AIRCRAFT ACCIDENT REPORT 1/2003

Air Accidents Investigation Branch

Department for Transport

Report on the accident to Hughes 269C, G-ZAPS at Hare Hatch, near Twyford, Berkshire on 8 March 2000

This investigation was carried out in accordance with
The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996

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Department for Transport
Air Accidents Investigation Branch
Berkshire Copse Road
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January 2003

The Right Honourable Alistair Darling MP
Secretary of State for Transport

Sir,

I have the honour to submit the report by Dr E J Trimble, an Inspector of Air Accidents, on the circumstances of the accident to Hughes 269C helicopter, G-ZAPS, which occurred at Hare Hatch near Twyford, Berkshire, on 8 March 2000.

I have the honour to be
Sir
Your obedient servant

K P R Smart
Chief Inspector of Air Accidents

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GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	-	Air Accidents Investigation Branch
AD	-	Airworthiness Directive
AFI	-	Assistant Flying Instructor
amsl	-	above mean sea level
ANO	-	Air Navigation Order
ATC	-	Air Traffic Control
ATSB	-	Australian Transport Safety Bureau
BASI	-	Bureau of Air Safety Investigation
BCAR	-	British Civil Airworthiness Requirements
°C	-	degrees Celsius
CAA	-	Civil Aviation Authority
CAP	-	Civil Aeronautical Publication
C of A	-	Certificate of Airworthiness
FAA	-	Federal Aviation Administration
FAR	-	Federal Aviation Requirements
HMI	-	Handbook of Maintenance Instruction
hrs	-	hours
IAS	-	Indicated Air Speed
INS	-	Inertial Navigation System
JAA	-	Joint Aviation Authorities (Europe)
JAR	-	Joint Aviation Requirement
KCAS	-	Knots calibrated airspeed
kg	-	kilogram(s)
kt	-	knot(s)
LAE	-	Licensed Aircraft Engineer
LAMS	-	Light Aircraft Maintenance Schedule
lb	-	pound(s)
LTO	-	Letter to Owners/Operators
°M	-	degrees magnetic
mb	-	millibar(s)
No	-	number
PFM	-	Pilot's Flight Manual
PFI	-	Pre-flight inspection
RT	-	radio telephony
SB	-	Service Bulletin
SIN	-	Service Information Notice
S/N	-	serial number
UK	-	United Kingdom
USA	-	United States of America
UTC	-	Co-ordinated Universal Time

Air Accidents Investigation Branch

Aircraft Accident Report No: 1/2003 (EW/C2000/3/3)

Registered Owner and Operator	Dennis Raymond Kenyon/The Aviation Bureau
Aircraft Type and Model	Hughes 269C
Nationality	United Kingdom
Registration	G-ZAPS
Place of Accident	Hare Hatch near Twyford, Berkshire
Date and Time	8 March 2000 at 1644 hrs
	All times in this report are UTC

Synopsis

The accident was notified to the Air Accidents Investigation Branch (AAIB) on 8 March 2000 at 1705 hrs and the investigation was initiated that evening. The AAIB team comprised Dr E J Trimble (Investigator in Charge), Mr J J Barnett (Operations) and Mr R Parkinson (Engineering).

Whilst flying on a southerly heading near the village of Hare Hatch, the attention of ground witnesses was drawn to the helicopter by the sound of its engine and its low height. The helicopter was then seen to break into two sections, amidst a short-lived but large cloud of dark coloured 'smoke', before falling to the ground. The three occupants of the helicopter were fatally injured.

The investigation identified the following causal factors:

1 A pre-existing fatigue fracture of the upper clevis lug on the left centre frame rear cluster fitting, which induced a rapid fatigue failure of the associated lower lug and consequent separation of the tailboom left lower support tube from this cluster fitting; this allowed the aft end of the tailboom to displace into the plane of the main rotor disc before the tailboom detached completely.

2 Initiation of very high cycle tension fatigue crack propagation in the upper clevis lug at the weld bead edge of a non-approved welded patch repair to this lug.

3 An omission by the Licensed Aircraft Engineer, who had instigated the welded patch repair of the previously cracked upper clevis lug in April 1999, to reference the helicopter's Handbook of Maintenance Instruction, or the manufacturer regarding this weld repair combined with a lack of awareness that no weld repairs of these clevis lugs were permitted. The presence of such cracking required replacement of the cluster fitting.

4 Non-detection of the welded patch repair on this left upper clevis lug or associated fatigue cracking as a result of the pilot's Pre-Flight Inspection, the helicopter's previous Daily Inspections and the last recorded specific visual examination of the clevis lugs using 10X magnification which had been carried out by the Licensed Aircraft Engineer on 18 February 2000, 112:20 flying hours after this non-approved repair and some 16 flying hours before the accident.

5 Absence of any requirement to inspect these clevis lugs during a Civil Aviation Authority Survey of this helicopter in October 1999 and the attendant non-detection of the welded patch repair to the left upper clevis lug prior to the issuing of a Certificate of Airworthiness.

6 The regulatory decision not to mandate the fitment of available re-designed strengthened cluster fittings, despite a history of fatigue cracking of the original clevis lug design over some 30 years and six resultant tailboom detachments, combined with unsound reliance upon the effectiveness of a strategy of repetitive inspections and Federal Aviation Administration Airworthiness Directive 76-18-01; such modification had therefore not been made mandatory by the Federal Aviation Administration, the primary certification authority for this type, or the Civil Aviation Authority for such helicopters on the UK Register, and this UK registered helicopter had not had such re-designed clusters fitted.

Fourteen Safety Recommendations were made during the course of this investigation.

1 Factual information

1.1 History of the flight

On the day of the accident the owner, who was an instructor and type-rating examiner, had intended to use the helicopter for recurrent training and testing of a private pilot, but the wind conditions were unsuitable. The helicopter was therefore released to the owner's son and his friend for their use.

During the morning the helicopter had been refueled at Shoreham Airport and had then flown to a private landing site nearby. At around 1500 hrs, the two pilots and a mutual female friend had boarded the helicopter to fly to Wycombe Air Park. The mutual friend occupied the centre seat position. Before the centre seat can be occupied, the right seat occupant's collective lever must be removed and the gap between the seats bridged with a purpose-designed cushion. The helicopter manufacturer provided a lap belt for the centre seat occupant, whereas the other two 'permanent' seats were equipped with lap and shoulder straps. The flight to Wycombe Air Park was apparently uneventful.

During the time that the helicopter was shut down at Wycombe Air Park, the female passenger had remained onboard while one pilot had collected some ground handling wheels and the other had paid the landing fee, 'booked in and out', and attended to some private business. Before the helicopter took off, a member of staff at a training centre had taken a digital photograph of the friend who had just completed his helicopter instructor's course. The picture showed the friend standing at the left side of the helicopter, with his back to the tailboom attachment area. After the photograph was taken, the friend had ducked under the tailboom and had gone to the right hand door, which led to the seat without a collective lever.

Nobody recalled seeing the two pilots boarding the helicopter and only two people saw it take off; they reported nothing abnormal. At 1636:40 hrs, one of the pilots transmitted that he was changing to an en-route frequency; this was the last RT message recorded from the helicopter on any of the likely frequencies. However, a minute later the helicopter's transponder was interrogated by radar at Heathrow and the data was recorded. The data did not include height encoding, but after making due allowance for the likely wind it enabled an accurate reconstruction of the helicopter's track which ceased some two minutes later, a few metres from the crash site.

The helicopter was tracking over the town of Wargrave on a southerly heading at about 65 kt indicated airspeed (IAS) when witnesses on the south side of the town first noticed it. Their attention was drawn to the helicopter because it was quite

low and the sound of its engine changed as it progressed towards the village of Hare Hatch. They reported that the engine note changed from a steady noise to a 'spluttering sound'. Other witnesses in the vicinity of Hare Hatch also heard an unusual engine note, but most saw the helicopter either coming towards them or going away from them.

