DATA SUMMARY

LOCATION

Date and time	**Friday, 23 July 2011; 13:05 local time[1]**
Site	**Vicinity of the Santa Cilia de Jaca Aerodrome (Huesca, Spain)**

AIRCRAFT

Registration	**G-CCRC**
Type and model	**CESSNA TU-206 (S/N U206-07001)**
Operator	**Centro de Paracaidismo Pirineos**

Engines

Type and model	**TELEDYNE CONTINENTAL MOTORS TSIO 520-M7B (S/N: 532404)**
Number	**1**

CREW

Pilot in command

Age	**39 years old**
Licence	**CPL(A)**
Total flight hours	**1,720 h**
Flight hours on the type	**800 h**

INJURIES

	Fatal	Serious	Minor/None
Crew			**1**
Passengers			**5**
Third persons			

DAMAGE

Aircraft	**Minor**
Third parties	**None**

FLIGHT DATA

Operation	**Aerial work – Non-commercial – Parachute drop**
Phase of flight	**En route – Parachute drop**

REPORT

Date of approval	**27 February 2014**

[1] All times in this report are local (LT) unless otherwise specified. To obtain UTC, substract two hours from local time.

1. FACTUAL INFORMATION

1.1. History of the flight

On 23 July 2011 at 13:05, a Cessna U-206 aircraft took off from the Santa Cilia de Jaca Aerodrome for the purpose of conducting a parachute drop. It was the aircraft's third such flight that day. The weather conditions were suitable for visual flight and for parachuting. There was a slight wind from the west. Onboard the aircraft were five parachutists and the pilot.

As the pilot was reducing engine RPMs to level out after the climb while flying above the airfield at an altitude of about 3,300 m (approximately 11,000 ft), he smelled smoke and felt vibrations as the engine lost power.

The parachutists made a routine jump from the airplane, descended without difficulties and landed in the planned spot. The pilot started to descend for landing, keeping the selected engine RPMs. Shortly before landing the pilot commanded power from the engine, which did not respond though it remained operational.

The terrain along the approach to runway 27 at the Santa Cilia de Jaca Aerodrome descends sharply and there is usually mountain turbulence in the area before the threshold. The pilot, noticing the turbulence had increased in strength, opted to make an emergency landing on a clear field outside the aerodrome that was parallel to and to the right of runway 27. He reported this intention on the radio and after the landing informed the aerodrome of his situation.

Neither the pilot nor the aircraft was harmed in the landing. All of the material damage was confined to the engine.

1.2. Aircraft information

1.2.1. *General*

The Cessna TU-206 is a single-engine, high-wing strutted airplane with a maximum takeoff weight of 1,633 kg.

The incident aircraft was equipped with a Teledyne Continental Motors TSIO-520-M engine with a maximum takeoff power of 310 HP. This aircraft was registered by the United Kingdom's CAA under registration G-CCRC in February 2004 to its current owner.

The aircraft's owner, Skycentre Moonjumper International, based in Coleraine – Londonberry – North Ireland – United Kingdom, dry leased the aircraft to the Centro de

Paracaidismo Pirineos, based in Santa Cilia de Jaca – Huesca – Spain. The renewable one-year contract was for a minimum of 250 hours and for conducting parachute drops. The cost of maintenance was deducted from the weekly rental payment.

The aircraft, registration G-CCRC, had an ARC (Airworthiness Review Certificate), reference 058/2010, issued by the CAMO Köhler (Approval ref. DE.MG.1007) on 29/06/2010 with expiration date 24/09/2011.

1.2.2. *Engine*

The TCM TSIO-520-M turbocharged, fuel injected engine has six horizontally opposed, air cooled cylinders with a bore of 5.25 inches. This alternating turbocharged engine is the most popular in light aviation and has been utilized on several types of single- and dual-engine airplanes, having been manufactured in large numbers.

1.2.3. *Maintenance program and history*

The aircraft had a generic maintenance program approved by the CAA, CAP 766 and CAP 411, for piston-engine aircraft under 2,730 kg used for commercial and non-commercial aviation.

During the airplane's last two years of operation, the Centro de Paracaidismo Pirineos had contracted the maintenance out to Locavions, located in Pau, France. The maintenance was then shifted in June 2011 to Futurhangars, S.L., located in Sabadell, Barcelona.

The Locavions maintenance center relied on assistance from Rectimo for major work on the engine and from Aeromecanics in Marseille to solve one-time failures in other systems from time to time.

Locavions followed a generic maintenance program, with 50FH, 150FH and annual inspections.

On 05/06/2011, Futurhangars sent an email to the Centro de Paracaidismo Pirineos to inquire about the maintenance program to use, as there seemed to be no schedule for weighing the airplane, keeping track of ADs or conducting structural inspections, tasks included in airworthiness continuing management to be carried out by the CAMO.

