Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A10O0018

IN-FLIGHT SEPARATION AND IMPACT WITH TERRAIN

VANS RV-7A C-GNDY
MADOC, ONTARIO
23 JANUARY 2010

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Aviation Investigation Report

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Synopsis

The amateur-built Vans RV-7A (registration C-GNDY, serial number 72932) was part of a formation of 3 aircraft that departed Lindsay, Ontario, on a visual flight rules flight to Smiths Falls, Ontario. En route, 1 of the 3 aircraft diverted to Bancroft, Ontario. The 2 remaining aircraft continued with C-GNDY in tandem. The lead conducted a series of aerobatic manoeuvres, which C-GNDY was to film. While manoeuvring, the lead lost contact with C-GNDY. The lead conducted a visual search, but could not find C-GNDY. The Joint Rescue Coordination Center was alerted and a search was conducted. The aircraft was located in a wooded area. It was destroyed on impact and the pilot, the sole occupant, was fatally injured. The accident occurred at approximately 1345 Eastern Standard Time. The Emergency Locator Transmitter functioned, but its range was reduced significantly, as its antenna was sheared on impact.

Other Factual Information

History of Flight

After departing Lindsay, Ontario, C-GNDY and 2 other aircraft (an RV-9A and another RV-7A, hereafter known as the lead) joined in formation and climbed to 9500 feet above sea level (asl). C-GNDY had a video camera mounted inside the cockpit and was filming the other 2 aircraft. After a short period of time, the RV-9A left the formation and headed toward Bancroft, Ontario, while C-GNDY and the lead continued toward Smith Falls, Ontario.

The 2 aircraft descended to about 3600 feet asl. C-GNDY was in a right echelon formation behind the lead. The pilots agreed that C-GNDY would film the lead during some aerobatic manoeuvres, which began with a sudden pitch up and a steep right bank. They were followed by a series of tight turns, partial rolls, climbs and descents.

At some point during the manoeuvres, the lead lost all contact with C-GNDY and subsequently began a search for the aircraft. The lead radioed the RV-9A and together the 2 aircraft searched for, but could not locate, C-GNDY. The 2 aircraft flew to Smith Falls, Ontario, and called the Joint Rescue Coordination Centre (JRCC). C-GNDY was located by JRCC at 2220 [1] near Wolfe Lake, Ontario, approximately 11 nautical miles (nm) north of Madoc, Ontario.

Vans RV-7A Information

The aircraft was designed to support operational stress limits of both aerobatic and normal categories. Seeing as weight and distribution can severely affect performance, handling, controllability and structural integrity, the aircraft must be operated within its weight and balance limitations. The aircraft must be at or below the specified weight and operated within the vertical acceleration (*g*) [2] limitations, as expressed in Table 1.

RV-7A Aircraft Information			
Category	**Maximum Weight**	**(*g*)**	
Aerobatic	1600 pounds	+6.0	-3.0
Normal	1800 pounds	+4.4	-1.75

Table 1. Vertical acceleration limitations

The maximum manoeuvring speed (Va) of 124 knots is the maximum permissible speed at which full and abrupt controls can be applied. Any speed in excess of Va with full control application could result in *g*-loads in excess of design limits.

The never exceed speed (Vne) of 200 knots is the maximum permissible speed under any condition. Any speed in excess of this could result in structural damage. Full control application at Vne would produce a load of approximately +15.0 *g*.

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[1] All times are Eastern Standard Time (Coordinated Universal Time minus 5 hours).

[2] Vertical acceleration (*g*): The unit of acceleration. One *g* is the attraction of gravity for a body.

The aircraft was built by the pilot using a quick build kit and was registered in the amateur-built category. Prior to its first flight on 10 October 2008, the aircraft had passed all required inspections and was certified within existing regulations. It had accumulated approximately 232 hours of total air time prior to the occurrence and was authorized for aerobatics. There was no indication that the aircraft had previously encountered any flight control difficulties.

The aircraft was weighed on 21 June 2008; the empty weight of the aircraft before paint was 1159 pounds. The aircraft was finished with an elaborate paint scheme in October 2008. The flight controls were removed prior to painting and were returned to the owner for reinstallation. It could not be determined who reinstalled the flight controls. The paint scheme and reinstallation of the associated flight controls were not recorded in any of the available aircraft records. There was no record of the aircraft being reweighed or flight controls rebalanced.