Only two witnesses had an appreciable side view of the helicopter. They were standing in a garden and saw it flying at a steady height and speed, but the engine note sounded 'coarse'. Suddenly the helicopter broke into two sections with an audible 'pop' sound. They thought the cockpit section broke away from the combined engine and tailboom assembly, amidst a short-lived but large ball of dark coloured smoke; the main rotor blades then folded downwards and stopped. The witnesses saw smaller parts detach from the two main sections as they fell, in a manner similar to a ballistic trajectory. One witness reported seeing one of the occupants 'jump out' of the helicopter.

This person's body, that of the female passenger, was found some 50 metres from the main wreckage and to the north of the cockpit section's trajectory.

1.2 Injuries to persons

All three occupants were fatally injured.

1.3 Damage to the aircraft

The helicopter was destroyed.

1.4 Other damage

There was no other damage.

1.5 Personnel information

1.5.1	Commander:	Male, aged 18 years	
	Licence:	Private Pilot's Licence (Helicopters)	
	Aircraft Ratings:	Enstrom 280, Hughes 269/Schweizer 300	
	Medical renewal:	Class 3, valid until June 2003	
	Flying experience:	Total flying:	200 hours
		On type:	107 hours
		Last 90 days:	3 hours
		Last 28 days:	1 hour

1.6 Aircraft information

1.6.1 General information

Manufacturer:	Hughes Helicopters
Type:	Hughes 269C
Aircraft serial no:	0041
Year of manufacture:	1970
Certificate of Registration:	UK registered as G-ZAPS on 26 November 1999
Certificate of Airworthiness:	Certificate of Airworthiness in the Transport (Passenger) Category, issued by the CAA on 12 November 1999 and valid at the time of the accident

This helicopter had been imported into the UK via Shannon, Ireland, in November 1970 and registered as G-AYLX. It had retained this registration until shortly before this accident. It had been operated by several different owners in both the private and transport roles, and had been maintained by a number of licensed aircraft engineers, some of whom worked as individuals and others who worked for approved maintenance organisations.

In December 1998, G-AYLX had been sold to an aircraft dealership in part exchange for a turbine-engined helicopter. This company also had a maintenance facility which had Joint Aviation Requirement (JAR) 145 aircraft maintenance approval. At that time the helicopter had a Certificate of Airworthiness in the Private Category and it had remained at the dealership's premises for several months awaiting a buyer. During that period it was not flown, but it was ground run and scheduled and unscheduled maintenance was carried out.

In August 1999, the helicopter was prepared for export. G-AYLX was then surveyed by a CAA Surveyor. Although it was duly granted the required Export Certificate of Airworthiness in October 1999, the intended sale did not take place.

In November 1999, the helicopter was granted a Certificate of Airworthiness in the Transport (Passenger) Category and sold to the current owner. No CAA or FAA Airworthiness Notices, Letters to Operators or manufacturer's issued maintenance instructions were included within the helicopter's documentation package that was given to the new owner, although there was no requirement for these items to be part of the helicopter's documentation package. A few days after his purchase, the new owner re-registered the helicopter as 'G-ZAPS'. The helicopter was then

used partly for commercial training by instructors, and partly for 'hours building' and advanced training by private pilots.

The male passenger on the accident flight was a private pilot who was a close friend of the both the owner/operator and his son, also a private pilot. The friend had recently completed a qualified helicopter assistant flying instructor (AFI) course at Wycombe Air Park, much of which he had flown in G-ZAPS. Although ownership of the helicopter was vested in a commercial company, the close friend intended to purchase a share and ultimately to purchase the helicopter outright.

Daily care and control of the helicopter was often vested with this friend who had custody of the Log Books which he had collected from the aircraft dealership a few days after the helicopter's purchase. With the helicopter's current Log Books were the CAA Light Aircraft Maintenance Schedule, LAMS/H/1999 issue 1, all of the previous Log Books, various items of current and previous documentation and photocopies of a few of the worksheets from 1996, 1997 and 1998.

1.6.2 Hughes helicopter model 269 history

The Hughes 269 helicopter was originally designed and produced as the 269A and was later developed and produced as the 269A-1/T, 269B and the 269C.

The 269A model was granted FAA type approval in April 1959 and was placed in production in July 1960. The 269A, a two seat side-by-side helicopter, was fitted with an engine capable of a maximum of 180 HP/160 HP continuous, and had a maximum gross weight of 1670 lb and a maximum speed of 75 KCAS. 307 model 269A's were produced with the original basic (BSC) design centre frame rear cluster fittings.

The 269A-1/T models went into production in 1963. These helicopters had the same engine power, gross weight and maximum speed as the 269A model. The main difference to the 269A model was longer main rotor blades for improved performance. 353 model 269A-1/T's were produced with the original (BSC) design centre frame rear cluster fittings.

The 269B model also went into production in 1963. This helicopter had the same engine power, gross weight and maximum speed as the 269A model. The main differences were longer main rotor blades and a wider cabin to accommodate three seats rather than the original two 390 model 269B's were produced with the original (BSC) design centre frame rear cluster fittings.

The 269C model went into production in 1970. This helicopter was fitted with an engine that produced 190 HP (maximum) and had a larger diameter main rotor.

The combined engine and main rotor system improvements increased the maximum gross weight to 1900 lb for airframe serial number up to 209, and 2050 lb for serial numbers after 209. The maximum airspeed increased to 95 KCAS. 307 model 269C's were produced with the original (BSC) design centre frame rear cluster fittings.

In November 1983, the Schweizer Aircraft Corporation (SAC) purchased the Hughes 269C Type Certificate from Hughes Helicopters, but did not accept any liability for the Hughes 269 A, B and C models which had been built previously by Hughes (up to serial number 1165). The associated company sale agreement apparently had a provision for Hughes to provide continued support for any required incident and accident investigations involving these older Hughes 269 helicopters. This support subsequently passed to McDonnell Douglas in 1984 when that company acquired Hughes, and later to Boeing in 1997, when it acquired McDonnell Douglas. However, such continued support includes close coordination with SAC since it has the technical, logistic and publication support responsibility for this type.

1.6.3 Weight and balance

The helicopter's weight and balance were within the prescribed longitudinal limits for the flights to and from Wycombe Air Park. The data required to reconstruct the lateral centre of gravity position were not available but, since the lateral weight distribution in the cabin was almost symmetrical (compared to the single occupant distribution), the lateral centre of gravity would also have been within the prescribed limits.

1.7 Meteorological information

A meteorological aftercast obtained after the accident stated that visibility was good, with a moderate west-northwesterly airstream. The mean surface wind at sea level was westerly at 11 kt, increasing to 35 kt at 1,000 feet amsl. This marked increase in wind speed with height created low-level turbulence beneath the overcast cloud base at 1,500 feet amsl. Wycombe Air Park is 520 feet amsl and it was a windy day there; consequently little flying training took place at the airfield during that afternoon.

1.8 Aids to navigation

Recorded radar data obtained from Heathrow Radar were used to reconstruct the helicopter's flight path in the vicinity of the accident site.

1.9 Communications

A recording of radio transmissions between the aircraft and Wycombe Air Park Tower was provided by the CAA Transcription Unit.

1.10 Aerodrome information

Not relevant.

1.11 Flight recorders

Not fitted and not required.

1.12 Accident site and wreckage examination

1.12.1 The accident site

The area over which the in-flight structural break-up occurred had a mixture of older individual residential properties, commercial office buildings, small industrial storage areas, a stables and paddock area, an area of woodland and agricultural fields. The area was bounded to the north by the A4 trunk road, running in a south-west to north-easterly direction; to the east by a road known as Milly Lane, running in a south-easterly direction from the A4; and to the south by a lane known as Castle End Road, running almost parallel to the A4 and joining Milly Lane from a south-westerly direction. See Wreckage Plot at Appendix 1.

The main accident site, which was approximately 158 feet amsl, was at the eastern edge of a field of young crop that was situated at the north-eastern end of Castle End Road, on the northern side. Between the accident site and Milly Lane, pieces of wreckage from the helicopter were found scattered over a large area of land on both sides of Castle End road.

1.12.2 On-site wreckage examination

Examination at the accident site indicated that at the point of ground impact the body of the helicopter had been almost inverted, and its right side had made the initial contact with the ground with the nose pointing back in the direction of the departure airfield. There was good evidence to indicate that at the moment of ground impact the helicopter had been travelling at a very low speed over the ground and had been descending almost vertically at high speed. No evidence was apparent to indicate that the helicopter was yawed or that the fuselage had been rotating at impact. An intense fire had followed ground impact.