The line and daily inspections were made by the crew, which reported any abnormal operations to the workshop and tracked the potential life of both airplane and engine hours.

1.2.4. *Number of flight hours and inspections*

Inspection type	Date	Airplane hours	Engine hours	Maint. center
Overhaul Motor	03/08/2008	2,807	0	¿?
Issuance and MSB 09-1ªA control	April 2009	2,845	38	Locavions
50 h	July 2009	2,896	89	Locavions
150 h	August 2009	2,942	135	Locavions
Change of cylinders (6) MSB 09-1B	October 2009	2,990	183	RECTIMO
50 h + 150 + annual	April 2010	3,038	231	Locavions
CAMO contract signing	June 2010			CAMO Köhler (Locavions)
Change of alternator	02/07/2010	3,077	270	Locavions
50 h	27/07/2010	3,086	279	Locavions
50 h + vacuum pump	22/09/2010	3,137	330	Locavions
Change of tires	14/10/2010			Locavions/AD Santa Cilia de Jaca
150 FH + change No. 3 cylinder	07/03 to 01/04/2011	3,184	376	Locavions/RECTIMO
50 FH	9/6/2011	3,234	425	Futurhangars
Incident	23/07/2011	3,281	472	Santa Cilia de Jaca

The next 50-FH inspection was scheduled with 475 total FH on the engine. The incident occurred 47 FH after the last inspection of the airplane, meaning it was almost due for a 50-FH inspection.

The last annual inspection had been overdue since April 2011. On that date the CAMO should have alerted to the operator and maintenance shop about this time calendar inspection.

A review of the maintenance documentation gathered from Locavions through the BEA revealed that the inspection of 22/09/2010 was listed as a 150-FH inspection when in fact it was a 50-FH inspection. There are also repeated errors in the documentation, which lists the engine as a Lycoming engine.

In the last 150-FH inspection on April 2011, additional work was done involving disassembling the exhaust to repair cracks, disassembling the turbocharger to replace gaskets and disassembling/assembling the no. 3 cylinder, followed by a search for the source of significant exhaust gas leaks. The cylinder was disassembled so as to machine the attachment of at least one exhaust gas outlet stud and its collar. Workshop personnel had great difficulty assembling the cylinder after this repair, resulting in a long delay in returning the aircraft to operation.

In the two last 150-h inspections, in April 2010 and April 2011, the cylinder compression test was annotated with an entry of 80 for each one of six cylinders and on both checks (without specifying the calibrated equipment used for the measurement or the units).

In the last 50-h inspection, a measurement carried out by the new maintenance shop contracted by the operator, it was perceived again smudge produced by exhaust gas leaks.

1.2.5. *Features of the engine and its operation*

Cylinders

Each of the six cylinders on the Continental TSIO 520-M7B engine consists of two cast halves: the cylinder itself made of cast steel and a cast aluminum cylinder head, both permanently joined during the manufacturing process. The head houses the spark plugs, fuel injectors and spring-loaded inlet and exhaust valves. The valves are operated by the motion of the tappets atop the rocker arms that drive the valve stems in the conventional manner. Being air cooled, the outside of the cylinders feature cooling fins that are integrated into the cast components.

The engine is designed so that the highest risk cylinders (one of the rear ones, no. 1 or 2) are equipped with CHT (cylinder head temperature) sensors. Normal operating temperatures should not exceed 380 °F, with the maximum being 460 °F. There is also an exhaust gas temperature, EGT, sensor on the right-side manifold (hotter side due to the location of the turbocharger). The engine in this incident included a digital indicator and 12 sensors that provided the CHT and EGT for each of the engine's six cylinders.

As stated by mechanics who have worked on this engine, it is expensive to maintain and it is intolerant of fast changes from cruise thrust to idle thrust. The drop from the high temperature associated with an engine at high thrust to the temperature of an engine at idle can lead to cracks and thermal stress on the cylinder heads due to rapid cooling.

When the engine is operated correctly during a parachute drop, it is regarded as reliable, though several expert mechanics reported that its 1,400-hour lifespan between overhauls was very rarely obtained.

The aircraft's lease contract stipulated that the lessor was to be sent copies of the aircraft logs so that it could check the times for each flight cycle and ensure that the descents were not being made too quickly.

TCM Service Bulletin SB 03-3 provides a differential pressure test and complements the leak check with a boroscope inspection. This SB is applicable at each 100-hr interval, annual inspection or when cylinder problems are suspected.

Valves

Combined experience in alternating engines reveals that valves in general can be damaged by thermal fatigue under various constant use conditions, such as:

- Extreme thermal cycles.
- Constant and sudden changes from maximum to minimum power.
- Incorrect valve seating.
- Bent valve stem.
- Incorrect tappet setting.
- Excessive temperature due to pre-ignitions and detonations.
- Lack of sealing in the cylinders.