According to the Vans Build Manual, paint will add a minimum of about 15 pounds to the empty weight of the aircraft for a normal paint scheme, while an elaborate paint scheme could add 2 to 3 times this weight. In addition, heavy paint schemes will tend to shift the center of gravity rearward because of the paint weight on the empennage. Control surface balance on the RV-7A has not been found to be critical. A normal paint application on the ailerons and elevator will not upset their balance to a noticeable degree. However, a heavy paint scheme will require that these surfaces be rebalanced and additional counter balance weight added, if necessary.

Pilot

The pilot was qualified and certified within existing regulations. The pilot had a private pilot license and had accumulated a total of about 280 hours flight time, including approximately 132 hours on the RV-7A at the time of the occurrence. The pilot had logged 3.3 hours of dual aerobatic training offered by an aerobatic rated flight instructor. There was no indication that incapacitation or physiological factors affected the pilot's performance.

Weather

The weather is not considered a factor. Visual meteorological conditions prevailed at the time of the occurrence.

Video

A video camera had been mounted behind and slightly over the starboard passenger seat of C-GNDY. It was positioned facing forward, looking out through the windscreen. The entire occurrence flight was recorded. The video showed that after takeoff, C-GNDY had maintained a formation position behind the other 2 aircraft.

Shortly after, the RV-9A left the formation and C-GNDY moved to a tighter right echelon formation position with the lead. Near Wolfe Lake, the lead began a series of manoeuvres. C-GNDY chased the lead through the manoeuvres and, at times, the lead could be seen within view of the recording video camera (see Photo 1). During this type of manoeuvre, the pursuing aircraft must turn at a higher rate or *g* in order to maintain the lead within the field of view of the video camera.

During a pull-out from a rapid descent, there was a sudden onset of an airframe vibration (shuddering around the longitudinal axis), which was followed by a yawing motion, a roll and ground impact.

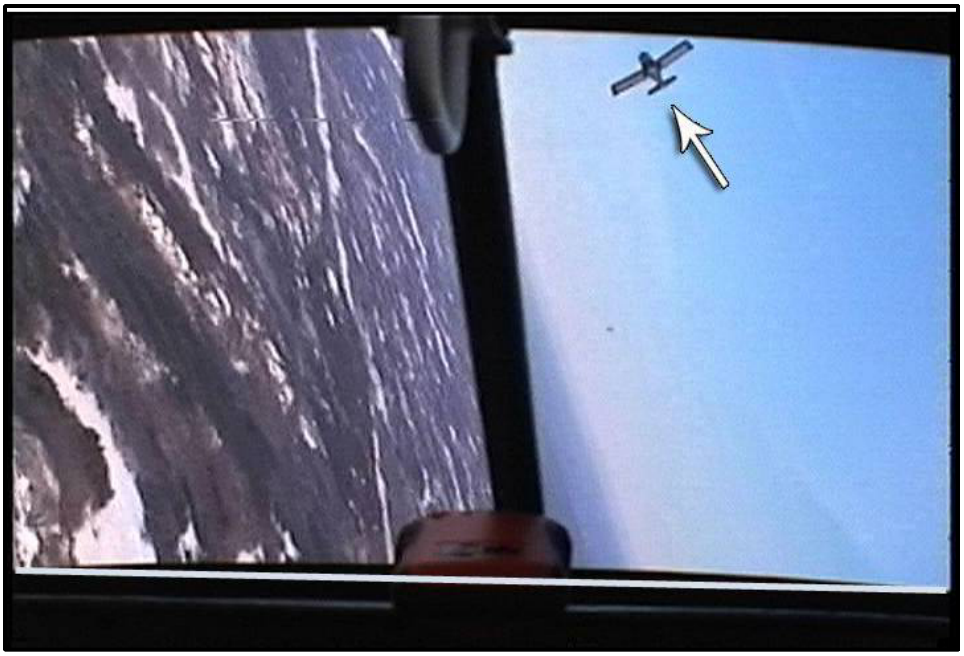

Photo 1. Video still image of the lead aircraft manoeuvring

Electronic Fight Information System and Aircraft Manoeuvring

The aircraft was equipped with an Electronic Flight Instrument System (EFIS), which functions as a flight instrument system and an engine monitoring system. It retains the data collected by these systems in non-volatile flash memory. In coordination with the manufacturer, the EFIS data were recovered. The entire occurrence flight was recorded at 5 second intervals and consisted of 384 records over approximately 33 minutes.