All of the major components of the helicopter were present at the main impact site, except for the tailboom assembly. Components from the tailboom assembly, pieces of cabin structure and items from within the cabin constituted the bulk of the wreckage which was found scattered over the area between the main impact site and Milly Lane. The severity of the post impact fire, together with areas of fuel affected vegetation, indicated that there had been a reasonable quantity of fuel in the helicopter's tanks at the time of the accident.

Those parts found at the beginning of the wreckage trail consisted of sections of both tail rotor blades, sections of the 45° stabiliser (from its position at the rear of the tailboom on the right hand side) and pieces of metal skinning from the tips of the main rotor blades. The sections of the tail rotor blades and 45° stabiliser showed good evidence of having been struck by the main rotor blades. The main rotor skin sections showed good evidence of having struck the tail rotor gearbox.

The tailboom assembly, without the tail rotor gearbox and the 45° stabiliser, was found within the mid wreckage trail, with a number of items that had come from the cabin of the helicopter. Amongst these was the helicopter's dry powder fire extinguisher. Examination of this showed that it had been struck by a main rotor blade. This impact had ruptured the extinguisher and allowed the powder media charge to escape. This powder release in flight could have been the 'smoke' that was reported by some of the eyewitnesses.

Lightweight items, such as pieces of cabin perspex, the cabin doors, pieces of internal cabin trim, the female passenger's overcoat and various items of paperwork had been blown a considerable distance to the south east by the wind. Amongst these items was found a 'locally produced' Pilot's Check List, but the Pilot's Flight Manual was not recovered.

Both of the ground handling wheels were found relatively close to the main impact site, but had separated from the body of the helicopter prior to its impact with the ground. These ground handling wheels had been manufactured by an organisation other than the helicopter manufacturer. They were each one metre long and weighed 11.75 lb, and did not have a stowage facility on the outside of the helicopter. Examination of these ground handling wheels and the main body of the helicopter indicated that they had been carried unsecured within the cabin.

There was good evidence that the dual control collective lever which can be fitted in the central seat position had been removed prior to the flight. The central seat lap belt was recovered intact but, because of the impact and fire damage, it was not possible to determine whether it was being worn at the time of the accident. There was no evidence that an upper torso restraint had ever been installed at the central seat position. No evidence was found of a lower seat squab having been fitted to

the central seat at the time of the accident. The lower central seat squab for this helicopter was later recovered from the organisation which had sold the helicopter to the owner. The owner later stated that from time to time the lower centre seat swab from a similar helicopter which was in storage at Shoreham had been used in G-ZAPS and had been missing since the accident.

1.12.3 In-flight break-up sequence

Examination of the detached tailboom assembly revealed that the attachment of the tailboom left lower support tube to the left centre frame rear cluster fitting, at the rear of the helicopter's fuselage structure, had separated in flight due to failure of the clevis lugs. This failure had allowed the rear of the tailboom, with the tail rotor and its gearbox, to displace upwards and to the right into the disc of the rotating main rotor blades. The resultant contact between the main rotor blades and the tail rotor blades, the 45° stabiliser and the rear of the tailboom had caused the break-up and detachment of these components, in addition to severe damage to the tips of the main rotor blades and detachment of the remains of the tailboom from the helicopter fuselage.

As the tailboom detached, the body of the helicopter had pitched downwards extremely rapidly until it became inverted. During this rapid pitch down, the helicopter's forward speed had abruptly decreased and the main rotor blades had deflected downward' (relative to the helicopter).

The combination of this rapid pitch down and deceleration had caused the middle seat passenger and a number of objects to be ejected from the cabin through the forward and upper cabin perspex panels, and light structure, before being struck by the still rotating main rotor blades.

1.12.4 Metallurgical examinations

A detailed metallurgical examination of the failed areas of the tailboom was carried out and a failure sequence determined. This examination confirmed that the initial failure was of the upper of the two clevis lugs of the tailboom left lower support tube attachment to the left centre frame rear cluster fitting. The diagrams at Appendix 2 illustrate this fitting and its location.

1.12.4.1 Metallurgical examination of the left centre frame rear cluster fitting

Metallurgical examination revealed that the upper clevis lug failure had been caused by a very high cycle tension fatigue crack which had originated in an area that had been the subject of a non-approved 'welded patch' repair over an existing crack (see Appendix 3, Photograph 1).

It was also apparent that the steel patch that had been welded onto the upper clevis lug did not lie 'flush' on the lug, and that there was a gap between the patch and the lug. Further examination of the area under the patch revealed a weld bead on the outer face of the clevis lug, from apparent 'in-filling' of the previous crack; this weld bead had been dressed down, but not flush with the lug's surface. The resultant gap would have tended to 'close-up' when the nut and bolt, that attached the tailboom support tube to the clevis lug, was tightened. The manufacturer's recommended torque for this nut and bolt was 90 to 110 lb ins. This would have increased the stresses in the patch and the weld beads. In the opinion of the metallurgist, the ensuing new fatigue crack had probably initiated shortly after the repair had been carried out (within some 25% of the service time between the repair and the final failure).

Following the fatigue induced failure of the upper lug, the associated load would have been transferred to the lower lug, which had also failed as a result of the initiation of rapid fatigue propagation, with consequent detachment of the lower end of the left tailboom support tube.

The metallurgist considered that the repaired upper clevis lug may have been completely failed for a period of time prior to the failure of the lower clevis lug.

The upper left tailboom attachment to the main airframe had then failed in overload. This had been followed, almost instantaneously, by failures of the tail rotor drive shaft, the upper right tailboom attachment to the main airframe, and the lower right tailboom support tube/clevis lug attachment on the right centre frame rear cluster fitting.

Examination of the standard of the welding and the steel used for the patch repair showed that the quality of workmanship, except for the gap between the patch and the lug, was satisfactory and that the steel patch material was of a similar specification to that of the clevis lug steel.

1.12.4.2 Metallurgical examination of the right centre frame rear cluster fitting

During the metallurgical examination it was also observed that the right centre frame rear cluster fitting had a crack in the outboard flange area, where the cluster fitting attached to the helicopter's crosstube, as shown in Appendix 3, Photographs 2 and 3. Examination revealed that an (approved) welded patch repair had been carried out and that the crack had occurred in the patch repair coincident with the original crack in the outboard flange. Microscopic examination of the crack revealed that it had also been caused by a high cycle tension fatigue mechanism. There was no evidence of plastic deformation or

simple overload tearing to indicate that any growth of the crack had occurred during the helicopter's in flight break-up, or impact with the ground.

The metallurgical assessment was that this crack had initiated as a result of stress concentration(s) caused by discontinuities in the poor quality of the weld attaching the patch repair. The stress concentration(s) were considered probably sufficiently high to have initiated fatigue cracking shortly after this 'approved' welded patch repair had been carried out.

The standard of the associated welding was of a much lower quality than that of the non-approved welded patch repair to the upper clevis lug on the left cluster fitting, and below the standard required of an aircraft approved welder. It could not be determined when the approved weld patch repair to the outboard flange of the right centre frame rear cluster fitting had been carried out.

1.12.5 Engine examination

The engine was taken to an approved overhaul facility for strip examination. This examination showed the engine to be in good condition for the 818 hours that it had run since it had been overhauled by the engine manufacturer in May 1990. Due to extensive post impact fire damage it was not possible to examine and test all of the engine accessories. However, no defects or failures were found on those items that could be examined/tested and which could have caused a loss of power output, or induced unusual vibrations.

1.12.6 Tail rotor examination

The recovered remains of the tail rotor assembly were taken to an approved overhaul facility for strip examination. No evidence of any pre-accident defects were found in these remains that would have caused abnormal vibration levels.

1.13 Medical and pathological information

Post-mortem examination of the occupants revealed that neither the pilot nor his male pilot friend had been suffering from any pre-existing medical condition which would have contributed to the accident. The female passenger had suffered a fatal head injury before falling to earth.