1.2.6. *Aircraft flight operation conditions*

Information compiled from the three pilots that mainly flied the aircraft for skydiver jumping operations and annotations on the aircraft flight logbooks shown that skydiver jumping flights had an average duration of 24 minutes, varying slightly from the 22 minutes during some operation days in season with low temperatures and 25, 26 minutes in hot season.

It has been checked that all of the pilots were updated about the previous engine failure in 2008, they were aware of the need to operate the engine with a smooth regime variation and even they applied Flight Manual procedures in a conservative way.

The fuel charge was always made for two or three rotations as maximum, the maximum people on board was five parachutists, two tandems plus a cameraman, although most of the flights were done with one tandem and one cameraman or with 2 tandems The maximum height with sky divers was 14,000 ft QNH; the most common and used was 12,500 ft QNH.

Specifically, and related to flight procedures, the maximum power for takeoff, 35", was reduced to 30", maximum continuous power, as soon as the aircraft was flying over the obstacles and at 500 ft above the ground. The descent was achieved by reducing the mixture to avoid a quick engine cooling, with cowl-flaps closed, at a maximum speed of 140 kt and an engine power setting for the descent quite higher than the idle one.

1.3. Information on the condition of the aircraft after the incident

1.3.1. *On-site inspection*

After the off-field, power-off emergency landing, the aircraft was verified to have suffered no damage beyond the engine, the damage to which was mainly confined to the no. 3 cylinder.

Figure 1. Right side of the engine; Nos. 1, 3 and 5 cylinders

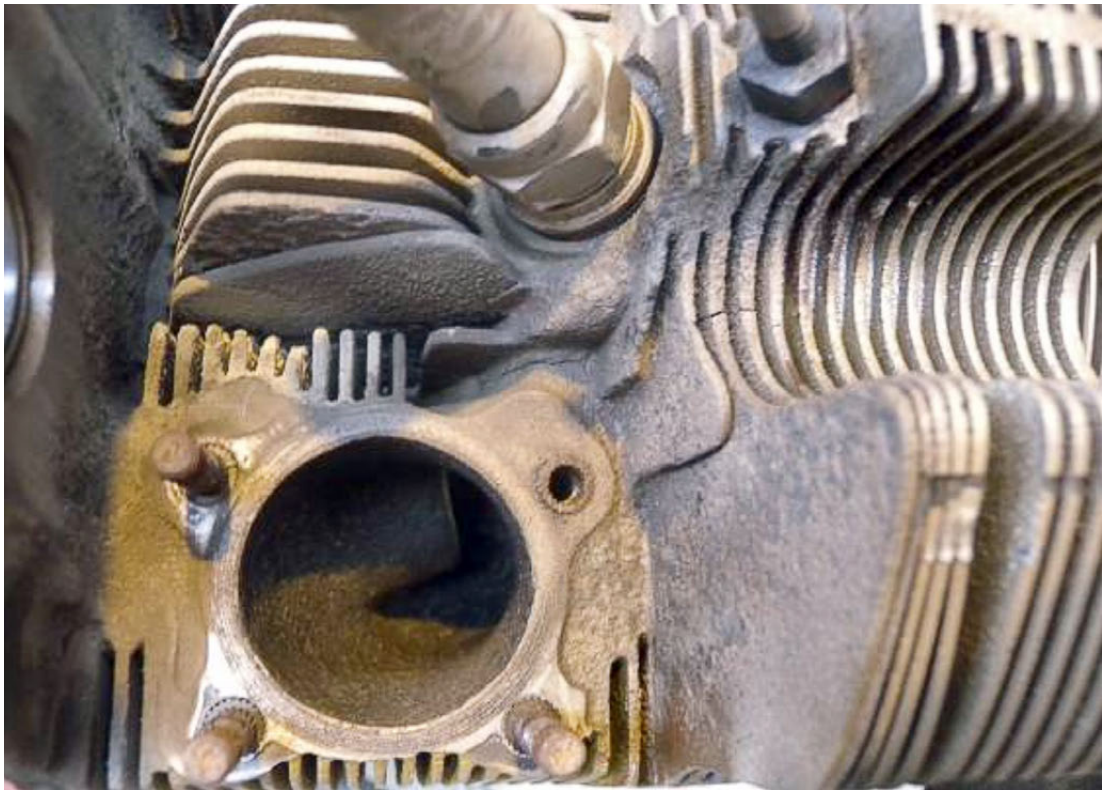

Figure 2. Cracks near the exhaust port and lower spark plug on the no. 3 cylinder

Once the airplane was moved to the hangar, the engine was opened in the presence of representatives of the parties involved (operator, maintenance center and France's accident investigation authority).