Prior to the start of the manoeuvres, the aircraft was level at approximately 3650 feet asl (2650 feet above ground level [agl]). The airspeed was 168 knots. The manoeuvres lasted approximately 51 seconds. The maximum recorded vertical acceleration was 3.5 *g*, roll 115°, pitch up 19° and pitch down 45°. The maximum rate of descent was approximately 12 000 feet per minute (fpm).

Following a rapid descent (10 560 fpm down, 45° nose-down pitch), the aircraft progressively descended during the manoeuvres to approximately 1690 feet asl (800 feet agl). It reached airspeed of 234 knots before levelling momentarily at 1870 asl. The last EFIS record prior to impact indicated a nose-down pitch of 31°, right bank of 105° and airspeed 181 knots.

Wreckage Examination

The aircraft struck terrain at approximately 80˚ nose down, flipped over and came to rest upside down. The aircraft was destroyed from impact forces and there was no post-impact fire.

Damage to the aircraft was consistent with severe impact forces. The vertical stabilizer and top half of the rudder were missing from the aircraft and could not be located at the wreckage site. The bottom half of the rudder was attached to the aircraft only by the rudder control cables; the remaining flight control surfaces were all located. The flight control systems were examined to the furthest possible extent and no indication of malfunction was found.

The instrument panel was destroyed along with most of the instruments. However, the global positioning system (GPS), EFIS and a video recorder were salvaged from the wreckage.

Search for Vertical Stabilizer and Rudder

After an extensive ground search, the vertical stabilizer and rudder were found approximately 0.6 nm south east of the main wreckage site. The vertical stabilizer was intact. A portion of the rudder was attached to the vertical stabilizer. Numerous parts of the rudder, including the right aluminum skin and rudder trailing edge wedge, had separated from the main rudder structure and were located within 100 meters of the vertical stabilizer. The rudder counterweight could not be found.

Examination of the Vertical Stabilizer

The vertical stabilizer had completely separated from the fuselage. The fractures in the vertical spars occurred just above where the spars fastened to the fuselage. The fracture surfaces were consistent with failure by overstress. There were no indications of progressive failure. Material thicknesses were measured and found to be consistent with the specifications for the front and rear spars and the rear spar doubler. Material composition was found to be consistent with the specifications of the aircraft drawings.

Material deformation suggested that the vertical stabilizer had separated to the rear, buckling the rear spar at the separation location. There were indications that the vertical stabilizer had bent both right and left.

Examination of Rudder

The rudder had experienced severe structural damage and had fractured approximately in half. The bottom half of the rudder remained attached to the aft fuselage, linked only by the rudder cables and electrical wiring. The rudder was badly bent along its length, twisted chord wise, and the riveted joint at the trailing edge was split open. The top half of the rudder was still securely fastened to the vertical stabilizer by its top and centre hinges. The skin fracture surfaces were consistent with overstress. There were no indications of progressive failure.

The rudder was still attached to the vertical stabilizer at the top and centre hinges and had fractured in half just below the centre hinge. The rudder balance weight was missing. The vertical stabilizer was undamaged, but the rudder was badly torn and deformed.

