DATA SUMMARY

LOCATION

Date and time	**Thursday, 17 January 2013; 17:26 local time**
Site	**Runway 28 at the Cuatro Vientos Airport (Madrid, Spain)**

AIRCRAFT

Registration	**EC-ICG**
Type and model	**PA-60-601P (Aerostar 601P)**
Operator	**Private**

Engines

Type and model	**LYCOMING IO-540-S1A5**
Number	**2**

CREW

Pilot in command

Age	**48 years old**
Licence	**PPL(A)**
Total flight hours	**1,500 h**
Flight hours on the type	**500 h**

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

DAMAGE

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

FLIGHT DATA

Operation	**Private**
Phase of flight	**Landing run**

REPORT

Date of approval	**30 October 2013**

1. FACTUAL INFORMATION

1.1. History of the flight

The aircraft, which had taken off from the Axarquia Aerodrome (Malaga), was cleared to land on runway 28. The approach proceeded normally but after making contact with the ground, the front landing gear collapsed. The underside of the nose came to rest on the surface of the runway, sliding on it until the airplane stopped in the final third of the runway. The two occupants were uninjured and immediately exited the aircraft, which was damaged as a result of the friction between the fuselage and the asphalt.

While the aircraft remained on the runway, other arriving traffic at the airport either landed on the unpaved runway in the military part of the airport or was diverted to another nearby aerodrome.

1.2. Personnel information

The aircraft's pilot-owner obtained his first flying license in 1998. He then obtained a multi-engine rating, which was valid on the day of the incident.

He had purchased the aircraft in 2003 and regularly flew it 50-100 h a year. He had previously owned two other aircraft, the last of which had also been a twin-engine airplane.

The other person in the aircraft, though not a pilot, flew regularly with him as a passenger.

1.3. Aircraft information

The Aerostar 601P is a pressurized twin-engine airplane with retractable gear. It can hold 5 passengers and the pilot[1]. It was type certified in 1973.

The incident aircraft, manufactured in 1979, had a total of 1648:50 flight hours. It had an airworthiness review certificate (ARC) issued by AESA on 03/07/2012 that was valid for one year. It was the only unit of this model registered in Spain on the date of the incident.

[1] The type certificate, which had originally been held by the Piper Aircraft Corporation (since 1978), was transferred to the Aerostar Aircraft Corporation in 1991.

1.3.1. *Description of the nose landing gear*

The landing gear is hydraulically operated. The nose gear (Figure 1) is retracted by the action of a hydraulic actuator (item 1) which, when it extends, swing the upper drag link (item 2), which in turn drags the lower link (item 3), and with it the leg (item 4). There is no way to lock the gear in the retracted position, meaning that a loss of hydraulic pressure will cause it to drop due to gravity. When the hydraulic pressure is released from the cylinder, the weight of the leg compresses the stem on the actuator and the leg extends. Once this happens, an overcenter (item 5) keeps the two drag links aligned, keeping them from folding and the leg from retracting. A spring (item 6) stretches the overcenter to keep it locked.

The hinge in the overcenter houses a micro-switch that is responsible for transmitting the gear down and locked signal (item 7).

The rotating axis of the upper drag link (item 8) is screwed to the link itself and it rotates inside bushings housed in two U-shaped beams that are fixed on either side of the left landing gear bulkhead by means of rivets (Figure 2). Mounted at the outer end of the axis is a cam (item 9) that, when the gear retracts, makes contact with a micro-switch (item 10) that then sends the gear-up signal.

This design does not require any special action to extend the gear in the event of a hydraulic failure other than actuating the gear lever and waiting for it to drop by gravity.