It was discovered that the main material failure had been the fracture of the stem in the neck of the no. 3 cylinder exhaust valve. The detached head of the valve had fallen inside the cylinder with the engine in operation, triggering a cascade of damage inside the engine. An analysis of the engine's lubricating and cooling oil showed that it was full of bright bronze particles.

This damage resulted in cooling oil being lost to the outside of the engine through the no. 3 cylinder gasket, in bulging of the crank case in the area where the no. 3 cylinder is attached and in a recent crack at the port of the upper spark plug in the same cylinder.

The remaining damage to the no. 3 cylinder (twisted piston rod, crushed piston, bent tappet or pushrod, etc.) was also considered secondary and caused by the engine being driven by the remaining five cylinders after the failure of the exhaust valve in the no. 3 engine.

Other damage found that was apparently unrelated to that caused by the failure of the exhaust valve on the no. 3 cylinder included cracks and gas exhaust deposits in the fins of the cylinder in the area of the exhaust manifold, loosening of a stud on said manifold and a broken brake collar, deformation and grouping of several cooling fins on the no. 3 cylinder, and a circumferential crack in excess of 180° at the exhaust nozzle of the no. 3 cylinder.

Damage and tarnishing due to overheating were observed in the exhaust gas passages, exhaust valve and rocker arms on the no. 3 cylinder. The adjacent cylinders, nos. 1 and 5, exhibited similar signs though on a smaller scale.

The general condition of the remaining cylinders was acceptable.

The detailed inspection further revealed that:

- The timing on the right magneto was 26° from TDC (top dead center).
- The timing on the left magneto was 24° from TDC (the normal timing is 22° with a ±1° tolerance). Task 67 on magneto timing (as per MSB 94-08D) does not require that the adjusted values be annotated.
- The attachments of the magnetos to the engine crank case and the magneto covers still had the seal from the overhaul center, indicating that the magnetos had not been opened for routine maintenance since the last overhaul (the 150-hr and annual

inspections require opening the magneto covers to inspect the points, lubricate the felt and inspect the eccentric cam).

- There was excessive wear on the electrodes on several spark plugs., though within operating tolerances for the approximately 90 FH of operation since their replacement.
- The points on the magnetos were pitted and exhibited a gap, though they seemed to be within tolerance.
- The sensor to the head of the no. 2 cylinder was improperly connected and the one to the no. 3 cylinder was disconnected.
- The general exhaust temperature sensor was disconnected.

1.3.2. *Inspection of the valve*

The head of the no. 3 cylinder exhaust valve struck the inside of the cylinder several times after it separated from the stem. This led to various deformations of the rest of the stem as well as of the entire circumferential perimeter. An analysis of the head showed a large groove on its skirt that seemed to have resulted from the partial fracture of the head before it broke off from the stem, as shown in Figure 3.