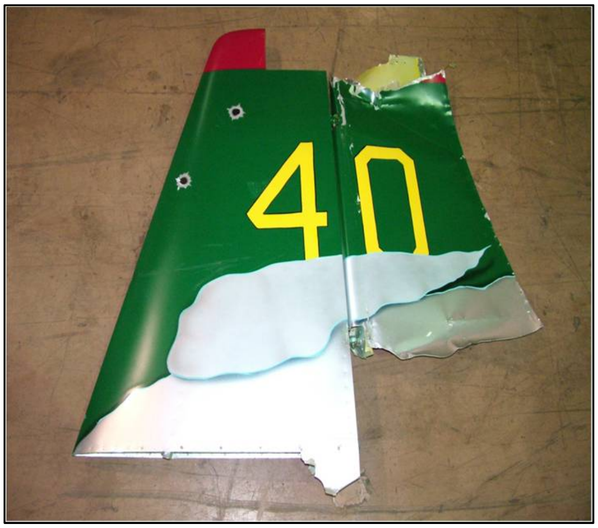

Photo 2. Left side of rudder

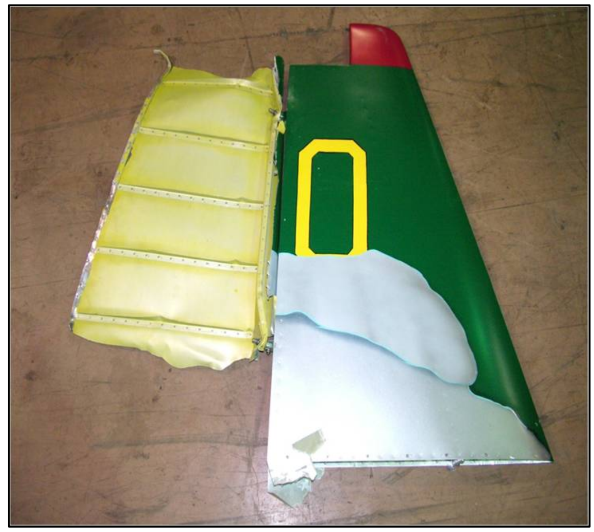

Photo 3. Right side of rudder

The thickness of the skin panels, stiffeners and the spar were consistent with the assembly drawings. The number and spacing of the skin stiffeners were also consistent with the specifications. Material composition of the rudder skin, spar and stiffeners were consistent with the specifications of the aircraft drawings.

The assembly drawings specify that an AN426AD3 rivet is to be used for the construction of the rudder. Such a rivet has a diameter of 3/32 inches. A representative rivet was removed from the trailing edge of the occurrence rudder and was found to have a diameter consistent with a 1/8 inch rivet. Representative rivet holes in the rudder trailing edge wedge were measured using 3/32 and 1/8 inch diameter drill bits. The holes were consistent with the use of a 1/8 diameter rivet.

A manufactured rivet head usually has a diameter approximately 1.5 times larger than its shank diameter. A representative manufactured rivet head from the occurrence rudder had a diameter consistent with a 1/8 inch rivet. The rivet spacing throughout the rudder was consistent with that specified in the drawings.

The bottom rudder hinge had fractured, consistent with failure by overstress. The fracture surface did not exhibit any indications of progressive failure. The rudder stops impact marks tended to be concentrated at only one location on each stop. There were no indications of pounding marks at multiple locations to suggest the rudder was experiencing stop-to-stop vibrations. Furthermore, no evidence was found to suggest the counter weight had been progressively working its way loose.

Flutter and Rudder Balance

Flutter is the rapid and uncontrolled oscillation of a flight control resulting from an unbalanced surface. Flutter normally leads to catastrophic failure of the structure. Due to the high frequency of oscillation, even when flutter is on the verge of becoming catastrophic, it can still be very hard to detect. Factors that can contribute to the onset of flutter include high speed, a reduction in stiffness and a change in mass distribution.

The kit manufacturer had conducted flight testing of the RV-7A prototype. No indications of flutter were encountered at a speed of 217 knots. Additional theoretical flutter analysis was done where the flutter speed was calculated to be 300 knots for the baseline design. The addition of weight, however, can decrease flutter speed by 50 knots or greater. Any imbalance, such as paint and filler, which increases the weight of the rudder aft of the hinge line, has an adverse effect on flutter speed.

No documentation was found to indicate whether the rudder was ever balanced and, due to its severely damaged condition, it was not possible to measure its balance. The top of the rudder containing the balance weight had separated and was not found. Its effect on rudder balance could therefore not be determined. The sheet metal used in the rudder was of the correct thickness and the skin stiffeners had been correctly installed. As such, these elements had no adverse effect on rudder balance.

There was no staining on the bottom-most rib to suggest rain water or ice had been pooling in the rudder and altering its balance. The drain hole was checked and it was not plugged by debris.