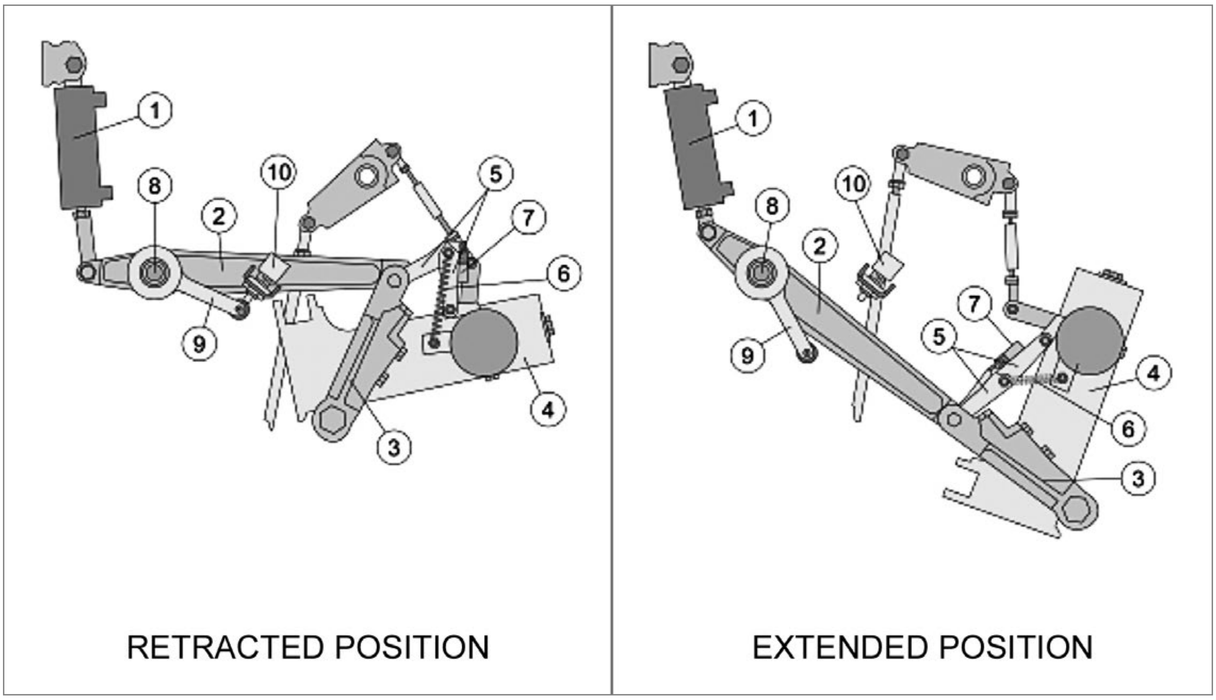

Figure 1. Diagram of the nose gear

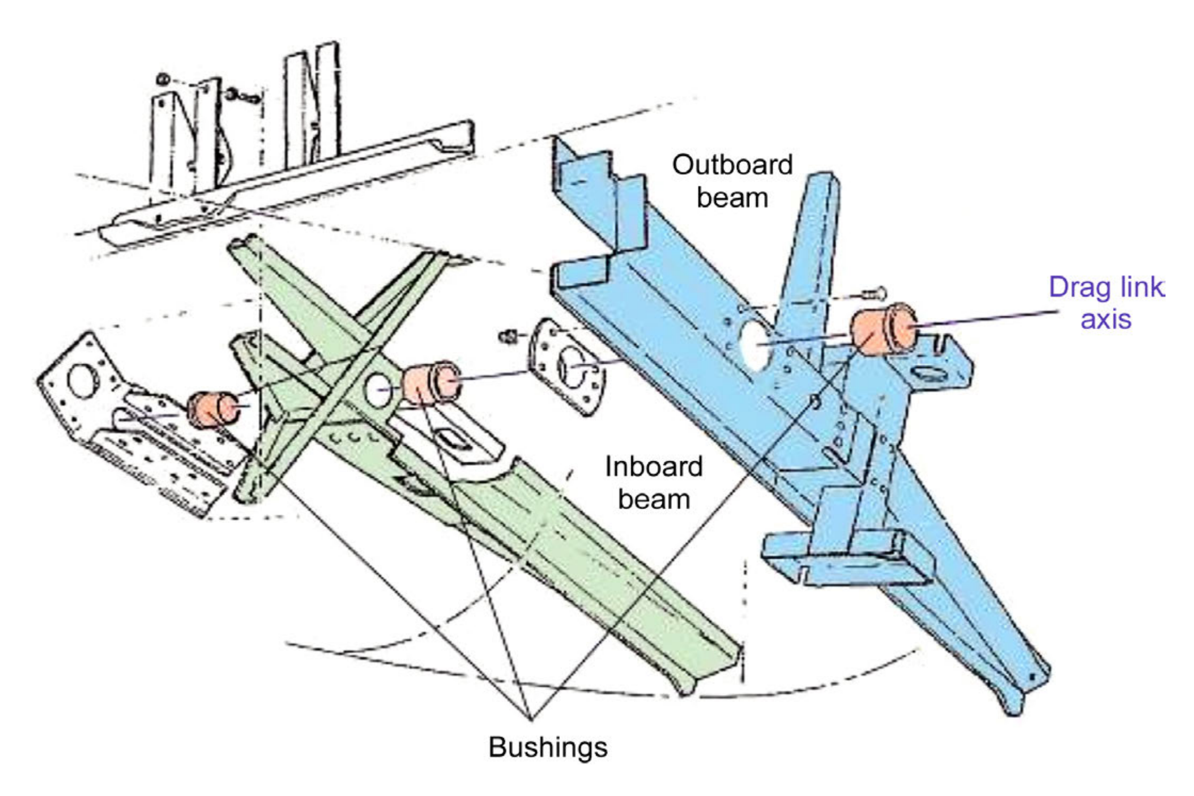

Figure 2. Anchoring beams for the axis of the main drag link

The nose gear has four doors. The two front ones open and close fully when the gear is lowered or raised, while the two rear doors remain open with the gear down. These doors are opened and closed by a system of linkages that mechanically transmit the motion of the gear leg.

The nose gear wheel can be steered through a 60° angle by means of a hydraulic actuator that doubles as a vibration (anti-shimmy) damper. The hydraulic line for this system enters the gear well through the well's aft bulkhead.

The gear actuating lever is located on the central part of the instrument panel. The gear down position is indicated in the cockpit by three green lights that turn on when the gear down and locked signal is received from micro-switches on each leg with the gear in the down position. The gear up position is indicated by a single amber light that turns on when it receives a signal from three other micro-switches. There is no light to indicate that the gear is in motion. All of these lights can be checked for proper operation by pressing them.

The main gear's position can be observed directly from the cockpit. The nose gear's position can be observed indirectly through its reflection in either propeller hub.

So as to prevent the gear lever from being inadvertently moved to the up position while the airplane is on the ground, there is a squat micro-switch on the nose gear that sends a signal to lock the landing gear lever in place when the strut is compressed.

The airplane also features a horn and a red warning light to indicate when the engine intake pressure is below 14 in Hg (low throttle) and the landing gear is not down and locked.

The flaps, which can extend to 45°, are also hydraulically actuated, like the gear.

1.3.2. *Maintenance history*