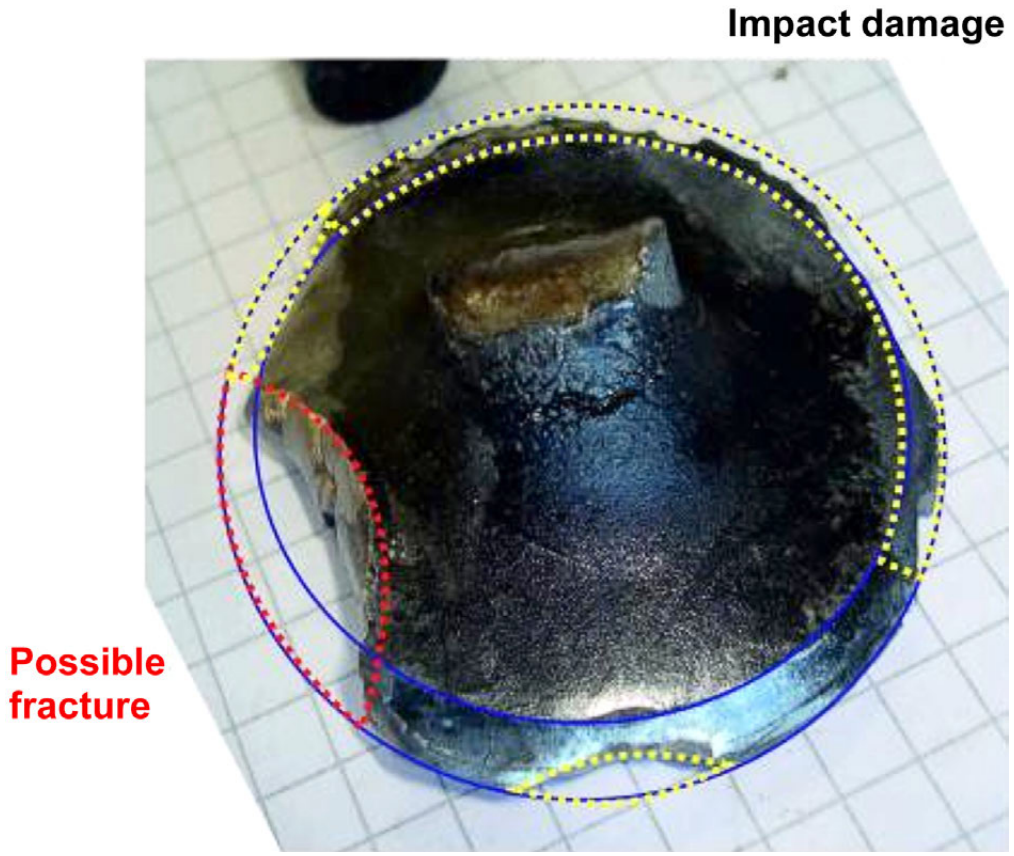

Figure 3. . Head of the valve on the no. 3 cylinder

1.4. Tests and research

1.4.1. *Disassembly and inspection at the manufacturer, TCM*

The entire engine was sent to Continental Motors, Inc. for an in-depth examination by the manufacturer, which yielded the following significant results:

The lubrication system was intact, with no damage to the radiator or oil pump. The oil sump was normal, with only a residual amount of oil contaminated by the mechanical damage to the engine. There were no signs of insufficient lubrication to either the crankshaft bearing or to the cylinder head components (rocker arms, axles, valve guides, etc.), including the no. 3 cylinder.

The distribution and timing of the crankshaft and the camshaft were correct.

Functional magneto tests were satisfactory and showed them to be operating normally. The wear on the spark plugs was also normal. The timing on the magnetos was confirmed to be slightly advanced.

The fuel pump and system were working normally.

All of the cylinders and their pistons and pushrods, except for the no. 3, were in good condition with only normal wear. The intake and exhaust valves were properly seated. The amount of combustion deposits on the cylinders, pistons and valves, except for no. 3, was normal.

Figure 4. Cracks and signs of overheating in the no. 3 exhaust port.

The no. 3 cylinder and its internal components, pistons, segments, pushrod, etc., showed heavy generalized damage.

The head on the no. 3 cylinder exhaust valve was recovered from the inside of the cylinder.

The remaining components, such as the gearbox, turbocharger, half-casings, etc., were normal or had minimal external damage.

Figure 5. Piston, valve and other components of the no. 3 cylinder

Figure 6. Interior of the no. 3 cylinder

In summary, the engine showed no significant abnormalities with the exception of the fracture in the no. 3 cylinder exhaust valve, as well as cracks in that cylinder and overheating damage to the exhaust outlet, port and exhaust tubes. The remaining mechanical damage occurred as a result of the valve failure.

1.4.2. *Metallurgical report*

The valve seats, according to the engine design, are made of steel and are welded to the cylinder head to improve their resistance to wear and to heat cycles. Fragments from the seat of the valve that failed and the two pieces that resulted from the fracture of the valve were analyzed at the TCM laboratories. The hardness values at different points were determined and the material's macro and microstructures were examined, which led to the following conclusions:

- The valve failed due to thermal fatigue.
- The hardness measurements of the materials were within design specifications.
- No abnormalities were found in the material.

1.5. Eyewitness statements

1.5.1. *Statement of the aircraft's normal crew*

The aircraft's most frequent pilot, also charged with monitoring its operations, stated that as early as February 2010, in the wake of the replacement of the six cylinders to comply with MSB09-1, during the 25-FH inspection, high temperature readings were noticed for the no. 3 CHT sensor. Two months later large amounts of exhaust gas deposits were found in the area of the no. 3 cylinder, which was reported to the Locavions maintenance center. This was repeated on 22/07/2010 during an inspection visit in Pau.

The maintenance center was repeatedly informed of the high CHT readings on the no. 3 cylinder, as well as of the high exhaust gas temperature readings on some of the cylinders.

Later, on 01/04/2011, when the airplane was picked up after the last 150-FH inspection, it was discovered that the maintenance center had cleared the airplane for service with the CHT reading from the no. 3 and another cylinder inoperative. The pilots insisted on reporting these abnormalities, seeing as they frequently saw widely varying CHT and EGT values that were occasionally out of specification.

The delay in delivering the aircraft in March-April 2011 was due to difficulties in assembling the no. 3 cylinder at the maintenance center, Locavions, which had to resort to an outside specialist to complete this task.

From August to September 2009 the airplane had an electrical problem that caused the fuel pump breaker to open. The workshop tried on four occasions to fix this problem, without fully solving the malfunction. In October another workshop, Rectimo located in Chambery-Aix les Bains, replaced all the engine cylinders but the electrical problem persisted in the return flight. By a suggestion of regular maintenance shop they consulted a third workshop, Aeromecanics in Marseille, which replaced the fuel booster pump and the electrical malfunction was finally solved.

