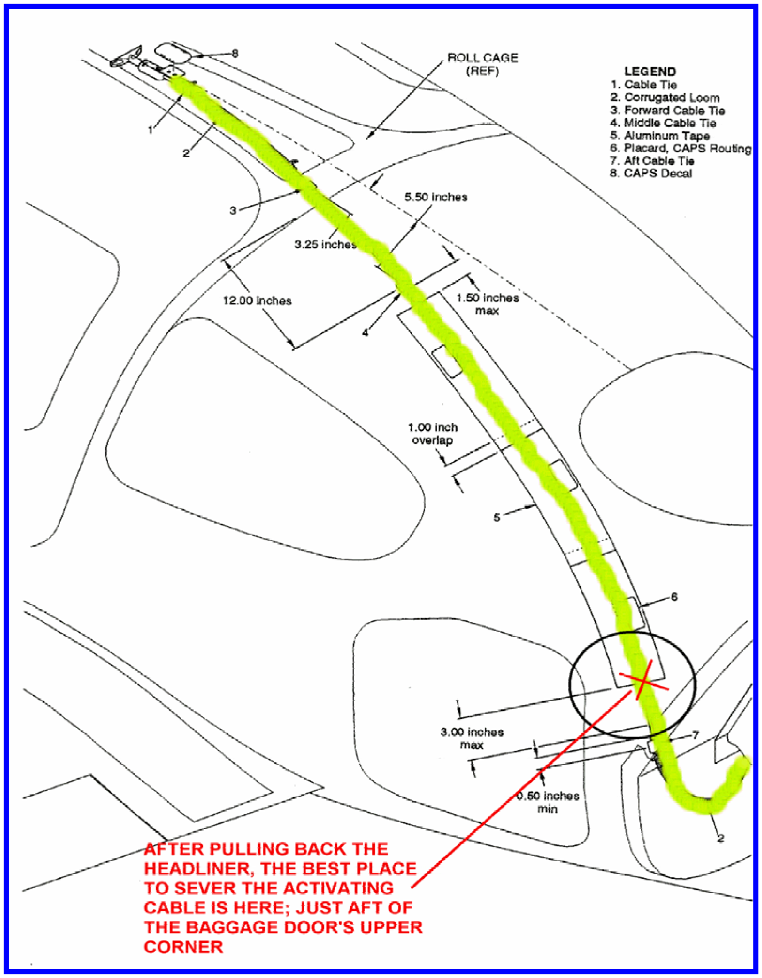
The parachute may be housed in a fabric covering called a *softpack*, in a fiberglass box called a *VLS* (vertical launch system), or a white aluminum *canister*. Each of the various container types may be mounted in a variety of locations, according to aircraft design.

At right is the BRS **Canister** system, very commonly used in a wide variety of ultralight, experimental and sport aircraft. They come in sizes for aircraft ranging from 500 to 1200 pounds GTW. Below are the softpack and VLS systems.

CIRRUS



The photo at left shows the **Cirrus** parachute installed into its stowage area, located just behind the baggage compartment. It is normally covered by a sheet metal panel and carpet, which is secured with Velcro. The rocket motor is mostly hidden behind the aluminum beam; the igniter is visible in the upper right center as a black cylinder. The Cirrus parachute is contained within a heavy nylon bag, so it is a *softpack* by definition.



AFTER PULLING BACK THE HEADLINER, THE BEST PLACE TO SEVER THE ACTIVATING CABLE IS HERE; JUST AFT OF THE BAGGAGE DOOR'S UPPER CORNER

CIRRUS

This illustration shows the routing of the activation cable in a Cirrus SR20 or SR22 aircraft, which is covered entirely by headliner panels. The best place to expose the cable is just aft of the baggage door, near the upper right corner.

Cessna 172


Top View


Interior View


Activating Cable

The above three photos show the location of the parachute canister and rocket in the **Cessna 172**. The aluminum parachute canister (large box) is in the left rear of the

baggage area, as viewed from the front seats. The rocket is on the left of the parachute canister; the activation cable runs down to the floorboard, under a cover, then forward to the activation handle, located near the fuel selector.

At left, the **C172** rocket and igniter with the plastic cover having been removed. The rocket motor is secured to the igniter base by three 10-32 nylon screws which fracture at firing.

Here is another perspective of the **C172** rocket assembly with cover removed. It is just a few inches below the rear window, which it will readily break through when fired. Inside the launch tube resides the rocket motor, it's the red cylinder.

This is a close up of the **BRS 900** rocket motor, common to both Cessna and Cirrus installations. It produces roughly 225 pounds of thrust over a 1.2 second burn time and must be respected. It burns solid propellant derived from military formulations and is very resistant to accidental initiation.

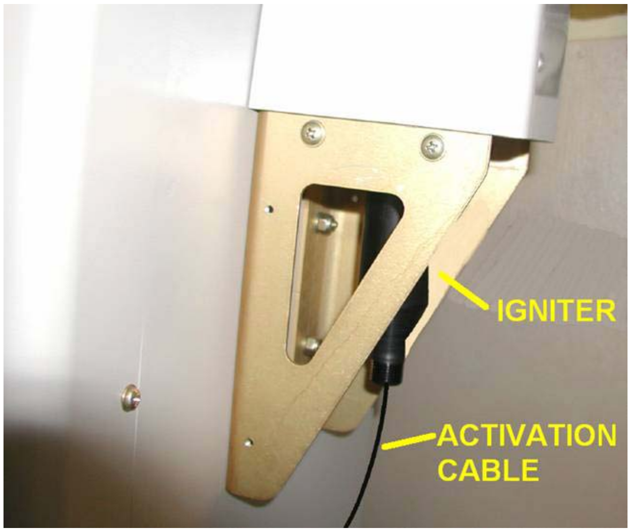
Cessna 182

Top View, thru window

Top View, inside

Handle Box

Many of the design elements of the newer, C182 ballistic parachute system are similar to its predecessor, the C172. The canister is rotated 90 degrees and the rocket is located *aft* of the canister, however, the activation cable is still relatively accessible prior to being covered on the floorboard. The best way to reach the cable would be through the left side baggage door, if possible. As shown here, the rocket motor and igniter are covered by the upper and lower rocket shields, which are intended to protect the components from bumping. To gain access to the cable, perform the following steps:



1. Using a Phillips screwdriver, remove the two 8-32 screws securing the left side of the lower rocket shield
2. Place force on the shield in an effort to move it *away* from the parachute canister. Even though there are two more screws on the right side, it should fracture and may then be pushed out of the way.
3. You will then see the igniter and the activation cable, as at left.
4. Using the Felco cutter, or equivalent, proceed to cut the cable 1” – 2” from the end.
5. The rocket has now been rendered safe, and it may be removed for disposal or safe storage.

Note: This photo shows the routing of the activation cable between the front seats in either C172 or C182 installs. It is partially protected by aluminum channel, as you see in the right of the photo. Aluminum tape is also used to secure the cable to the floor. For any reason, should you be unable to access the cable near the igniter, this is a secondary point of access.

HISTORICAL NOTES:

ROCKET OR DROGUE GUN?

In 1987, a determination was made that a solid propellant **rocket motor** was the best choice to extract the parachute. It is, therefore, increasingly unlikely that emergency personnel will encounter the older systems which employed a device called a *drogue gun,* which relies on *kinetic energy* to extract the parachute. The drogue gun is basically a small cannon which fires a heavy weight using a propellant charge. Both systems, however, will be located very near the parachute; and both are disarmed using these techniques.