The aircraft's maintenance program[2] requires that it be subjected to scheduled inspections at intervals of 50, 100 (or annual), 500 and 1,000 h. Neither the listing of limited lifetime components nor the structural inspection program applicable to the pressurized versions of this airplane require checking the U-beams that house the rotating axis of the main link.

The last scheduled maintenance task performed on the aircraft was a 100-hr check, done in April 2012. This inspection checks the overall condition of the landing gear and involves greasing all of its moving parts and conducting an operational test of the gear. There is no specific requirement to inspect the beam for cracks. During this check the tire on the nose gear wheel was also replaced due to wear.

Subsequently, in October 2012, the airplane experienced a problem with the well door for the left main landing gear leg. The problem was solved by replacing a solenoid valve in the hydraulic system. According to the maintenance personnel that carried out the work, once the problem was repaired, the necessary adjustments and operational tests were carried out for the entire landing gear, all of which were satisfactory. The records for these tasks do not reflect any work specific to the nose gear.

During the previous annual inspection, in March 2011, a crack was detected on the interior attaching beam for the upper locking link axis on the landing gear. The crack was repaired by riveting a reinforcing plate over the area with the crack. This repair was not performed by following any specific documentation from the manufacturer, which does not have documents for structural repairs, instead referring to an FAA document[3]. Also during this inspection a bushing was replaced on a loose locking bar hinge. Apart from this repair, there are no records of any changes or reinforcements being made to the original structure.

[2] Maintenance Program with approval reference PM.ICG rev. 2 19/06/2012.
[3] AC.43.13.-1B Acceptable Methods, Techniques, and Practices - Aircraft Inspection and Repair. Section 4.4 of this document contains guidelines for repairing metal components.