The day before the 50-hour inspection in September 2009, the workshop was notified of the need to replace the nose tire due to wear. After the nine-day long inspection, the aircraft was returned with the old tire, which was not able to be replaced until three weeks later when a new tire was finally found.

The maintenance center suggested the services of a German CAMO to renew the aircraft's airworthiness certificate in June 2010 three months ahead of its expiration date as it lowered the cost, since several aircraft could be flown to Pau and recertified together. So it was decided to fly the aircraft from Santa Cilia to Pau, though unfortunately an alternator malfunction grounded the aircraft. As a result, one of the workshop supervisors along with the airworthiness inspection personnel from the CAMO went to Santa Cilia to renew its ARC with the aircraft in the hangar.

In May 2011, efforts were made to have the workshop contact the CAMO so that it could renew the AC, though these efforts were fruitless since the trust between the operator and the maintenance center had deteriorated.

In early June 2011, as part of the operator's search for a new center to maintain the aircraft, it contacted Futurhangars, based out of the Sabadell Airport, which conducted the last 50-h inspection prior to the incident.

1.6. Background

The CIAIAC has records that show at least two similar events occurring, one of them involving the same operator:

- A-001/2008 of 13 January 2008 in Abay-Jaca (Huesca) involving the same operator, Centro de Paracaidismo Pirineos, and the same engine type mounted on the same aircraft type, G-BYIC. It was determined that the engine failed due to inadequate lubrication of the crank head bushings, which caused the head on the no. 4 pushrod to overheat and fracture.
- IN-013/2003 of 8 August 2003 in Pastrana (Guadalajara) involving the private operator of a Socata Rallye-100-ST aircraft, registration EC-ICI, with a TCM O-200-A engine. The engine failure was determined to have been caused by the fracture of an exhaust valve head due to several radial thermal fatigue cracks.

1.7. Organizational and management information

The Centro de Paracaidismo Pirineos is covered by the regulation on non-profit sports clubs and has a certificate from AESA (Spain's National Aviation Safety Agency) recognizing it as a parachuting center. It is a Spanish non-profit aviation center that is not necessarily required to contract a CAMO to maintain its airworthiness.

Aircraft G-CCRC had an ARC that expired on 24/09/2011 issued by a CAMO approved by the Federal Republic of Germany (approval reference DE.MG.1007), which managed the continuous airworthiness as from June 29 of year 2010.

The maintenance center Locavions, PART-145 Licence FR 145.297 and approved by aeronautical authority of the Republic of France, was contracted by the operator, with the consent of aircraft owner, since March 01 2009, and it was in charge of maintenance up to May 02 2011; that date the Centro de Paracaidismo Pirineos terminated unilaterally the contract, they paid the invoices of late tasks done and finalized first of April (150 h check and tasks in cylinder no. 3) and they removed whole aircraft documentation from maintenance shop.

Locavions proposed to the Centro de Paracaidismo Pirineos that it use the services of the German CAMO (license no. DE.MG.1007). The professional relationship between Operator and CAMO was not fully established. The interchange of information about flight time and any service anomalies follow the pattern Operator – Maintenance shop - CAMO; instead Operator –CAMO - Maintenace shop should have been more appropriate.

When the incident involving the in-flight engine failure took place, the maintenance center contracted was Futurhangars S.L., with EASA Part 145 license ES 140.

As regards the aircraft with United Kingdom registration G-CCRC, it was owned by an organization located in Northern Ireland – United Kingdom.

2. ANALYSIS

2.1. General

When the Cessna U206 took off on 23 July 2011, it had a long history of abnormalities involving the operation of its engine, a history that went back to shortly after the six cylinders were replaced in compliance with a mandatory service bulletin from October 2009 (MSB 09-1B) and that included abnormally high temperature readings, especially for the no. 3 cylinder, and more recently signs of exhaust gas leaks.

A parachute drop operation is demanding for an aircraft. It requires all of the power that its turbocharged engine can provide, an engine that warms up during the takeoff

and climb phases until the drop altitude, and that then cools rapidly during the descent. In the summer, with high noontime temperatures at airfield level and noticeably lower temperatures aloft, the thermal variance is extreme.

The flight to drop parachutists takes place in a small area in the vicinity of the field that the pilot is very familiar with. In this case when the failure occurred mid-flight, no problems were encountered in completing the parachute drop or in finding a place deemed best by the pilot for carrying out a smooth landing.

The failure took place mid-air, where the pressure difference between the inside of the engine and ambient pressure is at a maximum and when the pilot changed the engine output by reducing RPMs to stabilize the horizontal flight and start the drop. It could, however, have failed in a more difficult situation for the aircraft, such as during the takeoff or when flying at a lower altitude, which would have put the aircraft and its occupants in grave danger.