1.14 Fire

An intense ground fire had occurred which had affected the wreckage on the main impact site, melting a significant amount of the light alloy structure and components.

1.15 Survival aspects

The accident was non-survivable.

1.16 Tests and research

Not applicable.

1.17 Organisational and management information

1.17.1 The weld repair of the left centre frame rear cluster fitting

A few days after the accident, a LAE employed in the maintenance facility of the aircraft sales organisation which had sold the helicopter to the owner came forward and volunteered the information that he had called up the weld repair of the left centre frame rear cluster fitting.

In April 1999, whilst carrying out a Daily Inspection (A Check) prior to a ground run, an unlicensed aircraft engineer employed by the same organisation had noticed what appeared to be a crack in the upper clevis lug of the left centre frame rear cluster fitting. He had brought this to the attention of the LAE.

The LAE had duly inspected the fitting, confirmed that a crack was present and decided to have it assessed for a possible weld repair. He recalled that the crack extended all the way across the upper clevis lug, but not all the way through it. He had not consulted the manufacturer's HMI, or sought advice from the manufacturer of the helicopter, and was not aware at that time that weld repairs of these clevis lugs were not permitted by the manufacturer.

A local specialist welding company, which employed personnel who held CAA Welder's Approval Certificates, was contacted and asked if they could carry out a weld repair to the helicopter. The director of this specialist welding company, who had held a CAA Welder's Approval Certificate up until the mid 1980s and had been involved in aviation welding since the 1950s, went to view the helicopter to assess the task. He recalled being shown the cracked upper clevis lug on the left centre frame rear cluster fitting, where the tailboom support tube attached, and was asked by the maintenance fitter how it could be repaired. The crack had extended across approximately three-quarters the width of the clevis lug, and completely through the material thickness.

In view of the fact that there were at least three existing welded areas apparent on the cluster fitting, he assessed that the clevis lug was 'weld-repairable'. He established the material specification of the steel cluster fitting from the

maintenance fitter and told him 'that the normal practice is to double up after welding with another plate of equal thickness welded on'. This repair was agreed.

He was not made aware of the structural significance of the clevis lug, and his training as an approved aircraft welder had not equipped him for such structural assessment (see next section 1.17.2). He sketched out the shape and size of the patch required and returned to his company premises. He later stated that he had not met the LAE during this visit, but dealt only with the fitter.

A few days later he tasked his Works Manager with the job; he held a CAA Welders Approval Certificate and had done so for the previous 15 years.

The Works Manager could not recall the detail of the task or the actual welding, but could remember going to the maintenance facility's premises and the awkwardness he had experienced in gaining access to the area of the repair.

He could not recall approaching any member of the maintenance staff regarding the material specification of the cluster fitting, or to confirm that a weld repair in that particular area was acceptable, or approved. He stated that he had assumed that the maintenance personnel would have researched the acceptability of a weld repair in the area before contacting his employer to request assistance.

He did recall that upon finishing the repair he had reported to a member of the maintenance staff. That member of staff had then gone with him to inspect the repair and was reportedly 'happy with his work', and had stated that it would be painted before re-assembly. Painting of the steel structure and welded areas was required for corrosion protection and stipulated in the HMI.

1.17.2 CAA approval of aircraft welders

All persons who weld metallic parts which are essential to the airworthiness of an aircraft are approved in accordance with the requirements of British Civil Airworthiness Requirements (BCAR) sub-section A8, Chapter 10, entitled 'Approval of Welders'.

These requirements for the approval of aircraft welders focus upon the required standard of welding for the type of materials used on aircraft.

Once a person has gained the initial Welder's Approval Certificate from the CAA, that person has to submit a test sample of their welding to the CAA for examination every 12 months in order to maintain their Certificate.

Following paragraph 2(c) of the BCAR, there was a note which stated:

> 'An approved welder is not permitted to certify welded parts unless separately qualified as a person competent to issue a Certificate of Release to Service, eg holder of an appropriate Maintenance Engineer's Licence or equivalent approval.'

1.17.3 Welding Certificate of Conformity

The welding company completed the required Welding Certificate of Conformity for the repair.

However, this Certificate did not require the aircraft type or registration to be stated, or the approval authority for the repair. None of this information was required by the CAA to be entered on such Certificates. There was thus no information on this Certificate which could, of itself, link the associated welding to this helicopter.

Examination of this Certificate of Conformity indicated that only one weld repair had been carried out at that time.

1.17.4 Absence of authorised approval for the welded patch repair

Neither the LAE, whose responsibility it was, nor the two members of the specialist welding company sought or received authorised approval for the welded patch repair that was carried out on the helicopter. The LAE stated that neither of the two members of the specialist welding company had questioned the acceptability of a weld repair in the area of the clevis lug.

1.17.5 Absence of record of the welded patch repair

No worksheet was raised or airframe Log Book entry made by the maintenance organisation to record this repair, and no Certificate of Release to Service was issued contrary to the requirements specified in the Air Navigation Order (ANO) Article 12, Airworthiness Notices No 3 and No 12 Appendix 52 and BCAR's.

1.17.6 Maintenance record entry and retention requirements

In the ANO Articles 17 and 80 and Schedule 6 specify the requirements for maintenance records, maintenance entries and their retention.

Article 17, paragraph (4), requires that any document which is incorporated by reference in a Log Book shall be deemed to be part of the Log Book.

Article 17, paragraph (6), requires that every Log Book shall be preserved by the operator of an aircraft until a date two years after the aircraft or component has been destroyed, or has been permanently withdrawn from use.

Article 80 requires that an operator of an aircraft preserves any document or record, and that if they cease to be the operator of the aircraft shall continue to preserve the document or record as if they had not ceased to be the operator. In the event of the operator's death the duty to preserve the document or record shall fall upon their personal representative.

Schedule 6, paragraphs (e), (f) and (g), require that particulars of any defects, overhauls, repairs, replacements, modifications, action to rectify defects and maintenance work be entered in the aircraft Log Book.

JAR 145 issued by the Joint Aviation Authorities details the requirements for the approval of aircraft maintenance organisations.

JAR 145.55 paragraph (a) states that approved maintenance organisations must record all details of work carried out in a form acceptable to the Authority.

JAR 145.55 paragraph (b) states that approved maintenance organisations must provide a copy of each Certificate of Release to service to the aircraft operator together with a copy of any specific [approved] data used for repairs/modifications carried out.

JAR 145.55 paragraph (c) states that approved maintenance organisations must retain a copy of all detailed maintenance records and any associated [approved] data for two years from the date the aircraft or aircraft component to which the work relates was released from the approved maintenance organisation.

1.17.7 Legal responsibilities of a LAE

The duties and responsibilities of a LAE are specified in the ANO Article 12, BCAR's Chapter B6-2 and Airworthiness Notices No 3 and No 12 Appendix 52. These include the need to ensure that work has been properly carried out, having due regard to up-to-date instructions and approved airworthiness data including manuals, drawings, specifications, mandatory modifications, inspections issued by the primary certification authority (in this case the FAA) and the CAA, in addition to any applicable company procedures.

1.18 Additional information

1.18.1 Centre frame rear cluster fitting description

The centre frame rear cluster fittings were low carbon/low alloy steel castings. There were two such fittings on the helicopter, one on each side to the rear of the engine, which formed the rear cluster attachments for the welded steel tube fuselage frame structure. In addition, these two fittings provided structural attachments for the tailboom lower support tubes. They also attached the support struts for parts of the power transmission system and attached the rear crosstube for the landing skids. The cluster fittings were welded to the tubular fuselage structure, whereas all other connections to these fittings used nut and bolt attachments (Appendix 2 and Appendix 3 Photograph 5).

The part numbers imprinted upon the cluster fittings during the manufacturer's casting process result in slightly raised numbers and letters on the body of the cluster fittings. In addition, once the cluster fittings have been welded into the tubular fuselage structure, they are painted for corrosion protection. A number of other helicopters of the same type as G-ZAPS were examined during the course of this investigation and in all cases, except one, the paint which had been applied to the cluster fittings had made the part numbers impossible to read. Also, on a large number of the helicopters examined, the centre frame rear cluster fittings had an accumulation of grime and oil that could mask the presence of cracks to unaided visual inspection, particularly during Pre-Flight and Daily Inspections.