1.4. Meteorological information

The aerodrome observation reports (METAR) indicated good visibility conditions with few clouds at 3.000 ft and wind at 7 kt more or less in line with the runway heading (varying between 230° and 290°).

Moments before landing, the controller informed the aircraft that the average wind speed was from 230° at 7 kt gusting to a maximum of 15 kt.

In the previous flight from Cuatro Vientos to Axarquia, there were strong winds in the destination aerodrome when the airplane landed, with gusts of up to 50 km/h.

1.5. Communications

The Cuatro Vientos tower was in communications with both the incident aircraft and with other traffic in and around the airport. After the incident the tower also established communications with airport services, with the Madrid area control center and with the tower at the Getafe Airport.

At 16:22:50, the pilot reported his position near the aerodrome's circuit. The tower controller requested that he report once established on the left downwind leg for runway 28.

At 16:23:57, while on final approach, the pilot asked for the wind information, which the controller provided.

At 16:24:36, the aircraft was cleared to land.

At 16:26:26, the controller ordered the next aircraft in the landing sequence to go around, diverting it and another aircraft to hold points around the aerodrome and asked the pilot of the aircraft that was still on the runway what his intentions were.

At 16:27:22 the controller informed the firefighting service of the aircraft's position and condition, authorizing its entry into the movement area.

Several calls were then made to coordinate the activities of the emergency services on the runway and to exchange information with the ARO office[4]. The controller notified the Madrid area control center and the Getafe tower of the incident in anticipation of requiring their assistance to handle the traffic that was heading to Cuatro Vientos.

[4] Air Traffic Reporting Office, where flight plans are filed and approved.

At 16:35:48, after being notified by the firefighters that the task of cleaning the runway would take some time, the controller informed all stations (in Spanish and English) that the airport was temporarily closed due to an accident on the runway.

1.6. Airport information

The airport has one 1,500-m long asphalt runway in a 28/10 orientation. In the military part of the aerodrome, next and parallel to the asphalt runway, there is an unpaved runway measuring 1,127 m in length.

1.7. Tests and research

1.7.1. *Statement from the pilot and the passenger*

The pilot stated that after taking off from Axarquia, the amber gear-up light did not turn on. He remained above the airfield for a while to check the condition of the gear. He thought that the speed and aerodynamic noise were consistent with a gear up configuration. He also saw the position of the nose gear reflected in one of the propeller hubs (a typical practice) and confirmed that it was retracted, as was the main gear, which he could see directly through the windows.

The light remained off for the duration of the flight. While in the Cuatro Vientos circuit before landing, he checked the position of the gear through the cockpit indication (three green lights indicating the gear was down and locked) and by direct observation through the windows.

The approach and landing were normal. He stated that though there was some wind, it did not concern him.

After the main gear made contact, the nose gear touched down. He then heard a strange noise, like a sudden thud. The airplane continued moving for a few seconds before the gear collapsed, with the nose of the airplane resting on the runway until it came to a stop. While still moving he cut the mixture control, fuel supply, magnetos and master. Although he could not give a specific time, his perception was that the firefighters reported to the scene quickly.

He recalled that during two pre-flight checks on previous flights, he had noticed that the front doors on the nose gear were not closed. The first time they were partially open, and even more so during the second check. He called the maintenance shop, which informed him that it was not a problem as long as the doors were firmly attached to the rods and they were not loose. They agreed to check the doors during the next visit to the shop.

When asked about the previous landing in Axarquia, he confirmed that it had been a fairly turbulent flight, though he did not think that the landing had been unusually difficult. He did not recall making any particularly hard landings in recent flights, though he also did not rule out the possibility. He did mention one previous event in this regard but it had happened a long time ago (a year and a half or two years earlier), when the airplane "pancaked" on the runway while making a landing in gusty conditions. He did not consider it significant enough to warrant informing the maintenance workshop.

The passenger did not notice anything unusual during the approach and corroborated the pilot's report of the sudden thud during the landing run and feeling the gear give way after the airplane had traveled normally for a few seconds after touching down on the runway.