Since the immediate concern of terminating the flight was successfully resolved, the investigation focused primarily on analyzing the engine failure, on the airplane's routine operations, on its material condition prior to the failure and on the regulated aviation business environment that did not prevent this hazardous situation from developing.

2.2. Engine failure

TCM's detailed inspection of the engine revealed that all of the components and systems, except for the no. 3 cylinder, were in good operating condition and were functioning normally. The crankshaft bearings, the cylinder head components, rocker arms, tappets, etc., were all being properly lubricated. The camshaft timing was perfectly synchronized and the spark plugs were firing correctly, though somewhat advanced in their timing. The fuel feed and turbo-compressor were also functioning properly.

The analysis of the engine showed that the no. 3 exhaust valve had failed. It also revealed the presence of cracks in the walls of this cylinder and on the exhaust flanges, as well as wear of the components near the exhaust due to heating.

TCM's metallurgical analysis confirmed that the engine, a Teledyne Continental Motors TSIO 520-M7B, S/N 532404, failed due to thermal fatigue of the fractured valve. Several conditions can contribute to this fatigue if they are repeated over a prolonged period of time:

a) Sudden and constant changes from maximum to minimum power.
b) A bent, off-angle or improperly seated valve.
c) Improper regulation of the engine's distribution components.
d) Excessive temperature due to pre-ignitions and detonations.
e) Improperly sealed cylinders.

Figure 7. Taken from SB03-03 by TCM. Shows a burned exhaust valve with signs of leakage and damage

Even without knowing exactly how the failure initiated, it can be surmised that since it only affected one cylinder, the cause must be related to a unique feature of that cylinder and its assembly or adjustments. In light of the evidence found, it is very likely that an improperly seated exhaust valve causing leakage through that valve (see Figure 7) resulted in the initial degradation and loss of material around the perimeter of that valve's head (see Figure 3).

This leakage caused the partial fracture, which in turn led to a larger leak and greater heating of the cylinder head due to combustion that was not contained within the cylinder and piston. Over a period of time with the engine operating in these conditions, thermal fatigue made the incubating cracks grow until the head finally broke off from the stem.

The cracks on the outside of the no. 3 cylinder and on the exhaust port and tubes, as well as the wear, discoloration and damage to the cable linings and components in the area prove that the combustion was not confined to the combustion chamber and that the flames reached the exhaust pipes. These signs of wear, readily observable externally

when opening the fairing, should have pointed to the abnormal operation of that cylinder.

Early detection of the problems with leaks, overheating and thermal fatigue would have prevented the failure.

Conducting the differential pressure and boroscope inspection tests of the cylinder would have detected these problems in time. There is no record in the maintenance files of a boroscope inspection ever having been conducted on the cylinders, and there are serious doubts as to whether valid differential pressure and compression tests of the cylinders were ever conducted since the values recorded for the six cylinders on the last two inspections performed by Locavions were always the same and the pressures for the "Master Orifice" calibration standard were not annotated, as required by procedure. The manufacturer's service bulletin MSB03-3 has instructions on the applicable procedures.

The statements from the crews regarding other repeated and unsuccessful maintenance activities involving other malfunctions not related to the engine could be indicative of incompetent performance by the maintenance center.

2.3. Normal operation of the airplane and engine

The constant takeoff-climb-descent-land cycles to which the airplane was subjected as part of its parachute drop operations have a direct bearing on the propagation of the thermal fatigue that led to the failure. Pilots, mechanics and operators know that the reliability of this engine is highly dependent on the careful operation and management of the engine's heating/cooling cycles. In this regard, the lease contract for the aircraft underscores the concern of the lessor, who demanded to be kept informed of the cycles and typical operating times. This information can be used to verify that sufficiently slow cooling cycles are being observed during the normal use of the aircraft. In fact, so as to better monitor the operation of the engine, the aircraft had an additional digital sensor installed with readouts for all the cylinders.

This notwithstanding, various accounts and exchanges between the operator and the maintenance center referred to problems involving a lack of CHT and EGT readings going back two years, which calls into question how an operator can monitor heating/cooling cycles without constantly measuring these temperatures.

2.4. Maintenance

The line and daily inspections at the Centro de Paracaidismo Pirineos were the responsibility of the crews, which notified the maintenance center of any operating abnormalities so that they could be corrected.

Judging by the mistakes in the documentation, the repeated maintenance actions that failed to correct faults, it is reasonable to presume that the maintenance center was not properly maintaining the Cessna G-CCRC aircraft.