1.18.2 Design history of the centre frame rear cluster fitting

The original design (BSC) centre frame rear cluster fittings that were fitted to the 269C model helicopters and similar to those fitted to G-ZAPS [part numbers 269A2234 (LH) and 269A2235 (RH)], were found to develop in-service fatigue cracks in the clevis lugs where the tailboom support tube lower end fittings were connected (Appendix 2).

In 1970 the manufacturer, Hughes Helicopters, issued a Service Information Notice (SIN) N-82 which required daily visual and 200 hour dye penetrant inspections of the centre frame rear cluster fittings for evidence of cracks. This SIN was incorporated into the HMI in November 1972.

In 1976, the FAA issued AD 76-18-01 which mandated the 200 hour dye penetrant inspection of these (original design) centre frame rear cluster fittings in accordance with an updated SIN N-82 issued by Hughes Helicopters. This FAA AD required replacement of a damaged cluster fitting with either one of the same part number or the re-designed –3 cluster fitting. It was noted that the

manufacturer's SIN N-82 referred to in this AD stipulated that the re-designed –3 cluster fitting must be used to replace any damaged fittings.

As a result of this cracking problem on the original cluster fitting design, Hughes Helicopters had re-designed the cluster fittings. Part of this re-design had included increasing the thickness of the clevis lug steel material by some 55 to 65%; these re-designed centre frame rear cluster fittings were identified by the part numbers 269A2234-3 (LH) and 269A2235-3 (RH).

All 269C helicopters from serial number 0500 onwards were fitted with the re–designed right centre frame rear cluster fitting during manufacture, and helicopters serial number 0570 onwards were also fitted with the re-designed left centre frame rear cluster fitting during manufacture.

G-ZAPS was serial number 0041 and had therefore been manufactured by Hughes Helicopters with the original design cluster fittings.

The manufacturer's SIN N-82 stated that:

'Step 1 -- VISUAL INSPECTION (daily)

Without disassembly, visually inspect 269A2324 tailboom center attach fitting, and 269A2234 (LH) and 269A2235 (RH) center frame aft cluster fittings for cracks, deformation or damage.

CAUTION

If cracking is suspected, dye penetrant inspect fittings per Step 2 of this Notice.

Step 2 -- DYE PENETRANT INSPECTION (200 hours)

e. Immediately retire from service and tag as unserviceable any aft center frame cluster fitting found to have unrepairable cracks or other structural damage. The 269A2234-3 and/or 269A2235-3 aft cluster fittings MUST be used for replacement where required.

NOTE
Refer to Step 3 of this notice for weld repair criteria for cracks occurring in flange area of aft center frame cluster fittings. Only cracks in the flange area on outboard side of fitting may be repaired. Cracks in any other area require fitting replacement per Step 2.

j. Record compliance with this Notice in Compliance Record of helicopter Log Book.'

The FAA AD 76-18-01 referred to the above SIN.

However, as a result of improper heat treatment during manufacture the re–designed centre frame rear cluster fittings, part numbers 269A2234-3 (LH) and 269A2235-3 (RH), were subsequently also found to develop in-service cracks in the areas where the cluster fitting was welded into the fuselage tubular frame. This cracking was not associated with the clevis lugs. In January 1988, the Schweizer Aircraft Corporation (which had acquired the Hughes 269C Type Certificate in November 1983) issued 'mandatory' SINs N-217, N-220 and N-221 which were later the subject of AD 88-17-04 which was issued by the FAA in August 1988. SINs N-217 and N-220 introduced 'one time' visual inspections of the modified fittings for cracking, whereas the FAA AD and SIN N-221 introduced a daily visual inspection and a 100 hour dye penetrant inspection to a limited group of parts and helicopter serial numbers which were terminated by replacement of all the affected cluster fittings, identified by material analysis, by 31 December 1988.

In addition, Schweizer issued 'mandatory' Service Bulletin (SB) B-263 in 1995 which required a further 'one time' visual inspection, using 10X magnification, the re-designed –3 centre frame rear cluster fittings. Schweizer later amended Appendix B of the HMI to include a 10X magnification visual inspection of all centre frame rear cluster fittings every 100 hours.

1.18.3 Manufacturer's inspection and repair procedures

Section 13, paragraph 43, of the HMI described the inspection procedures for the centre frame section, tailboom support struts and mast support tubes.

Sub paragraph 'a' stated:

> 'Visually inspect all welded frame members (Fig. 13-11 which includes the centre frame rear cluster fittings) in accordance with the following. Perform repairs according to Paragraph 13-44 unless otherwise specified.'

Sub paragraph 'a.(11)' stated:

> 'Inspect aft cluster fittings for cracks in clevis lugs with 10X magnifying glass. Refer to Paragraph 13-44 for repairable flange cracks on 269A2234 and 269A2235 cluster fittings. NOTE: In the next step, 269A2234-3 and 269A2235-3 aft cluster fittings do not require dye penetrant inspections, unless corrosion is found or cracks are suspected. Refer to Paragraph 13-44 for description of these fittings.'

Sub paragraph 'b' stated:

> 'At each 200 hour Inspection, dye penetrant inspect (for cracks) the tailboom support strut clevis lugs on the 269A2234 and 296A2235 aft cluster fittings as follows:'

The bulk of this paragraph described the preparation of the helicopter and the centre frame rear cluster fitting for the dye penetrant inspection and the making good following the inspection (which included repainting the area for corrosion protection), but sub paragraph 'b.(4)' stated:

> 'Perform dye penetrant inspection in accordance with dye penetrant kit manufacturer's instructions. Use 10X magnifying glass to examine inspection area for indications of cracking. Cracks in clevis lugs are not repairable; replace any defective aft cluster fitting with 269A2234-3 and 269A2235-3 aft cluster fittings in accordance with Paragraph 13-44.'

Figure 13-13 in the HMI detailed the inspection and identification of the centre frame rear cluster fittings.

Section 13, paragraph 44, described the repair procedures for the centre frame section.

Part of sub paragraph 'h' stated:

> '269A2234 (BSC) and 269A2235 (BSC) centre frame aft cluster fittings having cracks in the outer flange area may be repairable in accordance with step i. below. Only cracks in the flange area are repairable (Fig. 13-16).'

AAIB Note: 'BSC' referred to the 'basic', original, cluster fitting.

Step 'i' described the procedure for the weld patch repair for cracks found in the outboard flange area of the original cluster fittings. A Caution note in this section stated:

> '269A2234-3 and 269A2235-3 centre frame aft cluster fittings (those with thick lugs – 0.115 to 0.155 inch) are not repairable. Any cracks found on these –3 fittings is cause for removal of the fitting from service.'

Figure 13-16 in the HMI showed the detail of the patch repair and contained two notes:

> 'Only cracks in flange on outboard side of fitting may be repaired. Cracks in any other area require replacement of fitting.'
> and,
> 'Caution: Weld repair is not permissible for 269A2234-3 and 269A2235-3 aft cluster fittings (those with thick clevis lugs – 0.115 to 0.155 inch)'

1.18.4 Manufacturer's maintenance schedules

Appendix B, Section 2, of the HMI specified the requirements for the Daily Inspection (A Check), periodic and special inspections, component overhaul schedules and mandatory replacement schedules.

Table B-1 in the HMI specified the requirements for the Daily Inspection before the first flight of the day and consisted of eleven pages of A4 sized sheets (Appendix 4). Under the section entitled 'LEFT SIDE - Fairing Assembly, Engine Components and Landing Gear', item 17 stated:

> 'Visually inspect attachment lugs for tailboom support strut on BSC aft cluster fittings (fittings with thin lugs - 0.070 to 0.100 inch) for cracks or damage. Dye penetrant inspect fittings if cracking is suspected.

There was a similar requirement to check the basic (BSC) aft cluster fitting at item 10 in the section entitled 'RIGHT SIDE - Fuel Tank, Clutch Assembly, V-belts and Pulleys'.

Table B-2 in the HMI specified the requirements for the 50, 100, 200, 300, 400, 600 and 1200 hour Inspections, as summarised below:

The 50 hour Inspection required that a Daily Inspection be performed as part of that inspection.