CHANGES TO THE ACTIVATION HOUSING (CABLE)

The activation housing on BRS units has changed over the years. The material formerly was a flexible, spiral-wound, bright silver stainless tube of about a half inch diameter. Later this became a braided stainless material similar in appearance and size. The newest models use a black plastic exterior that resembles a bicycle brake cable.

AT THE SCENE

Rescue personnel should first determine the **existence** of a BRS-brand unit. You can scan for a company logo, often placed on the outside of the aircraft. Or you can look for the unit itself. The container, which holds the parachute canopy, will always have a company logo on it, and it's the largest component. If possible, l**ocate** the parachute container, rocket, activation cable (housing) assembly and activation handle.

The activation housing, again, joins the firing handle on one end to the rocket motor on the other. **Pulling either end away from one another can fire the unit**. Normally the handle and the parachute unit will be mounted securely, but as stated above, in an accident, orientation may change. Rescue workers, police officers, and fire fighters should initially exercise extreme care when working around these systems, especially if the airplane is severely broken up or the activation cable appears to be tightly stretched.

Examine the parachute container. Alongside the parachute container should be a 2-3 inch diameter black, silver or white tube about 10 inches in length. This is called the **launch tube** and it contains the rocket motor. In Cessna installations, the rocket is further covered by a rectangular plastic or fiberglass cover, as discussed previously.

A rocket motor assembly consists of two principle parts: The launch body, which will leave the launch tube when fired; and the igniter, which remains in the launch tube after ignition. The launch tube on newer units is covered with a plastic cap while on certain older models it remained open.

Cirrus/Cessna Rocket

Sport Launch Tube

Sport Launch Body

HAS THE ROCKET FIRED?

If the airframe has experienced significant breakup, there is a very good chance that the rocket motor has been initiated. Telltale signs of this would be the parachute canopy extracted from it's container, the rocket motor no longer in the launch tube, a burned appearance on the lanyards joining the rocket motor to the parachute or being unable to locate the rocket motor at all. A rocket motor that has separated from the igniter poses no significant hazard, unless it is exposed to fire. Experience has shown that a rocket motor subjected to high temperatures (fire) will not ignite in a normal manner and launch. Rather, they have been observed to burst in a relatively non-threatening display.

After a determination is made that the rocket is live, under no circumstances should rescue personnel place any part of their person in front of the launch tube. Clear a 90 degree area in front of the rocket motor, extending 100 feet out, if possible.

THE IGNITER ASSEMBLY

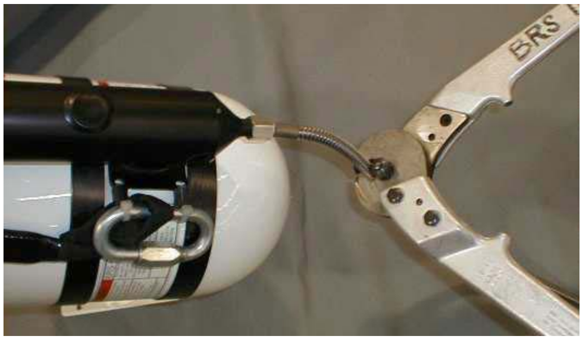
THE ROCKET MOTOR IGNITER IS NOT AN ARMED, HAIR-TRIGGER DEVICE. It requires a deliberate pull of about 30-40 pounds to cock and fire the system. Both cocking and firing are accomplished by one pull of the handle. Because of the design, the handle will come free of the handle holder and travel roughly **two inches** unimpeded. Then, spring compression begins. At that point, the system needs only about **7/16 inch of additional movement to ignite**.

Under certain circumstances, crash forces may physically separate the rocket from the igniter. This separation alone greatly reduces risks. The igniter contains two shotgun primers and a small amount of black powder/magnesium mix. The output is a loud report and a flash of flame. This could cause minor injury, but it is not particularly dangerous. Should one encounter this scenario, cutting the activating cable is still desirable.

SEVERING THE ACTIVATION CABLE

BRS **STRONGLY RECOMMENDS** using a Felco-brand cutter, which is sold in several models from the compact C7 to the larger C16. They can be obtained from various sources, including Sanlo Manufacturing Co: http://www.sanlo.com/product/tools.htm.

Greenlee Company, Div. of Textron, manufactures similar products made specifically for cutting cables, which can be viewed on line at: http://www.greenlee.textron.com. Greenlee offers several catalog numbers that would work well, including 704,706,718 or 727(compact).



This photo shows the larger **Felco C16** cutter being used to sever one of the older style, stainless steel cable assemblies.

NOTE: DO NOT ATTEMPT TO CUT THE ACTIVATION HOUSING WITH AN ORDINARLY BOLT CUTTER OR SIDE CUTTER! They are ***NOT*** effective at cutting the cable housing. The Felco or Greenlee brand cutters gather the cable and work with surprising ease. They make a worthy addition to any rescue organization's standard tool box; being useful for cutting fences, steel cables, and other obstacles which may prevent workers from reaching the scene of an accident or freeing occupants.

Using the diagrams and information presented here, **locate** a point in the activation cable located near the igniter, then cut it using the Felco or Greenlee cutter. Care must be taken, however, not to twist the housing while cutting it. Once the housing is severed, the system is rendered relatively harmless and rescue workers should face no further danger handling the accident victims or aircraft wreckage.

ATTACHMENT TO THE AIRFRAME

Worth mentioning are the mounting hardware components and attachment bridles which connect parachute to aircraft. Made from nylon or Kevlar, the bridles connect the parachute canopy to designated points on the fuselage. Conceivably, it may be necessary to cut or remove the bridles to gain access to components or injured parties. A sharp knife, or your Felco cutter, may be used to sever them if required.

DISPOSTION OF ROCKET MOTOR

Later, after immediate concerns have been addressed, emergency workers are advised to remove the rocket motor and to completely disarm it by removing the rocket fuel, and firing the igniter. Alone, separated from the igniter, the rocket poses very little danger, but it should be stored in a secure location. BRS will provide assistance for this effort, which can be obtained by calling 651-457-7491 during business hours, CST. Alternatively, contact Cirrus Design at 800-279-4322 or 218-727-2737.

ALTERNATIVES

Some agencies that BRS has communicated with take a very conservative position regarding how best to handle an unfired rocket. They feel that this is work best left to the local bomb squad. We leave such decisions entirely up to the individuals in charge at the scene. However, if the above steps are followed and normal precautions observed, we feel that disarming the system can be safely accomplished by emergency personnel without undue risk.

A CAUTION AND DISCLAIMER

While the advice above should prevent problems for safety personnel in most situations, the instructions given **apply to BRS brand products only**. Other brands identified as Pioneer, Second Chantz, Advanced Ballistic Systems, Galaxy, or GQ Security have been sold in the past. While these systems are similar, they are not identical. BRS can provide no information on how to disarm these systems.

Annex 5

Australian Government
Australian Transport Safety Bureau

Aviation safety issues and actions

Recommendation

Output No:	R20040095
Date Issued:	21 January 2005
Safety Action Status:	
Background:	**SADN DESCRIPTION**

Some light aircraft are fitted with rocket-assisted recovery parachute systems. These parachute systems are designed to recover the aircraft and passengers to the ground should a serious in-flight emergency arise.

Composite structured aircraft such as the Cirrus Design SR20 and SR22, Pipistrel Virus and Sinus and the Sting TL-2000 are fitted with the system at manufacture. Others, such as the Cessna 150/152, 172 and 182 series aircraft can be retro-fitted with these rocket-assisted recovery parachute systems.