As previously mentioned, 1/8 inch rivets were used in the rudder rather than the 3/32 rivets specified in the assembly drawing. This will increase the imbalance aft of the hinge line. Since larger diameter rivet shanks are accommodated by drilling out larger diameter holes, it is only the larger rivet heads that add weight to the assembly. The rudder contained approximately 200 rivets with a significant moment arm from the hinge line, amounting to 0.05 pounds, which would have a minimal effect on rudder balance.

Paint and filler chips were removed from different regions of the rudder. Thicknesses varied from 0.009 inches to 0.066 inches. The thickest paint and filler chip weighed approximately 0.00277 pounds per square inch; the thinnest one weighed 0.00051 pounds per square inch. If the entire rudder had been uniformly covered with the thickest layer of paint and filler, the total weight would have been increased by approximately 5 pounds. If the rudder had been uniformly covered with the thinnest layer, the total weight would have been approximately 1 pound. The weight of the paint and filler would have altered the balance of the rudder and negatively affected its flutter characteristics.

Weight and Balance

The maximum aerobatic gross weight for the RV-7A is 1600 pounds. The maximum recommended gross weight is 1800 pounds. According to documentation, the aircraft weighed 1159 pounds, however, this was prior to being painted. Seeing as there were no records of the aircraft being reweighed after being painted, the true empty weight of the aircraft could not be determined.

As previously mentioned, the paint chips and filler from the rudder were weighed after the accident. Using the same methodology for determining the weight added to rudder, 31 pounds would have been added to the aircraft if it was finished consistent with the thinnest paint/filler chip. The application of the thickest paint/filler chip finish could have added up to 170 pounds. Using the last documented empty weight of the aircraft for calculations, the gross weight of the aircraft was approximately 1605 pounds at the time of the occurrence, slightly over the maximum aerobatic gross weight. However, the paint and filler added extra weight to the empty weight of the aircraft, which in turn increased the gross weight at the time of the occurrence. The aircraft actual gross weight at the time of the occurrence was likely in the range of 1636 to 1775 pounds.

Regulations

Transport Canada defines an aerobatic manoeuvre as a change in the attitude of an aircraft, which results in a bank angle greater than 60°, an abnormal attitude or an abnormal acceleration not incidental to normal flying.

Paragraph 602.27(d) of the *Canadian Aviation Regulations* (CARs) states, in part, that no person operating an aircraft shall conduct aerobatic manoeuvres:

> below 2,000 feet agl, except in accordance with a special flight operations certificate issued pursuant to section 603.02 or 603.67.

Chapter 549 of the Airworthiness Manual (AWM) - Airworthiness Standards – Amateur-Built Aircraft sets out the design and construction standards and the requirements for inspections, equipment and instruments, and operating information necessary to obtain a Special Certificate of Airworthiness for amateur-built aircraft.

CARs 549.01 states:

A person who intends to construct an aircraft and obtain, under paragraph 507.03(b), a special certificate of airworthiness in the amateur-built category in respect of the aircraft must:

> (a) before starting construction,
>
> > (i) inform the Minister of the intention to construct the aircraft,
> > (ii) show that the aircraft design meets the standards specified in Chapter 549 of the Airworthiness Manual, and
> > (iii) show that the major portion of the aircraft will be constructed from raw material and assembled on a non-commercial, non-production basis for educational or recreational purposes; and
>
> (b) during construction and again before the first flight, make the aircraft available to the Minister for inspection.

On 30 June 2006, Transport Canada published an exemption to section 549.01 of the CARs and Chapter 549 of the AWM excusing applicants from following the above mentioned CARs and Airworthiness Standards. Applicants are still required to follow the requirements set out in the exemption, some of which are below. (For a full list of the continuing airworthiness items see Appendix A.)

- The details of all maintenance and elementary work performed on an amateur-built aircraft must be entered in the aircraft's technical record.
- All maintenance activities require a maintenance release.
- Repairs and modifications to amateur-built aircraft must conform to technical

data acceptable to the Minister; sources of acceptable data include, but are not limited to:

- Drawings and methods recommended by the manufacturer of the aircraft kit, component, or appliance;
- Transport Canada advisory documents;
- FAA Advisory Circular 43.13-1 and -2, UK CAA Civil Aircraft Inspection Procedures (CAIP), JAA Advisory Circulars, (ACJ) and publications issued by recognized authorities on the subject matter concerned.