The 100 hour Inspection (which consisted of seven pages of A4 sized paper) had to include a 50 hour Inspection, and specifically required that the centre frame rear cluster fittings be inspected, without disassembly, for cracks, corrosion and other damage using a 10X magnifying glass.

The 200 hour Inspection, which included 50 and 100 hour Inspections, specifically required that a dye penetrant inspection be performed on the two original (thin steel lug) lower centre frame rear cluster fittings for cracks and other structural damage.

The 300 hour Inspection required the inclusion of 50 and 100 hour Inspections, but the 200 hour Inspection was not required.

The 400 hour Inspection required that 50, 100 and 200 hour Inspections be included, but the 300 hour Inspection was not required.

The 600 hour Inspection required that the 50,100, 200, and 300 hour Inspections be performed as part of the 600 hour Inspection, but the 400 hour Inspection was not required.

The 1200 hour Inspection required that the 50, 100, 200, 300, 400 and 600 hour Inspections be performed as part of the 1200 hour Inspection, which specifically required the disassembly and inspection of the tailboom strut fittings, tailboom centre attachment fittings and the centre frame rear cluster fittings for deformation, cracks, corrosion or other damage and that a dye penetrant check was required if cracks were suspected.

1.18.5 CAA Light Aircraft Maintenance Schedule (CAP 412)

This helicopter was being maintained to the CAA Civil Aeronautical Publication (CAP) 412 Light Aircraft Maintenance Schedule for Helicopters, CAA/LAMS/H/1999 Issue 1. This included the A Check (Daily Inspection), 50 hour/6 monthly, 100 hour, Annual and Annual Star Inspection requirements. However, this CAA Maintenance Schedule for helicopters contained only general requirements, which were not specific to helicopter type (see next section 1.18.6).

The A Check (Daily Inspection) was described within this CAA Maintenance Schedule on three sides of A5 sized paper (Appendix 5). Listed under the heading 'Fuselage' was the requirement to:

> 'Inspect - skin/covering, struts, and tubular structure for damage, corrosion and security of all items.'

There was no stated requirement, in this CAA Light Aircraft Maintenance Schedule for Helicopters, to inspect the centre frame rear cluster fittings on this type of helicopter (see next section 1.18.6).

The 100 hour Inspection was described on five pages of A5 sized paper within this CAA Maintenance Schedule. Listed under the heading of 'Structural/Zonal' were:

> 'Inspect - External structure of cabin, centre section, tail boom, cowlings, nacelles, stabilisers.' and 'Inspect - Internal structure of cabin centre section,

tail boom, engine bay, transmission platform. Floors, bulkheads, pylons, structural attachment joint assemblies, ballast weight attachments.'

There was no stated requirement within this 100 hour Inspection in the CAA/LAMS/H/1999 issue 1 document to inspect, using a 10X magnifier, the centre frame rear cluster fittings (see next section 1.18.6).

The CAA provided a brief description of LAMS, CAP 412 - Helicopters, and this is reproduced at Appendix 6.

1.18.6 CAP 520

CAP 520, entitled 'Light Aircraft Maintenance', contained guidance material and a more detailed explanation of the intended application of the Light Aircraft Maintenance Schedule (LAMS). Part 1 of this document, entitled 'Owner's and Operator's Responsibilities', is included at Appendix 7.

In summary, this CAP suggested two routes for the owner/operator to follow regarding aircraft maintenance. Either the owner/operator could make a contract with an approved aircraft maintenance organisation to carry out and manage the maintenance of an aircraft, or the owner/operator could carry out the maintenance management function and contract a maintenance organisation to undertake specific maintenance tasks when required.

Considerable guidance material was contained in Part 1 for those owner/operators who elected to manage the maintenance of their own aircraft. Part of this guidance stated:

'Owner/Operators must take steps to ensure that the maintenance organisation obtains, or is provided with, all relevant information such as Service Manuals, Service Bulletins, Airworthiness Directives, etc, for his particular type and model of aircraft.

If an Owner/Operator elects to manage the maintenance himself he must take steps to ensure that he has all the Service Information as indicated above, together with a full revision service. Above all, he must have an adequate understanding of the intent of such information.

It should be borne in mind that if the Owner/Operator elects to perform the overall maintenance management function, he will have to present the full maintenance history to the maintenance organisation prior to scheduled maintenance taking place.'

Part 3 of CAP 520, entitled 'Light Aircraft Maintenance Schedules', described the LAMS and stated the CAA's general philosophy for use of the LAMS:

Paragraph 2 stated:

> 'The LAMS is based on the philosophy that the certifying person is responsible for the depth of the inspection undertaken, dependent upon the variables existing at the time of such inspection and taking into account the equipment and modification standard. In addition to compliance with the LAMS, certifying persons are expected to exercise their skill and judgement in observing any other matters which could affect the airworthiness of the aircraft.
>
> Where the aircraft or engine type design organisation recommends maintenance tasks on a repetitive basis which are not reflected in LAMS, then these must be recorded in CAP 543, Time Limited Task and Component Change Record, and carried out at the appropriate period. Furthermore, the absence or inclusion of an item in the LAMS in no way absolves the certifying person from ensuring that the aircraft is in an airworthy condition at the time the check is carried out. The LAMS should therefore be considered as a schedule defining the minimum level of scheduled maintenance, taking into account the aircraft type design organisations recommendations.'

Paragraph 3.2 stated:

> 'Record of overhaul, test periods and airworthiness life limitations should be recorded in CAP 543, Time Limited Task and Component Change Record, which should also be kept in the same binder as the LAMS log books.'

Part 5, entitled 'Pilot Maintenance', contained guidance to pilots regarding the maintenance that they could undertake.

Paragraph 1 of this stated:

> 'There are two aspects of light aircraft maintenance which may be carried out by a licensed pilot *who is the owner or operator of the aircraft*:
>
> (a) A 50 hr Check to the LAMS for aeroplanes (CAA/LAMS/A/1999), but only if the aeroplane has a C of A in the Private Category (not helicopters).

(b) Certain maintenance tasks prescribed in the Air Navigation (General) Regulation 16, but only if the aeroplane or helicopter has a C of A in the Private or Special Category.'

Paragraph 3 stated:

'Implicit in the completion of both scheduled maintenance and defect rectification is the fact that the certifying pilot has available the information essential to carry out the check, including the aircraft type design organisations maintenance manuals. Implicit also is the fact that he possesses the necessary skills, together with tools and any equipment required to carry out the particular tasks.'

1.18.7 G-ZAPS maintenance history

The helicopter, manufactured in 1970 under serial number 0041, was imported into the United Kingdom in November 1970 and registered as G-AYLX. Between November 1970 and mid 1998, the helicopter was owned and operated by a number of individuals and operators, both in the private and transport category. During this period, it was maintained by a number of individual LAEs and CAA approved maintenance organisations.

In December 1998, the helicopter was obtained by an aircraft sales company in 'part exchange' for another helicopter. This sales company had a maintenance facility which had JAR 145 approval.

Subsequent to the non-approved welded patch repair to the left clevis fitting in April 1999, when the Log Book recorded an airframe flying time of 3950:30 hours, the helicopter was prepared for a Certificate of Airworthiness in October 1999 for an intended export sale. Prior to this Certificate of Airworthiness being granted, an aircraft survey had been carried out by a CAA Surveyor. The associated Survey Report, Appendix 8, was completed and presented to the maintenance organisation. During this CAA survey, only the following areas were examined:

The lower and upper halves of the fuselage, the empennage, the powerplant and struts, the Pilot's Flight Manual and the Weight and Balance Data

The CAA Survey Report identified that modified main rotor blades were installed without the required Approved Pilot's Flight Manual supplement being embodied and also recorded a defect on the air intake system. It also noted that scheduled maintenance for the compass system had not been completed.

However, the weld repair to the clevis lug of the left centre frame rear cluster fitting was not commented upon in the CAA Survey Report; that specific area was apparently not required to be inspected during this survey. In addition, the requirement for carrying out FAA AD 76-18-01 was not called up in Part C of the Aircraft Log Book (CAP 398) or the Cardex/Visicard system; but SB B263, which was not applicable to this helicopter, was called up; neither of these errors were identified in the survey report.