Numerous sport aviation and ultra-light aircraft in Australia are also fitted with rocket-assisted recovery parachute systems. Estimates from Recreational Aircraft Australia (RAA) indicate that there are currently at least six different types of ultra-light aircraft on the RAA register that are fitted with rocket-assisted recovery parachute systems. The exact number of sport aviation and ultra-light aircraft with these installations was not determined.
An armed and un-deployed rocket-assisted recovery parachute system presents a potentially serious safety risk to personnel attending the site of an accident. There is also inconsistent identification and marking of the hazards posed by the rocket and the associated equipment on the external surfaces of the aircraft. Any failure to correctly identify the hazard posed by the rocket at an accident site could result in serious injury or death.

Cirrus Airframe Parachute System (CAPS)

The Cirrus Design SR20 and SR22 aircraft are fitted with the Cirrus Airframe Parachute System (CAPS) ballistic recovery parachute system at manufacture. The CAPS system is manufactured by Ballistic Recovery Systems Inc. (BRS) in the United States (US). When deployed in an emergency situation, the system is intended to bring the aircraft and its occupants safely to the ground.

The system consists of a composite enclosure containing the parachute and a solid-propellant rocket for parachute deployment, a CAPS Activation T-handle that is positioned in the ceiling liner of the cockpit and a parachute harness.

The composite enclosure containing the parachute and rocket assembly is positioned in the aircraft immediately behind the cabin baggage compartment bulkhead. The parachute on the Cirrus is enclosed within a 'deployment bag' inside the box. The deployment bag stages the parachute's deployment and inflation. A thin composite cover that is faired into the aft upper fuselage structure protects the parachute assembly.

The parachute is attached to the aircraft by three harness straps. The single rear harness strap supports the rear of the aircraft and is attached to the structure of the rear baggage compartment bulkhead. The two forward harness straps are attached to the engine firewall area and support the front of the aircraft following parachute deployment. Both of the front straps are concealed in channels beneath a thin composite fuselage outer skin and pass from the rear baggage compartment below the cabin windows and door frame.

The CAPS Activation T-handle is positioned in a recess in the cabin ceiling lining above the front seats. The T-handle is concealed by a placarded cover that must be removed before the handle can be pulled for CAPS operation

(See Figure 1).

Figure 1: Roof mounted CAPS activation handle cover
For Figure 1 photograph refer to Analyst Notes 2
The CAPS handle is made 'safe' by the insertion of a safety pin into the Activation T-handle mechanism. The safety pin is normally removed during the pre-flight inspection of the cabin area. The pin has a 'remove before flight' tag attached.

To operate the CAPS system in an emergency, the pilot removes the placarded cover and pulls down on the CAPS Activation T-handle. A pull force of about 35 lb is required to activate the system. During the deployment sequence, the rocket forces the parachute canister up through the concealed composite fuselage cover. As the parachute inflates, the two forward attachment harnesses are pulled through their composite covering beneath the fuselage skin.

A warning in the Cirrus's maintenance manual indicates [1]:

The rocket exits the fuselage with a velocity of 150 mph in the first tenth of a second and reaches full extension in less than one second. People near the airplane may be injured and extensive damage to the airplane will occur.

Rocket ignition will occur at temperatures above 500^{o} F (260o C).

Cessna Aircraft

The Cessna 150/152 series of aircraft can be fitted with a specifically designed BRS manufactured General Aviation Recovery Device - GARD-150 parachute system. The system uses a rocket for deployment and is approved for fitment by a Federal Aviation Administration (FAA) Supplemental Type Certificate (STC). The rocket deploys the parachute through a fabric covering in the rear upper fuselage area.

The Cessna 172 and182 aircraft can also be fitted with a BRS parachute by STC. The BRS installations in these aircraft position the rocket in the baggage compartment at the rear of the cabin area and the parachute is ejected through the right half of the rear window. The forward parachute attachment straps are routed from the exit point across the upper centreline area of the fuselage beneath a fibreglass fairing unit.

Sting T-2000, Pipistrel Virus and Sinus Aircraft and Ultralight Aircraft

The Sting TL-2000 aircraft can be registered on the Australian civil aircraft register or as an ultra-light aircraft. The Sting uses the European-manufactured rocket powered Galaxy Recovery Systems (GRS) installation as do the Pipistrel Virus and Sinus aircraft. This system is installed in the rear cabin area of the aircraft and projects the parachute through the rear cabin window area. Once the parachute has been deployed, the rocket continues beyond the canopy until the propellant is spent and then falls away to the ground.

Other ultra-light aircraft use one of several styles of parachute depending on the type of aircraft. Some of these systems deploy in an upward direction, while others deploy downward or rearward. Systems from BRS, GRS and others were identified as installed in these aircraft. A check of the BRS web-site revealed a list of 100 different mounting installations, in both ultra-light and other types of aircraft such as hang gliders and gyrocopters.

Information from BRS indicated that some systems made before 1987 used a 'drogue-gun' device for parachute deployment. The 'drogue-gun' utilises a weight fired by a propellant charge to pull the parachute out of its canister.

Danger markings and accident site safety

There are a variety of warning markings on aircraft to indicate the presence of the parachute systems. On the Cirrus aircraft there is a small black text warning that is placed adjacent to the unmarked exit point for the parachute (see Figure 2). The largest size text on the warning is about 6 mm high. The Cirrus warning is not conspicuous and could easily be overlooked following an accident.

The Cirrus warning decal states the following (see Figure 3):

WARNING!
ROCKET FOR PARACHUTE DEPLOYMENT INSIDE
STAY CLEAR WHEN AIRPLANE IS OCCUPIED

There are no warning markings printed on the rocket motor canister. There are also no markings on the aircraft's fuselage to delineate the exit path of the forward harness straps on the aircraft, or that clearly mark the outline of the concealed hatch above the parachute.

Figure 2: Side view of rear of Cirrus aircraft highlighting the CAPS warning decals on fuselage

For Figure 2 photograph refer to Analyst Notes 2

Figure 3: Warning decal on Cirrus aircraft

For Figure 3 photograph refer to Analyst Notes 2

The Cessna 172 BRS system STC includes a requirement for a warning decal to be placed on the rear window of the aircraft and another on the rocket canister. The rear window decal has an orange background and contains the following text:

WARNING
This aircraft is equipped with a ballistic parachute recovery system
Rocket motor is installed under cover. Remain clear. Factory sealed unit
Do not open or disassemble. See Airplane Flight Manual Supplement or BRS Operators Manual for inspection procedures.

A warning decal sheet supplied with the GRS systems included a small decal with a directional arrow head that indicated:

ATTENTION
PYROTECHNICAL DEVICE
Keep away from the firing line

Another decal listed warning text detailing some of the dangers of the system.

The small black text warning on the Virus aircraft GRS system (see Figure 4) indicated the following:

ATTENTION
EXPLOSIVE
ROCKET INSIDE!

Figure 4: The Pipistrel Virus aircraft and GRS parachute exit cover

For Figure 4 photograph refer to Analyst Notes 2

A document for Emergency Personnel, that was located on the BRS Inc. website, indicated that rocket-deployed parachutes have the potential to cause injuries or death to rescue workers at aircraft accident sites. The document indicated that the 38 mm by 250 mm rocket will accelerate to over 160 kph in the first 1/10th of a second on activation. Similar information is published by Cirrus Design in a DVD titled Cirrus Airframe Parachute System, Advisory DVD for First Responders.

The activation of the Cirrus CAPS installation relies on the pilot pulling on the handle connected to the cockpit roof mounted inner activation cable. The GRS and BRS units in other aircraft are similarly activated. During an accident, where the parachute has not been deployed, deformation of the fuselage can result in the activation cable being under abnormally high tension, with the activation device ready to be triggered by any further movement of the wreckage. This warning is highlighted in the BRS Emergency Personnel document and in the Cirrus Design DVD.