1.7.2. *Controller's statement*

The circuit and approach phases were uneventful. He reported the wind at 7 kt practically in line with the runway. It was the first aircraft in the landing sequence. There were no preceding aircraft.

A couple of seconds after the landing he saw how the airplane collapsed on its nose. He then saw sparks and flames bursting from the nose. The airplane remained more or less in the center of the runway, stopping in the final third of the runway.

He immediately sounded the alarm and informed the traffic behind to go around. He called the aircraft and received no reply, but saw someone exiting it right away. He reported the aircraft's location and type to the firefighting service (FFS) and, after checking with the ARO office, the number of people onboard.

The runway was closed until 17:19 (about 50 minutes). Other aircraft were diverted to alternates or were cleared by military controllers to land on the unpaved runway.

1.7.3. *Post-incident inspection*

The position of the switches and controls of the electrical (master, alternators) and fuel supply (mixture and throttle) systems were consistent with the pilot's statement regarding the actions he took during the landing run.

The gear lever was in the down position.

The flaps were extended to an intermediate position (20°) that matched that selected on the flaps lever.

The U-beam that houses the axle on which the nose gear's upper drag link pivots was broken near the housing where the actuating rod that moves the front left well door shifts back and forth. The part of the beam forward of this housing had lost the rivets that attach it to the side bulkhead and was loose (Figures 3 and 4).

Figure 3. Forward gear wheel well showing the fracture area and the loss of the rivets that hold the drag link in place

Figure 4. Beam disassembly

There was a reddish mark on the beam next to a crack that started in the hole for a screw that attached the part to the bulkhead (see figure 6). Workshop personnel could not ascertain its origin, indicating that it was probably present when the airplane was first taken to the workshop in 2007. Two other centers that had carried out maintenance on the airplane before were contacted, but neither one had records indicating that this crack had been detected and was being monitored.

The plate that had been used to reinforce the area where a crack had been detected two years earlier was itself cracked.

This part was sent to a laboratory for an analysis of the fracture.

The beam that houses the extension of the link axis on the other side of the bulkhead was also broken, such that the axle had moved from its position. Due to the motion, with the leg in the retracted position, the cam that is attached to the axle and that makes contact with the micro-switch responsible for transmitting the gear-up signal could not reach its normal position, meaning it was unable to make contact with the micro-switch (Figure 5).

There were no impact marks on the tire on the front gear wheel, which had been replaced recently. The left tire did exhibit a flat spot consistent with a hard landing.

The hydraulic return line from the actuator was broken, possibly as a consequence of the movement of the actuator itself when it was dragged by the locking arm when its axle moved (Figure 6).

Figure 5. Cam and gear-up micro-switch

As a result of the loss of rigidity of the locking system caused by the fracture and motion of the beam, the leg swung excessively toward the rear, such that its structure made contact with the wheel well's rear bulkhead at the point indicated by an impact mark. This part of the bulkhead houses an elbow of the hydraulic line for the nose wheel steering system, which had broken (Figure 7).

The doors on the front wheel well exhibited damage that was consistent with being dragged on the asphalt surface.

Figure 6. Return of the hydraulic line that supplies the actuator

Figure 7. Impact on the rear bulkhead and part of the leg responsible for the impact

The gear position alerting system was verified to be working correctly.

The interlock that prevents retracting the gear on the ground was also working properly, keeping the lever from actuating with the strut compressed.

1.7.3.1. Laboratory analysis of the beam

The analyses indicated that material was made from an AW 2024 aluminum alloy with no apparent micro-structural defects or discontinuities in the failure zones.

The study revealed the presence of failure zones with different characteristics.

The rivet holes in the top front part of the component exhibited a micro-morphology indicative of a fatigue process. The crack developed over the course of many cycles that encompassed a relatively long period of time, as evidenced by the signs of corrosion that were found. The end of the piece, which had been repaired, and the red-tinged hole for the mounting screw, also exhibited fatigue cracks of the same nature.

In contrast, the fracture in the central part of the beam, which had broken the part in two, resulted from a ductile tearing mechanism, typical in this material when subjected to excessive stress. The rivets used to attach the part to the component that were closest to this central area also broke as a result of this same ductile mechanism. Likewise, on the section of the arm that remained attached to the bulkhead, a stress fracture was identified on both the transversal fracture on the body of the arm and on the rivets.