In November 1999, in preparation for the sale of the G-AYLX to the current owner, an application was made by the LAE to the CAA for a Certificate of Airworthiness in the Transport (Passenger) Category.

On the 12 November 1999, at 3,952:20 airframe hours (ie 1 hour and 50 minutes flying time after the non-approved welding repair), an Annual Star maintenance Inspection had been carried out to the CAA/LAMS/H/1999 issue 1, in addition to a 300 hour Inspection in accordance with the manufacturer's HMI.

A Certificate of Maintenance Review, valid for 12 months, was signed by the LAE and issued by the sales company's maintenance facility. Aircraft registered in the United Kingdom with Certificates of Airworthiness in the Transport Category (Passenger) are subject to a maintenance review at intervals specified in the Approved Maintenance Schedule. In the case of aircraft which are maintained in accordance with the CAA LAMS, such maintenance reviews coincide with the Annual Inspection and the associated qualifications for the issue of an associated certificate are as described below:

'The signatory shall only issue a Certificate of Maintenance Review when satisfied, at the time of the review, that the following aspects of maintenance have been carried out:

(a) All maintenance specified in the LAMS has been carried out with the prescribed time period and any extension to limiting periods with Civil Aviation Authority procedures.

(b) All modifications and inspections deemed mandatory by the CAA have been carried out within the prescribed time periods and any extensions to limiting periods have been authorised by the CAA. Due account must be taken of any repetitive inspections.

(c) All defects entered in the Technical Log have been rectified or deferred in accordance with CAA approved procedures

(d) All Certificates of Release to Service have been issued in accordance with the procedures of BCAR's Chapter B6-7.'

As part of the application for the Certificate of Airworthiness to the CAA, a 'Survey Report and Recommendation for the Renewal of a Certificate of Airworthiness in Accordance with BCAR A/B 3-4' had been completed by the LAE. Part 2 of this form was a 'Compliance Statement' which included a statement to the effect that all FAA and Foreign Airworthiness Directives had been complied with and had been properly entered and certified in the aircraft technical records; and that all modifications and repairs revealed during this inspection and carried out since last Certificate of Airworthiness renewal had been assessed for approval and had been adequately recorded and certified in the appropriate log books. Both of these parts of the Compliance Statement had been completed and signed by the LAE, despite the absence of records of the non-approved weld repair in April 1999 and the absence of any records of compliance with FAA AD 76-18-01. (The last occasion on which the latter AD had been accomplished on this helicopter, according to the associated Log Book, was on 16 August 1990 at 3,263 flying hours).

Following the above application to the CAA, the helicopter was duly granted a Certificate of Airworthiness in the Transport (Passenger) Category and sold to its new owner, who then had its registration changed to 'G-ZAPS' on 26 November 1999.

On 20 December 1999, at 4,002.20 flying hours a 50 hour Inspection and on 18 February 2000, at 4,062:50 flying hours (ie 112: 20 flying hours after the non-approved welded repair in April 1999), a 100 hour Inspection was carried out by the sales company's maintenance facility in accordance with CAA/LAMS/H/1999 issue 1, and a Certificates of Release to Service issued by the LAE. Only the helicopter's Technical Log was made available to the maintenance facility, by the owner/operator, during these maintenance inspections.

SB B-263 was recorded as having been carried out during this maintenance inspection despite the fact that the helicopter had the original design of centre frame rear cluster fittings and SB B-263 was only applicable to the re-designed –3 cluster fittings, requiring a 'one time' visual inspection of these using a 10X magnifier; this SB B-263 inspection was nevertheless recorded as having been completed satisfactorily by the LAE.

G-ZAPS had accumulated a total recorded flying time of 4078:15 hours up to the beginning of the day of the accident. The in-flight structural failure thus occurred some 16 to 17 flying hours after the last recorded maintenance inspection of the centre frame rear cluster fittings, carried out 112:20 hours after the non-approved repair in April 1999.

All of the maintenance between April 1999 and the date of the accident had been carried out by the JAR 145 approved maintenance facility which was part of the aircraft sales company that had sold the helicopter to the new owner. The new owner/operator had not made any arrangements with any maintenance organisation for regular ongoing maintenance of the helicopter, and the close friend of the owner had retained the helicopter's Log Books.

1.18.8 Airframe Log Book (CAP 398)

The flying time and maintenance for the period from when the helicopter had been imported into the United Kingdom in 1970 until the time of the current owner's purchase in November 1999 was recorded in four Airframe Log Books, all of which were made available to the investigation. A detailed examination of these Log Books did not reveal any entry to indicate that any particular work had been carried out on the helicopter, other than routine maintenance and repair.

There were no entries to record the welded patch repairs that had been carried out on the left and right centre frame rear cluster fittings.

The last regular flying hours entry was made on 5 June 1998. Between 5 June 1998 and 8 March 2000, the date of the accident, no flying time entries had been made in the Log Book except for two test flights undertaken in October 1999 for the later issue of the Certificate of Airworthiness. Both of these test flights were flown by the LAE, who held a PPL(H), under the supervision of a CAA approved pilot for test flight purposes.

The last maintenance entry in Airframe Log Book No 4 was the Star Annual Inspection in accordance with CAA/LAMS/H/1999 issue 1 and the HMI 300 hour Inspection which had been entered on 12 November 1999 at 3,952.2 airframe hours at the time of the application for the Certificate of Airworthiness.

In Part C, entitled 'Modifications and other Technical Instructions' of Airframe Log Book No 4 were listed FAA and CAA Airworthiness Directives and Notices, in addition to the manufacturer's Service Bulletins and Service Information Notices which were applicable to this helicopter. This section of the Log Book had been compiled by an LAE in May 1998.

Amongst those Notices listed was SIN N-263, which was described as a 100 hour Visual Inspection of the 'aft clusters'. However, the manufacturer had never issued a 'SIN N-263', although it had issued SB B-263 which specified a 100 hour Visual Inspection of the re-designed -3 centre frame rear cluster fittings. The entry indicated that this inspection had last been carried out at 3,948.2 airframe hours on 24 May 1998, and was to be next carried out at 4,048 airframe hours.

There were no entries for FAA AD 76-18-01 or SIN N-82, which required mandatory dye penetrant inspections of the original centre frame rear cluster fittings, as fitted to this helicopter.

Examination of the other three Airframe Log Books showed spasmodic entries which indicated that FAA AD 76-18-01 and SIN N-82 had been carried out up until 1990. The last entry for AD 76-18-01 was 16 August 1990 at 3,263 hours (Appendix 9).

A copy of CAP 412, CAA/LAMS/H/1999 Issue 1, was found in the folder containing the Airframe and Engine Log Books, but there was no CAP 543, the 'Time limited Tasks and Component Change Record' (see next section).

1.18.9 Component and repetitive AD/Bulletin compliance records

The helicopter had a Cardex/Visicard folder that contained Component Record cards and Repetitive AD/Bulletin Compliance Record cards which the CAA considered to be an appropriate equivalent to CAP 543.

Amongst the Repetitive AD/Bulletin Compliance Record cards was one for SB B–263 which called for a 100 hour 10X Visual Inspection of the centre frame rear cluster fittings. However, as previously stated, this SB was not applicable to the original cluster fittings on G-ZAPS. This Record card was compiled in May 1997.

There were no Record cards for FAA AD 76-18-01 or the manufacturer's SIN N–82, which were both applicable to the original cluster fittings on G-ZAPS.

1.18.10 Maintenance worksheets

All of the maintenance worksheets from January 1980 onwards were recovered during this investigation from a number of maintenance organisations and LAEs. The worksheets prior to 1980 could not be located because the particular maintenance organisation that had carried out the maintenance at that time had been taken over in the 1980s. This second company had ceased trading a few years later and their records had been distributed to two other aviation companies, both of which no longer existed. It was surmised that these records had probably been destroyed.

A detailed examination of the available worksheets revealed inconsistencies in maintenance practises. Appendix 9 lists the recorded maintenance that had been carried out. It was noted that regular 25 hour, 50 hour, 100 hour, Annual and Annual Star Inspections in accordance with CAA/LAMS/H had been carried

out, but the inspections specified by the helicopter's manufacturer and FAA AD 76-18-01 were only spasmodically accomplished.