The BRS Emergency Personnel document and the Cirrus Design DVD both mention cutting of the activation cable as a method of temporarily making the system safe. The BRS information strongly recommends that the cable should only be cut using Felco C16 or Greenlee Company cable cutters.

Aircraft accident sites can often be contaminated with flammable materials and with flammable liquids such as petroleum products following the destruction of integral fuel tanks in wings and fuselages. Due to the possibility of causing a fire, rescue organisations, police and investigators need to be vigilant about the type of equipment used on site, including the use of mobile telephones. ATSB investigators also use sealed, flash-proof torches on site for that reason. Any inadvertent activation of a ballistic parachute rocket motor could present a direct ignition source for these materials and liquids resulting in danger for on-site personnel and accident survivors.

ATSB Occurrence BO/200300548

A collision that occurred during landing, which involved a Cessna C172 and an ultra-light registered Sting TL-2000 aircraft in West Australia in 2002, highlights the on-site dangers of rocket-assisted recovery parachutes. During that accident the nose and propeller of the C172 aircraft had become entangled with the rear fuselage structure of the Sting aircraft.

The Sting aircraft had a GRS rocket-assisted parachute system fitted, which had not been deployed. On-site assistance was received from an expert experienced in the Sting aircraft and its GRS parachute installation. That expert noted that the GRS's rocket actuation cable had become entangled with the C172's propeller. He also indicated that any further rotation of the C172's propeller may have pulled the cable and activated the rocket. Activation of the rocket at that point may have deployed the parachute into the wing of the C172, possibly rupturing the aircraft's fuel tank. With the assistance of that expert the rocket was removed from the wreckage and disposed of by police explosive experts.

During the initial post-accident phase, no-one present on site was fully aware of the imminent dangers they were facing with the GRS installation.

Sukhoi SU-31M aerobatic aircraft Zvesda extraction system

While not yet on the Australian civil aircraft register, the Sukhoi SU31-M aerobatic aircraft utilises a Zvesda light weight pilot extraction system. This extraction system is a type of ejection seat and is used to quickly extract the pilot from the aircraft in the event of a problem.

The pilot extraction system weighs about 15 kg and utilises a 'small' quantity of explosive to simultaneously release the pilot's safety harness and extend a 5 metre long, 10 cm wide, telescoping tube. The telescoping tube punches through the cockpit canopy and extracts the drogue parachute 5 metres from the aircraft. The drogue parachute then deploys and allows the main parachute to pull the pilot free of the aircraft. This aircraft has a red, black and white 'ejection system' decal fixed to the outside of the fuselage adjacent to the danger area on the aircraft (see Figure 5). That decal is an immediately recognisable International danger symbol.
Figure 5: Example of an ejection seat danger symbol

For Figure 5 photograph refer to Analyst Notes 2

Applicable US Federal Aviation Regulation (FAR) requirements

The Cirrus SR20 and SR22 aircraft are certified for flight in accordance with the requirements of US Federal Aviation Regulations (FAR) Part 23.

FAR 23.1541 (a) (2) indicates that an aircraft certified under FAR 23 must contain 'Any additional information, instrument markings, and placards required for the safe operation if it has unusual design, operating, or handling characteristics'.

FAR 23.1541 (b) (1) and (2) indicate that each placard must be displayed in a conspicuous place and may not be easily erased, disfigured or obscured.

Type Certificate Data Sheet (TCDS) number A00009CH, revision 3, applies to the Cirrus SR20 and SR22. That certificate, including any Special Conditions, prescribes the conditions and limitations under which the aircraft meets the Federal Aviation Administration (FAA) airworthiness requirements. The Special Conditions listed on the Cirrus TCDS applies to the ballistic parachute in the CAPS system and refer to Special Condition 23-ACE-88. Note 2 in the TCDS indicated that all placards in the Pilots Operating Handbook and FAA Approved Airplane Flight Manual for the Cirrus SR20 and SR22 must be displayed in the aircraft in the appropriate locations.

Special Condition 23-ACE-88 indicates that a warning placard is to be located on the fuselage near the rocket motor to warn rescue crews of the ballistic system.

Based on the requirements of 23-ACE-88 the manufacturer of the aircraft had placed the two black-print warning decals adjacent to the exit point for the ballistic parachute (see Figures 3 and 4).

NTSB and ICAO Concerns

The ATSB contacted the US National Transportation Safety Board (NTSB) on 9 September 2003 regarding our concerns with the on-site investigation of aircraft equipped with ballistic parachutes such as the Cirrus. On 10 September 2003 the NTSB advised the ATSB, in part, that:

We [NTSB] share your concerns about accident site safety and the CAPS parachute system fitted to the SR20. We have begun drafting a safety recommendation regarding [making] the markings visible to rescue workers at an accident site.

On 11 September 2003, in a response to an approach from the NTSB a representative of the International Civil Aviation Organization (ICAO) indicated, in part, that:

... a rocket assisted parachute in an aircraft should definitely be on a list of possible hazards at accident sites. Also, markings on an aircraft could perhaps be further discussed with the civil aviation authorities as it might be a subject within the competency of FAA/CAAs (rule making).

On 29 April 2004, the NTSB issued six recommendations to the US Federal Aviation Administration (FAA), the National Fire Protection Association and the International Association of Fire Chiefs. These recommendations were numbered A-04-36 through to A-04-41 and are reproduced below:

To the Federal Aviation Administration:

A-04-36
Revise training guidelines for 14 Code of Federal Regulations Part 139-certificated airports to ensure that airport rescue and firefighting crews receive training in the recognition and disabling of aircraft ballistic parachute systems during emergency operations.

A-04-37
Distribute a safety bulletin to all 14 Code of Federal Regulations Part 139-certificated airports to raise awareness among airport rescue and firefighting crews regarding the hazards associated with ballistic parachute devices during general aviation rescue and firefighting operations.

A-04-38
Develop standards for the design and installation of ballistic parachute systems in future general aviation aircraft to enable emergency responders to quickly and safely disable the system using only common firefighting tools and examine the feasibility of retrofitting aircraft that currently have ballistic parachute systems installed with a system that complies with the new design and installation standards.

A-04-39
Work with Ballistic Recovery Systems, Inc., Cirrus Design, the National Fire Protection Association, and the airport rescue firefighting working group to establish design requirements for warning labels and exterior markings for airplanes equipped with ballistic parachute systems that meet the American National Standards Institutes guidelines (ANSI Z535.4) for conspicuity, coloration, visibility, and content.

To the National Fire Protection Association and the International Association of Fire Chiefs:

A-04-40
In cooperation with Ballistic Recovery Systems, Inc., and Cirrus Design, develop and distribute a safety bulletin to your membership to raise awareness among
non-airport fire/rescue organizations crews regarding the hazards associated with ballistic parachute devices during general aviation rescue and firefighting operations.

To the National Fire Protection Association:

A-04-41
Update existing firefighter training standards for non- airport firefighting

organizations to include information on the recognition and disabling of ballistic parachute systems.

Information received from the NTSB indicated that the FAA were working with BRS to develop appropriate training guidelines for 14 Code of Federal Regulations Part 139-certificated airport rescue and firefighting crews. They also indicated an intention to distribute a safety bulletin (Cert-Alert) to those personnel.

The FAA is also working with the American Society for Testing and Materials (ASTM), Committee on Ballistically Deployed Parachutes for Light Sport Aircraft, to develop a standard for the disabling of the ballistic parachutes by emergency responders. The committee is also working on the development of warning labels and exterior markings that comply with ANSI standards for any aircraft (light sport) equipped with a ballistic recovery system. The NTSB hopes that this symbol would be adopted for larger aircraft as well.