Recognized Standards

Federal Aviation Administration (FAA) Advisory Circular (AC) 43.13-1A/2A (hereafter referred to as AC 43.13) is an international recognized publication for the acceptable methods, techniques and practices of aircraft inspection repair and alterations. According to AC 43.13, to prevent the occurrence of severe vibration or flutter of flight control surfaces during flight, precautions must be taken to stay within the design balance limitations when performing maintenance or repair. Since control surfaces on some models are balanced for flutter-free operation up to maximum speed for which the aircraft was originally designed, special attention must, therefore, be given to such surfaces relative to the effects of structural repairs and rework on their balance condition.

Special emphasis is directed to the effect indiscriminate application of extra coats of dope or paint has on the balance of control surfaces. Proper maintenance of control surface balance may require removal of dope or paint, down to the base coat, prior to application of finish coats. AC 43.13 specifies that the aircraft manufacturer's instructions on finishing and balance of control surfaces should be consulted.

The following TSB Laboratory reports were completed:

LP009/2010 – Examination of Empennage
LP010/2010 – Video Recovery
LP011/2010 – GPS and EFIS Recovery
LP031/2010 – Flight Animation

These reports are available from the Transportation Safety Board of Canada upon request.

Analysis

Transport Canada recognizes the Vans Build Manual and AC 43.13 as the standards that must be followed for amateur built aircraft. These standards apply at fabrication as well as for continuing airworthiness purposes. In this case, they would apply to the rebalancing of flight control surfaces. There was no maintenance release or other data to suggest the rudder was rebalanced.

Notwithstanding the exemption to section 549 of the AWM, the owner/builder is still required to follow the stipulations in Appendix A of the exemption. However, there was no maintenance release recorded to indicate the aircraft was repainted or that the rudder was removed and reinstalled.

The aircraft was not reweighed after being painted. Its empty weight could not be determined, but the actual weight of the aircraft exceeded the maximum weight for aerobatics at the time of the occurrence. As such, the maximum allowable *g* was reduced from +6.0 to +4.4. Although a maximum of +3.5 *g* was recorded on the EFIS, which is within the limitation of the normal category, it records once every 5 seconds. It is therefore possible that the +4.4 *g* limit was exceeded, but not recorded.

At the time of the vertical stabilizer and rudder separation, the aircraft was at or near 234 knots, exceeding the 200 knot Vne and the speed at which the aircraft was shown to be flutter free. The theoretical flutter onset speed was 300 knots. Adding extra weight (paint and filler) can reduce the speed at which flutter onset occurs by 50 knots or greater. It is possible that the manoeuvre overstressed the rudder, reducing its stiffness, which further lowered the flutter speed.

Due to the large amount of energy associated with flutter, it is probable that if flutter had occurred, the vertical stabilizer and rudder would have separated. If flutter had occurred, the vertical stabilizer would have bent left and right at progressively higher amplitude until separation. Both vertical stabilizer spars showed indications of having been bent in both directions at their separation locations. It is unclear whether this bi-directional indication was caused by flutter or by compressive buckling during the separation.

The various skin tears on both the vertical stabilizer and rudder were examined for indications of sheet metal flexing. No such indications were found. The impact marks on the rudder stops were concentrated in one area. There was no evidence of progressive contact at other locations during the break-up, which may have indicated flutter. The absence of such marks, however, may mean that separation occurred before full travel and does not necessarily indicate that flutter did not occur. While vibration was observed on the video at the time of the separation, it is unknown whether this was due to flutter or airframe buffeting.

At the time of separation, the airspeed exceeded the 124 knot manoeuvring speed. Full control movement is not permitted above this speed because the aircraft can be overstressed. Furthermore, at such airspeeds, it might be possible to overstress a component using less than maximum control movement, depending on the strength of the particular structure and the aircraft motion. Therefore, the possibility exists that the vertical stabilizer and rudder separated as a result of overstress.