Despite some items on the annual review and other checks not being completed in April 2011, the airplane continued to fly until the date of the incident. Likewise, the documentation indicates that neither the leak checks nor the boroscope examinations were properly carried out. This was also evidenced by the fact that the seals from the center that performed the overhaul were found intact, meaning that the magneto timings were never checked, which allowed for an improperly adjusted firing sequence during continuous operations.

This maintenance organization, assisted by the CAMO concerning the need for inspections and corrective actions that aircraft G-CCRC required, should have known about the applicable inspections, checks, tests and SB's, as well as the procedures for checking and correcting any anomalies that could have been present or that were reported by the operator.

As a result of the above, a safety recommendation is issued to the aviation authority on the country of the maintenance center to reevaluate the technical suitability of this aircraft's maintenance center, Locavions.

2.5. Airworthiness management

In this case an airplane from Northern Ireland, registered in the United Kingdom, operated by a Spanish organization and maintained by a French center with aid from a German CAMO seems to have created an environment in which responsibilities were enormously diluted.

The small operator tasked the duty of renewing the airworthiness certificate to a CAMO that was not involved efficiently in the day-to-day tracking of the airplane's airworthiness, for instance the aircraft operated with the annual inspection not in force. The PART-145 maintenance center should have performed the actions requested directly by the operator or the CAMO. It seems that this maintenance center did so without adhering to the applicable SB's, without coordinating with a CAMO and, ultimately, without providing reliable solutions to the engine's operational problems.

The center that took over the aircraft's maintenance in June 2011, Futurhangars, also did not receive adequate information regarding possible earlier problems still affecting the engine, meaning that the potential for engine failure was still present.

An operator with the structure of the Club de Paracaidismo does not have the technical ability to control its aviation assets, which in this case consisted only of the incident

aircraft. As a result it was unable to confirm the deficient maintenance status and correct it, except for tangential aspects involving the reliability and timeliness of the tasks performed. This caused it to change maintenance organizations without adequately conveying the deficiencies and without managing to get the engine in good operating condition, this because the new maintenance center prioritized timeliness over the correct performance of its tasks.

As a result of the above a safety recommendation is issued to the operator so that it improve its oversight of the airworthiness of the aircraft it operates either by contracting qualified personnel or by contracting a CAMO capable of such oversight.

From July 2010 with the CAMO intervention, this should have been in charge of airworthiness continuous management, establishing a direct relationship with the operator to know flight activities and possible flight service anomalies, to communicate and coordinate the maintenance tasks with the shop. As a significant example of this deficient management the aircraft operated with its last annual time inspection not in force.

As a result of the above a safety recommendation is issued to the Civil Aviation Authority of the CAMO country, Federal Republic of Germany, so that it re-evaluate the technical suitability of the airworthiness continuous manager of this aircraft, CAMO Köhler.

3. CONCLUSION

3.1. Findings

- The airplane had a long history of engine problems involving leaks, high temperatures on the no. 3 cylinder heat and the CHT and EGT temperature indication systems.
- On the day of the incident, 23/07/2011, the airplane was on a flight with the pilot and five parachutists onboard.
- While over the airfield, at the desired altitude and before the parachute drop, the engine suddenly failed, losing practically all power as vibrations increased and smoke and the smell of burnt oil issued from the engine.
- The parachutists jumped out and the pilot made an uneventful, power-off emergency landing on a field north of the Santa Cilia de Jaca airfield, a short distance away from the runway.
- The no. 3 cylinder exhaust valve had broken off from the stem at the neck due to thermal fatigue. The cylinder head and the exhaust pipes had cracks caused by thermal stress and there was a loss of material from the cooling fins.
- The engine's cylinders had been installed some 450 FH earlier during a replacement required by a mandatory SB. The problems started in the wake of that replacement, first as high temperatures and as temperature indication problems, and then as losses and leaks of exhaust gases.

- The deficient maintenance of the aircraft was not able to correct the problem with the abnormal operation of the engine.

3.2. Causes

- The immediate cause of the engine failure was the fracture of the exhaust valve on the no. 3 cylinder.
- The fact that the failure was not detected earlier is attributed to deficient maintenance of the aircraft.
- Possibly contributing to the deficient aircraft maintenance was the sharing of responsibilities among organizations from various countries, even though they were all subject to EU regulations.

4. SAFETY RECOMMENDATIONS

REC 09/14. It is recommended that the French Civil Aviation Authority, responsible for monitoring and inspecting the maintenance center, reevaluate the technical suitability of this aircraft's maintenance center, Locavions.

REC 10/14. It is recommended to this Skydiver Club that it improve its oversight of the airworthiness of the aircraft it operates either by contracting qualified personnel or by contracting a CAMO capable of such oversight.

REC 11/14. It is recommended to the Civil Aviation Authority of Federal Republic of Germany, country of CAMO Köhler, that it re-evaluate the technical suitability of the airworthiness continuous manager of this aircraft.