Civil Aviation Safety Authority regulation requirements

In response to a letter from the ATSB, where advice was sought on the Australian Civil Aviation Safety Authority (CASA) requirements for the marking of aircraft equipped with rocket-assisted recovery parachute systems, CASA indicated in part on 19 April 2004 that:

...parachute systems can only be installed as part of the certification basis for an aircraft, for example the Cirrus SR20 and SR22, or through the issue of a Supplemental Type Certificate (STC).

In Australia, the Authority [CASA] accepts a United States of America (USA) Federal Aviation Administration (FAA) STC as an Australian approval in accordance with Civil Aviation Safety Regulation (CASR) 21.114.

The FAA placard requirements are accepted by CASA and the Authority has no plans to require any additional placards or markings.

ANALYSIS

Aircraft rocket-assisted recovery parachute systems are a safety feature. However, there are significant dangers associated with these systems for persons involved in the immediate aftermath of an aircraft accident or incident involving aircraft with these systems fitted. Handling of aircraft wreckage where one of these devices is fitted, but not deployed, could result in serious injury or death. Anyone attending an aircraft incident or accident site where a rocket-assisted recovery parachute is involved needs to be aware of the dangers.

There are no internationally recognised warning or danger symbols for aircraft equipped with rocket-assisted recovery parachute systems. The markings on aircraft should ensure that they sufficiently convey the extent of the hazards present. The markings currently placed on aircraft vary and are not sufficiently visible to immediately draw attention to the dangers. Markings such as the internationally recognised 'ejection seat' danger symbol are far more effective at drawing attention to the danger.

Rocket-assisted recovery parachute systems are made in several countries, including the US and in Europe. Following the issue of the NTSB recommendations, a warning decal is being developed for light sport aircraft that are made in the US. However, this will only apply to US developed 'light sport' aircraft.

There is a need for an immediately recognisable, internationally recognised, symbol to warn of the dangers associated with a rocket assisted recovery parachute system. It may be appropriate for ICAO to examine the development of a standard for such a warning.

SAFETY ACTION

Australian Transport Safety Bureau

The Australian Transport Safety Bureau has now included information to reflect the dangers associated with the rocket-assisted recovery parachute systems in the following ATSB manuals:

- Occupational Health and Safety Manual, Chapter 15;

- ATSB Accident and Serious Incident Investigation Manual, Chapter 2, Accident Notification Procedure.

The telephone contact details for persons with the appropriate information about these systems and their disarming has now been included in the ATSB's internal aviation telephone directory.

The ATSB and the Directorate of Flying Safety - Australian Defence Force jointly produce a handbook titled, Civil and Military Aircraft Accident procedures for Police Officers and Emergency Services Personnel. That publication highlights to police officers and emergency services personnel, some of the dangers that could be faced at an aircraft accident site. At the next re-print, that handbook will be updated to include information on the dangers associated with the rocket-assisted recovery parachute systems on some civil aircraft.

The ATSB has undertaken training of its aviation investigation personnel highlighting the dangers associated with the investigation of accidents and incidents involving light aircraft with ballistic parachutes fitted.

The ATSB has purchased several pairs of the Felco C16 cable cutters and distributed them throughout the organisation for use in an on-site investigation.

The ATSB has highlighted its concerns about the rocket-assisted recovery parachute systems to Airservices Australia, Aviation Rescue Fire Fighting service. Currently Airservices and the ATSB are collaborating to determine the most effective method to disseminate that information to all concerned.

Civil Aviation Safety Authority (CASA)

In response to a query from the ATSB regarding the highlighting of the hazards associated with ballistic parachute systems, CASA indicated on 19 April 2004:

In relation to the Bureau's concerns regarding the highlighting of the hazards associated with these devices, CASA has proposed an amendment to the CASA Aviation Occurrence Procedures Manual to include instructions regarding investigating aircraft that may be fitted with an un-operated BRS to incorporate action necessary to avoid danger from these devices.

The suggested amendment is outlined below.

Title: *Warning for possible fitment of rocket-powered parachute recovery system.*

Persons investigating a crashed aircraft should check for the presence of an unoperated ballistic parachute rocket. The only known aircraft on the Australian aircraft register at present are the Cirrus SR20 and SR22, and some small Cessna aircraft incorporating the system by an STC. Additionally, there may be aircraft registered with the Australian Ultralight Federation fitted with such a system.

Aircraft on the VH Register are required to have a warning placard installed on the fuselage at the exit point, as part of the certification basis or STC approval. If the aircraft has such a rocket and it has not been operated, approach with care, do not intrude into the area marked on the fuselage, do not move the parachute release if removing persons from the cockpit, and safe-secure the rocket as per instructions from the manufacturer as soon as possible.

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1. The BRS Inc website quotes an exit speed of 100 mph. Regardless, the exit speed is significant and represents a serious danger.

Output Text

Safety Recommendation

The Australian Transport Safety Bureau recommends that as a priority the Federal Aviation Administration liaise with the European Aviation Safety Agency and the International Civil Aviation Organisation to develop an international standard for the marking on all aircraft with rocket-assisted recovery parachute systems to ensure that they fully alert persons to the hazards and the danger areas on the aircraft.

Last update 01 April 2011

Annex 6

Bureau de la sécurité
des transports
du Canada

Transportation
Safety Board
of Canada

Canada

Rapports aviation - 2010 - A10O0101

Rapport d'enquête aéronautique
Perte de puissance et collision avec un immeuble
du Cirrus SR20 C-GYPJ
à l'aéroport municipal de Toronto à Buttonville (Ontario)
le 25 mai 2010

Rapport numéro A10O0101

Sommaire

Le Cirrus SR20 immatriculé C-GYPJ et portant le numéro de série 1008 quitte l'aéroport municipal de Toronto à Buttonville (Ontario) pour effectuer le vol de retour à destination de Burlington Airpark. Peu après le décollage réalisé à partir de la piste 15, le pilote signale un problème et amorce un virage à gauche afin de revenir à l'aéroport. À 12 h 25, heure avancée de l'Est, l'avion s'écrase sur le toit d'un immeuble voisin. Un incendie survient peu après l'impact et consume presque tout l'appareil. Les deux occupants perdent la vie. Environ 15 minutes après l'impact, une explosion se produit lorsque la chaleur de l'incendie provoque la mise à feu de la roquette de l'extracteur du parachute de cellule du Cirrus.

This report is also available in English.

Autres renseignements de base

Déroulement du vol

Le matin même de l'accident, le pilote accompagné d'un passager avait effectué un vol entre Burlington Airpark et l'aéroport municipal de Toronto à Buttonville afin de faire exécuter des travaux d'entretien sur les radios de l'avion. Une fois ces travaux terminés, le pilote et deux techniciens d'entretien d'aéronefs ont procédé à des points fixes comme vérification finale. Tout semblait fonctionner correctement. Le pilote et le passager ont ensuite monté à bord de l'avion et se sont préparés à partir pour Burlington Airpark.

Vers 12 h 25[1], l'avion a reçu l'autorisation de décoller à partir de la piste 15. Peu après le décollage, le pilote a signalé un problème et a décidé de revenir à l'aéroport. Comme la cible radar de l'avion n'est pas apparue sur l'écran radar, on estime que l'avion n'a pas atteint une altitude de plus de 500 pieds au-dessus du sol (agl). Une fumée gris pâle s'échappait de l'appareil quand il a amorcé un virage à gauche en faible montée. Le contrôleur de la tour a essayé, sans succès, de communiquer avec le pilote. Le contrôleur a autorisé le pilote à atterrir sur la piste de son choix.