The laboratory analysis concluded that the fracture sequence most likely started with the incubation and development of the fatigue mechanism, which propagated through cracks in the riveted junction. Once this junction was weakened, the beam was subjected to bending stresses that caused the adjacent rivets to break, eventually causing the fracture of the central part and arm of the beam.

1.7.4. *Additional information*

The type certificate holder stated that it was unaware of any prior similar events in which the nose gear collapsed due to the failure of this structure, though it is a component that has been the focus of repairs in other aircraft.

Aerostar also reported that a kit is available to reinforce the beam external to the bulkhead and inhibit cracks in that area. Its engineering department is evaluating the possibility of making a similar kit available for the internal beam. Investigators were unable to confirm if the reason for these reinforcements and repairs was the recurring appearance of fatigue cracks, nor were they able to compile detailed information on the modifications (such as their approval date, applicability or details on the implementation instructions).

The investigation did not find a history of accidents or incidents associated with the fatigue failure of this part in other units of this airplane model[5].

2. ANALYSIS AND CONCLUSIONS

Neither the pilot's nor controller's statements nor the condition of the front tire point to a particularly hard landing at Cuatro Vientos that could, by itself, account for the

[5] Investigators consulted the NTSB's (National Transportation Safety Board) online database.

fracture of the beam to which the locking system is attached and for the subsequent collapse of the nose gear.

The gradual degradation of the structure that houses the axis of the drag link was caused by the growth of the fatigue cracks that initiated at various points on the beam inside the bulkhead. This would also explain the worsening anomalies detected by the pilot.

The first effect of this degradation of the beam would have been a slight change in the angle of the leg in the down and locked position while on the ground. Since the motion of the rods that actuate the gear doors depends on the position of the leg, a change in this angle would imply a change in the position of the rods at the end of their travel, which would affect the position of the doors, as the pilot detected during the pre-flight checks.

The stresses associated with the subsequent taxiing, takeoff runs, cycling of the gear and landings (including the last landing in Axarquia under very windy conditions) would have deteriorated the structure of the beams even more such that on the return flight to Cuatro Vientos, even with the gear retracted, the cam that activates the micro-switch and switches on the gear-up amber indicating light was unable to reach its position due to the weight of the leg.

When the lever was actuated to lower the gear before the final landing, the gear would have dropped by gravity and, in the absence of loads before contacting the runway, would have extended normally, sending the signal that turned on the green light in the cockpit.

At this point the weakened structured would have been unable to withstand the landing stresses. The loss of rigidity in the locking system allowed a certain degree of motion in the leg, which probably struck the wheel well's aft bulkhead during the first few meters of the landing run. This would explain the dull thud felt by the pilot and the break in the hydraulic line that crosses the bulkhead. The return line on the gear actuating system broke when the end of the piston that pivots at the end of the locking arm moved excessively. Both hydraulic system failures took place on the ground and thus did not affect the gear retraction on takeoff or the extension of the flaps before landing.

Based on the laboratory findings, the part that failed exhibited fatigue cracks, one of which had been detected and stained apparently so as to facilitate its location and tracking, though it was not possible to determine who stained it, nor when or where. The appearance of a crack in the area repaired in the workshop indicates the persistent nature of the problem.

In the absence of specific airworthiness maintenance instructions for monitoring potential cracks in the structure that failed, these tracks were not being actively monitored, something that could have aided in anticipating the overall progression of the crack that eventually led to the weakening and fracture of the structure.

Neither the inquiries sent directly to the manufacturer nor the checks of the NTSB database yielded any information on previous occurrences that could be used to determine whether the fatigue of the part that failed could require fleet-wide corrective maintenance or engineering actions. Even though the manufacturer reported that it has engaged and continues to engage in activities designed to bolster the strength of this structure, it has not provided sufficient information for even a minimal evaluation of these activities, or specifically if their application in this case would have been of any use.

The fact that the tower controller was watching the landing allowed him to immediately alert the firefighting service and to properly handle the other aircraft by either diverting them to their alternates or having them land on the unpaved runway in the military part of the aerodrome.

3. CAUSES

The incident occurred when a generalized fatigue process caused the fracture of the support structure for the upper drag link on the nose gear.