While not considered contributory, larger-than-specified rivets were used in the construction. The manoeuvring sequence was consistent with one aircraft chasing another. The pilot was pursuing the lead while attempting to keep it in the field of view. To do so would require increasing bank and, consequently, the *g*-load. While focusing on the lead, the pilot was not likely aware of the aircraft's proximity to the ground or its increasing airspeed.

The aircraft was performing aerobatic manoeuvres below the minimum altitude required by the CARs.

Findings as to Causes and Contributing Factors

1. After painting, the rudder was not likely balanced, nor the aircraft reweighed. As a result, the rudder was susceptible to flutter at a lower speed than designed and the aircraft was over the maximum aerobatic gross weight during the manoeuvres.
2. During the manoeuvring sequence, the speed of the aircraft reached 234 knots, exceeding the 124 knot manoeuvring speed and the 200 knot never exceed speed (Vne).
3. The aircraft encountered either flutter or overstress of some rudder components. Subsequently, the vertical stabilizer and parts of the rudder separated from the empennage during flight. Consequently, the aircraft became uncontrollable resulting in the impact with terrain.

Finding as to Risk

1. Performing aerobatic manoeuvres below the minimum altitude required by the *Canadian Aviation Regulations* (CARs) introduces unnecessary risk.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 20 April 2011.

Visit the Transportation Safety Board's website (www.bst-tsb.gc.ca) for information about the Transportation Safety Board and its products and services. There you will also find links to other safety organizations and related sites.

Appendix A – Exemption from the Canadian Aviation Regulations

EXEMPTION FROM SECTION 549.01 OF THE CANADIAN AVIATION REGULATIONS AND CHAPTER 549 OF THE AIRWORTHINESS MANUAL – AIRWORTHINESS STANDARDS - AMATEUR-BUILT AIRCRAFT

PART VII - Continuing Airworthiness (Appendix A of the Exemption)

(61) Except where specifically stated to the contrary, amateur-built aircraft are subject to the same operating and maintenance regulations as type certified aircraft. Some of the applicable regulations, and their practical effects, are summarized in the following information notes.

Information notes:

(i) The details of all maintenance and elementary work performed on an amateur-built aircraft must be entered in the aircraft's technical record.

(ii) All maintenance activities require a maintenance release.

(iii) The owner of an amateur-built aircraft may sign the release for the maintenance of his or her own aircraft.

(iv) Elementary work does not require a maintenance release; however, it must be recorded in the aircraft technical record, together with the signature of the person who performed the work.

(v) The maintenance schedule requirements detailed in STD 625 Appendix B are approved by the Minister for use with amateur-built aircraft, at intervals not exceeding 12 months. STD 625 specifies that Appendix B must be supplemented by the applicable requirements of STD 625 Appendix C, for out of phase tasks and equipment maintenance requirements.

(vi) All entries in respect of the technical records for the airframe, engine and propeller for an amateur-built aircraft may be kept in the journey log, provided the requirements with respect to technical records are met.

(vii) A weight and balance report is required for each aircraft configuration.

(viii) Amateur-built aircraft are not required to comply with airworthiness directives; however, operators are strongly encouraged to review applicable airworthiness directives to determine if they wish to comply voluntarily, in order to enhance the safety of the aircraft.

(ix) Repairs and modifications to amateur-built aircraft must conform to technical data acceptable to the Minister; sources of acceptable data include, but are not limited to:

a) drawings and methods recommended by the manufacturer of the aircraft kit, component, or appliance;

b) Transport Canada advisory documents;

c) FAA Advisory Circular 43.13-1 and -2, UK CAA Civil Aircraft

Inspection Procedures (CAIP), JAA Advisory Circulars, (ACJ) and publications issued by recognized authorities on the subject matter concerned.

(x) Owners may devise their own data, which need not be approved, but must be subject to an appropriate level of review or analysis, or be shown to comply with recognized industry standards, or commonly accepted practice.

(xi) Changes that affect the structural strength, performance, power plant operation, or flight characteristics of an amateur built aircraft must be reported to the Minister before further flight of the aircraft; such changes may require re-evaluation to confirm that the aircraft continues to comply with the applicable standards.

(xii) The Minister is the final authority for determining the acceptability of data.