L'angle d'inclinaison de l'appareil a augmenté et le nez a piqué soudainement. L'avion a rapidement perdu de l'altitude et a amorcé une vrille. Juste avant de heurter le toit de l'immeuble, les ailes se sont placées à l'horizontale et le nez s'est redressé. Environ 5 minutes après l'impact, un incendie s'est déclaré. Les services d'urgence et d'incendie sont arrivés dans les 10 minutes suivant l'accident.

Environ 15 minutes après l'impact, il y a eu une explosion : la chaleur causée par l'incendie a mis à feu la roquette de l'extracteur du parachute de cellule du Cirrus (CAPS). Parce qu'elle était encore partiellement rattachée à la cellule par des câbles en acier inoxydable, la roquette a rebondi contre le toit avant de rompre ses liens et d'atterrir dans la rue, à environ 165 pieds du lieu de l'écrasement.

Conditions météorologiques

Les conditions météorologiques au moment de l'accident étaient propices au vol à vue et n'ont pas été considérées comme un facteur contributif dans cet accident.

Renseignements sur le pilote

Les dossiers indiquent que le pilote possédait les qualifications et les compétences nécessaires pour effectuer le vol en vertu de la réglementation en vigueur. Le pilote était titulaire d'une licence de pilote privé délivrée le 16 janvier 2009 et valide pour les vols à vue de jour et de nuit sur tous les avions terrestres monomoteurs à pistons. Le pilote avait à son actif environ 225 heures de vol, dont 100 heures sur le SR20. Le pilote avait effectué sa formation initiale sur un Cessna 172, un avion plus lent, aux caractéristiques de manœuvrabilité différentes de celles du Cirrus SR20. Rien n'indique que le pilote avait suivi une formation sur le Cirrus SR20.

Renseignements sur le passager

Les dossiers révèlent que le passager était aussi titulaire d'une licence de pilote privé. La licence délivrée le 30 avril 2010 était valide pour les avions terrestres monomoteurs à pistons.

Renseignements sur l'aéronef

L'avion a été construit en 1999 et a été acheté par le pilote en mars 2009. Les dossiers indiquent que l'appareil était homologué, équipé et entretenu conformément à la réglementation en vigueur et aux procédures approuvées.

Dans l'année suivant l'achat de l'avion, le pilote a piloté l'appareil régulièrement. Pendant cette période, ce dernier a totalisé environ 100 heures de vol, toutes sur l'avion en question. La dernière inspection annuelle a été menée en mars 2010 quand l'avion totalisait 2201,1 heures de vol cellule. Au cours de l'inspection, l'huile, le filtre à huile et les bougies d'allumage ont été remplacés et une vérification du taux de compression a été menée. Aucune anomalie n'a été décelée.

Au cours de cette dernière inspection, le pilote avait mentionné qu'il semblait y avoir une fuite d'huile sur le cylindre droit avant. Toutefois, aucune fuite n'a été repérée pendant l'inspection et les points fixes subséquents. Pendant l'inspection, on avait trouvé quelques défectuosités mineures sur l'avion, lesquelles furent réparées avant la remise en service. Au moment de l'accident, la dernière saisie du nombre d'heures de vol cellule datait du 17 mai 2010 et indiquait 2221,1 heures.

L'avion était équipé d'un moteur Teledyne Continental Motors (TCM), modèle IO-360-ES, numéro de série 357146. Au moment du vol en question, le moteur totalisait environ 2221 heures de vol et 715 heures depuis sa dernière révision. La période entre deux révisions recommandée par le constructeur pour ce type de moteur est de 2000 heures[2]. Le moteur en question avait été révisé au début de 2005 à la suite d'un heurt d'hélice. Les cylindres TCM d'origine n'ont pas été remplacés à ce moment-là. Cependant, ils avaient été rectifiés à 0,015 pouce de surdimension et on avait installé de nouveaux pistons et segments surdimensionnés.

Le Cirrus SR20 est muni d'un parachute de secours qui est fixé à la cellule. La description qui suit provient du Manuel d'information sur l'avion (AIM) du modèle SR20 de Cirrus :

> *[TRADUCTION] Le parachute de cellule du Cirrus (CAPS) est conçu afin d'aider l'aéronef et les passagers à bord à se poser au sol dans le cas d'une situation d'urgence mettant en danger la vie des occupants. Cependant, comme le déploiement du parachute occasionnera des dommages à la cellule et que, en présence de facteurs externes défavorables comme une grande vitesse de déploiement, une basse altitude, un relief accidenté ou des vents forts, les occupants pourraient quand même être grièvement blessés ou perdre la vie, il faut utiliser le CAPS avec beaucoup de discernement. En fait, les pilotes du SR20*

> *devraient prévoir les situations où il serait nécessaire de déployer l'ensemble et bien s'y préparer mentalement.*

Le manuel ne stipule pas l'altitude minimale nécessaire au déploiement du CAPS parce que la perte réelle d'altitude dépend de la vitesse, de l'altitude et de l'assiette de l'avion au moment du déploiement ainsi que d'autres facteurs environnementaux. L'AIM stipule :

> *[TRADUCTION] À titre indicatif, la perte d'altitude démontrée à partir de l'amorce d'une vrille à une rotation jusqu'à la stabilisation du parachute est de 920 pieds. La perte d'altitude démontrée lors de déploiements en palier était de moins de 400 pieds. Compte tenu de ces résultats, il serait utile d'avoir 2000 pieds agl en tête en tant que seuil d'altitude de décision. Au-dessus de 2000 pieds, il y aurait en principe suffisamment de temps pour évaluer systématiquement l'état d'urgence et y réagir. Au-dessous de 2000 pieds, la décision de déclencher le CAPS doit se prendre presque immédiatement afin de maximiser la possibilité d'un déploiement réussi. Néanmoins, quelle que soit l'altitude où vous vous trouvez, une fois que vous avez établi que le déploiement du CAPS est la seule option qui vous reste pour sauver la vie des occupants, déclenchez le mécanisme sans tarder.*

Le Cirrus SR20 n'est pas homologué pour les sorties de vrille et, par conséquent, Cirrus recommande le déploiement du CAPS si l'aéronef n'est plus maîtrisé.

La section 3 de l'AIM du Cirrus SR20, « Situations d'urgence en vol », fournit les renseignements suivants à l'égard de situations d'urgence en vol :

> *[TRADUCTION] Panne moteur au décollage (basse altitude)*
>
> *Si la panne moteur survient immédiatement après que l'avion ait pris l'air, interrompez le décollage et rétablissez l'avion sur la piste, si possible. Si l'altitude à laquelle vous vous trouvez ne vous permet pas d'interrompre le décollage sur la piste sans toutefois être suffisamment élevée pour vous permettre de redémarrer le moteur, baissez le nez afin de conserver votre vitesse et placez l'avion en assiette de vol plané. Dans la plupart des cas, l'atterrissage devrait se faire droit devant. Vous pouvez effectuer un virage seulement si vous devez éviter un obstacle. Après avoir établi l'assiette de vol plané en vue d'un atterrissage, exécutez autant de vérifications de la liste de vérifications que possible dans le temps qu'il vous reste.*
>
> ***AVERTISSEMENT***
>
> *Si vous décidez de regagner la piste, prenez garde de ne pas faire décrocher l'avion.*

Examen de l'épave

L'appareil a heurté le toit de l'immeuble à un cap d'environ 300° magnétique, légèrement en piqué et incliné à droite. L'avion a heurté un climatiseur de l'immeuble, a pivoté vers la droite et s'est arrêté sur un cap d'environ 060° magnétique. L'incendie qui est survenu après l'écrasement a détruit presque tout l'appareil, toutefois aucune défaillance du circuit de commandes de vol antérieure à l'accident, qui aurait pu être un facteur contributif, n'a été décelée.

Les pales de l'hélice étaient repliées vers l'arrière et lourdement endommagées par le feu. Les dommages constatés laissent croire que le moteur produisait peu ou pas de puissance au moment de l'impact.

L'examen du moteur a révélé que la culasse du cylindre numéro 3 s'était détachée du barillet (voir la figure 1). La culasse est restée en place parce qu'elle était retenue par les circuits d'admission et d'échappement. Aucune autre anomalie qui aurait pu empêcher le moteur de produire de la puissance n'a été découverte. L'examen de la culasse défectueuse du cylindre numéro 3 a révélé qu'elle s'était fracturée près des deuxième et troisième filets, et des criques de fatigue étaient visibles sur la surface de la fracture. Vue de l'extérieur, la fracture était située à la base des ailettes de refroidissement 4, 5 et 6[3].

Figure 1. Le cylindre numéro 3 déposé du moteur

Le cylindre est composé d'une culasse en aluminium qui est vissée à un barillet en acier au moyen d'un filetage. L'ajustement avec serrage élevé nécessite que la culasse soit chauffée et que le barillet soit refroidi à des températures préétablies, ce après quoi chaque composant est installé sur une machine qui les visse l'un dans l'autre selon un couple donné. Grâce à l'ajustement avec serrage, les surfaces de contact s'emboîtent hermétiquement. Normalement, une fois qu'on a monté les pièces d'un cylindre, on ne les désassemble pas.

Les culasses des 6 cylindres ont été envoyées au Laboratoire du BST pour y subir un examen métallurgique approfondi.

Une crique de fatigue mégacyclique s'est formée à l'encoche[4] causée par le chevauchement du bord coupant du filet du barillet en acier et du flanc de filet en aluminium du cylindre numéro 3. Lorsque la taille de la crique a atteint un point critique, la pièce n'a pas pu supporter la charge et la culasse s'est fracturée sous l'effet de contraintes monocycliques excessives. Bien qu'aucune défectuosité n'ait été décelée dans la région du cylindre où la fatigue a pris naissance, on a noté dans cette région des dommages dus au frottement, produits après que la fissure se soit manifestée, qui masquaient les caractéristiques originelles.

Les autres cylindres ont été sectionnés et examinés et on n'y a trouvé aucune autre fissure. On a convenu qu'il n'y avait aucun moyen pratique de localiser toute fissure dans cette région sans procéder à un essai destructif. Selon les renseignements obtenus, il s'agit de la première fissure de ce type sur cette série de moteurs.

L'examen a révélé de la corrosion intergranulaire à plusieurs endroits sur les filets de culasse des cylindres. Toutefois, on n'a pas pu déterminer la cause de cette corrosion.

Intervention en cas d'urgence et extracteurs pyrotechniques

Les parachutes de cellule installés sur certains aéronefs (y compris le CAPS) constituent un dispositif de sécurité supplémentaire destiné à protéger les occupants dans le cas où une situation d'urgence surviendrait en vol. Cependant, comme il a été démontré par cet accident, si le parachute n'est pas déployé avant l'impact au sol, un incendie qui se déclare après l'impact pourrait déclencher la mise à feu de la roquette de l'extracteur pyrotechnique.

Des renseignements sur les risques liés au CAPS à l'intention des premiers intervenants se trouvent sur les sites Web de Cirrus Aircraft et de la FAA[5]. Toutefois, en général, de nombreux premiers intervenants ne semblent pas connaître ces parachutes et n'ont pas reçu de formation sur leur manipulation.

L'enquête a donné lieu aux rapports de laboratoire suivants :

LP 077/2010 — *Examination of Aircraft Cylinder* (Examen d'un cylindre d'aéronef)
LP 076/2010 — *JPI Analysis* (Analyse d'un dispositif de J.P. Instruments)

On peut obtenir ces rapports en s'adressant au Bureau de la sécurité des transports du Canada.

Analyse

Malgré le fait que l'avion a été considérablement endommagé par l'incendie, l'examen de l'épave n'a révélé aucune défaillance du circuit de commandes de vol antérieure à l'impact qui aurait pu concourir à une perte de maîtrise de l'aéronef.

Le bris de la culasse du cylindre numéro 3 s'est probablement produit pendant la dernière portion de la course au décollage ou immédiatement après que l'avion ait pris l'air. Vu la nature de la défaillance du cylindre, le moteur aurait dû être capable de produire de la puissance avec l'aide des 5 autres cylindres. Toutefois, on n'a pas pu déterminer la quantité de puissance qui aurait été produite.

S'il se forme de la corrosion sur un coin tranchant du filetage en aluminium (causée par le contact avec le filetage du barillet en acier), celle-ci peut déclencher un ensemble de facteurs pouvant engendrer de la fatigue.

La crique de fatigue sur la culasse du cylindre numéro 3 a pris naissance au niveau de l'encoche créée par les filets du barillet en acier. Vu l'endroit où se trouvait la crique, il n'existe aucun moyen pratique autre que l'essai destructif pour détecter une telle crique. Une fissure sur la culasse d'un cylindre pourrait ne pas être repérée et le moteur continuerait de fonctionner normalement jusqu'à ce que la taille de la fissure atteigne un point critique où la culasse pourrait se rompre en surcharge sans qu'il y ait d'autres signes annonciateurs. Il y aurait par conséquent une perte de puissance et le moteur se mettrait à bafouiller ou s'arrêterait complètement.

Vu la forte concentration de bâtiments autour de l'aéroport, le pilote a probablement décidé qu'il valait mieux essayer de revenir à l'aéroport. Pour ce faire, le pilote aurait été obligé d'amorcer un virage à un degré d'inclinaison élevé, et de ce fait, il aurait augmenté la vitesse de décrochage de l'avion. Ce scénario correspond à la réaction de l'avion après son envol. L'angle d'inclinaison a augmenté de manière significative, l'avion a décroché et a amorcé une vrille à une altitude à partir de laquelle il était impossible d'en sortir.

Rien n'indique que le pilote a essayé d'utiliser le CAPS. Vu la basse altitude à laquelle se trouvait l'avion, il est probable que l'ensemble ne se serait pas complètement déployé.

Bien que le parachute de cellule constitue un dispositif de sécurité supplémentaire pour les occupants d'un aéronef dans le cas où une situation d'urgence se présente en vol, les extracteurs pyrotechniques qui servent au déclenchement de ces ensembles présentent des risques supplémentaires. Dans l'accident en question, c'est l'incendie survenu après l'impact qui a causé la mise à feu de la roquette, mais des dommages causés à un aéronef ou les actions des premiers intervenants pourraient également provoquer une telle mise à feu. À moins que les premiers intervenants soient au courant que certains aéronefs peuvent être équipés d'extracteurs pyrotechniques et qu'ils aient reçu une formation sur la manipulation de ces systèmes, ils seront en danger en cas de mise à feu d'une roquette.

Faits établis quant aux causes et aux facteurs contributifs

1. La culasse du cylindre numéro 3 s'est rompue en fatigue et s'est détachée du cylindre lors du décollage. Par conséquent, la puissance produite par le moteur a diminué.
2. Au cours d'une manœuvre exécutée par le pilote, l'avion a décroché et a amorcé une vrille à une altitude à partir de laquelle il était impossible d'en sortir.

Faits établis quant aux risques

1. Il n'existe aucun moyen pratique et non destructif d'inspecter les filets des culasses de cylindre afin de vérifier s'il y a des fissures. Sans vérification, les fissures qui ne seraient pas repérées pourraient occasionner la rupture du cylindre.
2. Le parachute de cellule du Cirrus a été déclenché après l'impact sous l'effet de l'incendie après écrasement. La roquette de l'extracteur pyrotechnique a atterri dans la rue. À moins que les premiers intervenants soient au courant que certains aéronefs peuvent être équipés d'extracteur pyrotechnique et qu'ils aient reçu une formation sur la manipulation de ces systèmes, ils seront en danger en cas de mise à feu d'une roquette.

Mesures de sécurité prises

Transports Canada

Transports Canada a rédigé et publiera un article dans l'édition de juillet de *Sécurité aérienne - Nouvelles*, afin de fournir des renseignements sur la sécurité à l'intention des premiers intervenants mettant en cause les systèmes de parachute de sauvetage à extraction pyrotechnique.

Le présent rapport met un terme à l'enquête du Bureau de la sécurité des transports du Canada (BST) sur cet événement. Le Bureau a autorisé la publication du rapport le 21 janvier 2011.

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1. Les heures sont exprimées en HAE (temps universel coordonné [UTC] moins quatre heures). ↑
2. TCM SIL98-9A. ↑
3. On compte les ailettes en partant du bas de la culasse. ↑
4. L'encoche dans le filetage de la culasse en aluminium sert à l'ajustement avec serrage. ↑
5. http://www.cirrusaircraft.com/flash/firstresponder; http://www.faa.gov/aircraft/gen_av/first_responders/media/mod4/mod4.htm (Adresses Internet confirmées comme étant valides à la date de la publication du rapport.) ↑

Date de modification :
2011-02-25

Annex 7

International
Civil Aviation
Organization

Organisation
de l'aviation civile
internationale

Organización
de Aviación Civil
Internacional

Международная
организация
гражданской
авиации

منظمة الطيران
المدني الدولي

国际民用
航空组织

Tel.: +1 (514) 954-8160

12 August 2005

Ref.: AN 6/26-05/46

Subject: Hazard associated with rocket-deployed emergency parachute systems

Action required: To note and take action as appropriate

Sir/Madam,

1. I have the honour to draw your attention to the potential hazards of rocket-deployed emergency parachute systems that are being installed in light aircraft in increasing numbers.

2. These devices may be installed as original equipment or as a retrofit in ultralight, sport, home-built, experimental and certificated aircraft up to the size of a Cessna 182. Their purpose is to lower the entire aircraft and its occupants to the ground in an extreme emergency, such as following structural failure, loss of control, pilot incapacitation or other critical flight conditions. These emergency parachutes have been credited with saving the lives of aircraft occupants.

3. The system consists of a parachute housed in a container, a bridle arrangement to attach the parachute to the airframe, and a rocket to extract and deploy the parachute. The system is armed by the pilot prior to flight and can be activated during the flight by a cable-operated firing mechanism.

4. A typical rocket-deployed emergency parachute system for a light aircraft includes a solid-fuelled rocket which develops some 1 300 newtons of thrust, sufficient to accelerate the rocket to over 160 km/h in a fraction of a second while deploying a 22 kg parachute. Placards are required to be placed on the aircraft to warn personnel of the hazards associated with the rockets, as these dangers are not obvious to those unfamiliar with such systems.

5. In the event of an accident to an aircraft with one of these systems, if the rocket has not been fired, subsequent movement of the aircraft structure may cause the cable activating mechanism to fire the rocket. To avoid danger to persons, an unfired rocket has to be deactivated before the aircraft wreckage is disturbed during rescue or recovery efforts.

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6. Approximately 20 000 rocket-deployed emergency parachute systems have been sold to date and this number is increasing. In at least one State, the system is mandatory equipment for all ultralight aircraft. In view of the growing danger associated with the improper handling of such systems, two accident investigation authorities, the United States National Transportation Safety Board and the Australian Transport Safety Bureau have issued safety recommendations addressing emergency parachutes. These safety recommendations primarily aim to increase the awareness of emergency response personnel to the dangers associated with such systems.

7. The main areas of concern with respect to rocket-deployed emergency parachute systems are the adequacy of the warning placards affixed to aircraft, the level of knowledge of the hazards associated with such systems, and the need to know how to render such systems safe. In order to address these areas, States are invited to:

a) review the adequacy of the warning placards associated with the installation of rocket-deployed emergency parachute systems in aircraft on their registry and, where necessary, ensure that the warnings are improved; and

b) ensure that emergency response services in their State, such as airport rescue/fire, police, ambulance, fire service personnel and accident investigators, are aware of the hazards associated with such devices. In this regard, the website of one of the manufacturers of such systems, http://brsparachutes.com/resourcessi/BRSFirstResponder.pdf, contains useful information on these devices.

8. To further raise awareness of these systems, the International Civil Aviation Organization (ICAO) intends to include in the *Manual of Aircraft Accident and Incident Investigation* (Doc 9756), Part III — *Investigation*, which is currently being redrafted, a reference to the potential hazards of such devices and advice on appropriate safety precautions.

Accept, Sir/Madam, the assurances of my highest consideration.

for Taïeb Chérif
Secretary General

Annex 8

Government of Canada Gouvernement du Canada

Canada

Transport Canada

Home Air Transportation Airlines and Aviation Operations National Operations
Air Navigation Services Oversight Division Audit Program and Regional Coordination
Aerodrome Safety Circulars Aerodrome Safety Circular

Aerodrome Safety Circular

Air Navigation Services Oversight Division

- ATC Operations
- AIS and Airspace
- CNS/ATM Systems
- FIS, Aviation Weather and Levels of Service
- How To Reach Us

ASC 2006-028
2006-05-05

- Subject
- Purpose
- Background
- Application
- Summary

Subject

Aircraft Rescue and Fire Fighting (ARFF) safety information on rocket-deployed aircraft emergency parachute systems.

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Purpose

This circular is to provide information for the ARFF to respond safely to incidents or accidents involving aircraft equiped with rocket-deployed aircraft recovery parachutes.

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Background

Following the crash of a small aircraft equipped with a rocket-deployed recovery parachute that had not been deployed, the emergency responders reported that some of the existing warning labels did not provide sufficient information on safety precautions for handling such systems when responding to an emergency. The U.S. National Transportation Safety Board (NTSB) issued a safety recommendation to provide emergency responders with training and information on such systems.

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Date modified: 2012-01-20

Application

To this date, a minimal number of these systems are in use in Canada. However, as the use of these systems received significant interest in the U.S., their use in Canada is expected to grow. It is important for airport operators to obtain and disseminate information regarding rocket-deployed emergency parachutes to the on-site and off-site responding agencies, to allow them to introduce pertinent information in their site-specific ARFF training and emergency response plan procedures.

The following Web sites include information that is currently available on rocket-deployed parachute systems:

- http://www.faa.gov/airports/airport_safety/media/accident_safety_scene_brs.ppt
- http://www.brsparachutes.com/
- http://www.junkers-profly.de/

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Summary

Awareness and training information should be provided to emergency responders to, first, identify the presence of an un-deployed emergency rocket-deployed parachute system and, second, de-activate it to render it harmless.

The information and pictures provided in the document published by the manufacturer, Ballistic Recovery Systems (BRS), entitled *BRS Ballistic Parachutes: Information for Emergency Personnel*, which is available at the following Web site: http://www.brsparachutes.com/files/brsparachutes/files/First%20Responders.pdf, should be used as reference for the development of response procedures to maximize the safety of emergency responders.

For additional information on this issue, please contact Bernard Valois of the Aerodromes and Air Navigation Branch in Ottawa, at 613 990-3708.

Aerodromes and Air Navigation Circulars are available electronically at:

http://www.tc.gc.ca/eng/civilaviation/opssvs/nationalops-audinspmon-program-safetycirculars-menu-273.htm

Jennifer J. Taylor

Director
Aerodromes and Air Navigation
Civil Aviation