None of the worksheets contained entries for the non-approved weld patch repair of the upper clevis lug of the left centre frame rear cluster fitting, or of the approved weld patch repair to the outboard flange of the right centre frame rear cluster fitting.

1.18.11 Aircraft Technical Log

Examination of the operator's Technical Log showed that it reflected, as far as it could be ascertained, the flying time and sectors that had been flown since the current owner had acquired the helicopter.

Each of the Technical Log pages had a signature box to show the completion of an A Check (Daily Inspection), and this included a space to indicate the time when that inspection had been carried out. Only one page, dated 5 March 2000, had an entry for an A Check having been carried out which had been signed off by the owner/operator.

No defects had been recorded in the Technical Log, and for the majority of the sectors flown the 'Defect yes/no' column contained an entry indicating that there had been no defects.

Two of the Technical Log pages, for an unspecified date in December 1999 and 17/18 February 2000, had entries which indicated that 50 and 100 hour Inspections in accordance with CAA/LAMS/H/1999 issue 1 had been carried out by an aircraft maintenance organisation. These inspections had been carried out by the maintenance facility of the aircraft dealership that had sold the helicopter to the current owner and had been signed off by the LAE.

1.18.12 Pilot's Flight Manual (PFM) and locally produced Pilot's Check Lists

The Pilot's Flight Manual (PFM) for this helicopter was, according to records held by the CAA, the issue applicable to this helicopter and contained those required amendments which were current up to the time of this accident. Section 4 of the PFM listed the normal procedures for the Pilot Pre-Flight Inspection (Appendix 10). Paragraph 4-1 specified the pre-flight requirements, one of which stated:

> 'Determine that a Daily Inspection (in accordance with the Handbook of Maintenance Instructions (HMI)) has been accomplished within 24 hours prior to the first flight of each day.'

Paragraph 4-2 specified the Pre-Flight Inspection procedure. Under the sub section 3, entitled 'ENGINE - LEFT SIDE', it contained a caution in bold capital letters which stated:

'CAUTION

IF CRACKING OF CLUSTER FITTINGS IS SUSPECTED DYE PENETRANT INSPECT IN ACCORDANCE WITH SERVICE INFORMATION NOTICE N-82.3 BEFORE FLIGHT.'

This caution was followed by the following inspection requirement:

'Center frame aft cluster fittings for cracks, deformation, or damage.'

There was no mention under sub section 8, entitled 'ENGINE - RIGHT SIDE', of this caution or to inspect the centre frame rear cluster fitting.

The locally produced Pilot's Check List (Appendix 11), which was found amongst the helicopter wreckage, contained a Pre-Flight Inspection procedure which simply stated:

'Tail boom, supports and fittings'

A number of other locally produced Pilot's Check Lists, one of which was used by a major helicopter training school, were examined and in all cases found to contain a Pre-Flight Inspection procedure which simply stated:

'Tail boom, supports and fittings----------Check'

A number of instructors and pilots were asked what Check List they used to carry out their Pre-Flight Inspections and Daily Inspections (A Check), and they all stated that if a 'locally produced' Check List was available that is what they used in preference to the PFM. None of those who used a 'locally produced' Check List could remember the last occasion on which they had used the Check List in the PFM.

None of the pilots interviewed were aware of FAA AD 76-18-01, SIN N-82 or the associated requirement to inspect, on a Daily and Pre-Flight Inspection, the centre frame rear cluster fittings for cracks or damage, and that if any were found or suspected that a dye-penetrant inspection was to be carried out before further flight.

The instructor of the male friend who had been a passenger in G-ZAPS stated that during the AFI course the pupil had used the CAA approved PFM provided by the organisation that was conducting the training. The instructor also stated that the Daily Inspections had been carried out by the pupil using the Pre-Flight Check List in the PFM.

1.18.13 Authorisation of a 'Certifying Person' to conduct Daily Inspections (A Check)

No specific statement could be found in CAA/LAMS/H/1999 issue 1 (CAP 412), CAP 520, the ANO or BCARs regarding who is a 'Certifying Person' authorised to carry out and sign for a Daily Inspection (A Check) on a helicopter that has a Certificate of Airworthiness in the Transport (Passenger) Category, which is maintained to CAA/LAMS/H/1999 issue 1 and is to be flown on a private flight.

There were also no statements as to how a 'Certifying Person' should be trained, by whom, the validity of authorisation, or where a 'Certifying Person' signs for having carried out a Daily Inspection.

1.18.14 Tail rotor maintenance and operation

Appendix B of the HMI required that the tail rotor assembly should be balance-checked every 100 hours, using electronic balancing equipment. Examination of the helicopter's Airframe Log Book No 4 and the related worksheets showed that a 100 hour Inspection in accordance with Appendix B of the HMI had been carried out on 18 February 2000 at 4,062 airframe hours, but there was no specific references to confirm that the required balance-check of the tail rotor assembly had been carried out.

From the time that the current owner had purchased the helicopter, it had flown a total of 126 hours over 173 flights up to the accident flight. During this period, the helicopter had been used for training and private flights by a number of student pilots and commercial pilots, instructors and the owner. A number of these pilots and the owner were interviewed; none could recall any unusual tail rotor vibrations being felt. However, a main rotor vibration had occurred in December 1999, which had been rectified during that month.

Subsequent to the maintenance check that had been carried out on 18 February 2000, the helicopter had flown approximately 16 hours over 19 flights, including the accident flight. A number of these flights had been flown by the close friend of the owner during the latter part of an AFI course, culminating in his final test flight on the 4 March, which he passed. Both the training instructor and the flight test examiner recalled that there had been no unusual mechanical or aerodynamic vibrations during their flights. In fact, both commented that G-ZAPS was a 'smooth machine'.

1.18.15 Upper torso restraint requirements

The requirement for the provision of upper torso restraint in an aircraft of the Hughes 269 helicopter type is stated in Schedule 4 of the ANO. Paragraph (i) (a) of the section entitled 'Scale B' stated:

> 'If the maximum total weight authorised of the aircraft is 2730 kg or less, for every pilot's seat and for any seat situated alongside a pilot's seat, either a safety belt with one diagonal shoulder strap or a safety harness, or with permission of the CAA, a safety belt without a diagonal shoulder strap which permission may be granted if the CAA is satisfied that it is not reasonably practicable to fit a safety belt with one diagonal strap or a safety harness.'

No exemption for the requirement to fit an upper torso (diagonal shoulder strap) to this helicopter type had been issued by the CAA.

In Section 2.2 of the PFM , titled 'Flight Limitations', it was stated that:

> 'Shoulder harness and seat belt is required for center seat passenger.'

1.18.16 Search for previous related incidents to G-ZAPS/G-AYLX

A review of the databases of the AAIB and the CAA did not reveal any entries for G-ZAPS or G-AYLX (this helicopter's registration prior to G-ZAPS) that had any relevance to the failure of the left centre frame rear cluster fitting.

In May 1989, a worksheet had been raised for the recovery of the helicopter from a field, the removal of a damaged engine and the painting of a new tailboom. However, there was no explanation of the reasons for this work, and no corresponding entry in the applicable Airframe Log Book. The Log Book for the damaged engine was not available.

1.18.17 Previous accidents caused by clevis lug failures

During this investigation, the AAIB identified six previous accidents involving this helicopter type, 269C, where failure of a clevis lug on the centre frame rear cluster fitting had been identified as the primary failure (Appendix 11). One of these accidents had occurred in England in May 1972, but had not caused injury to the occupants. It was noted that in all these accidents the initial failure had occurred in the left clevis lug attachment, with the upper clevis lug positively identified as the primary failure in three of the accidents. The other three investigations had not identified which of the two left lugs had been the primary failure. All of these failures had involved the original standard of centre frame rear cluster fittings.

In addition, in 1995 a fatal accident had occurred to a Hughes 269C in Australia. The associated report by the Australian Bureau of Air Safety Investigation (BASI), later re-named the Australian Transport Safety Bureau, concluded that the upper clevis lug on the left re-designed –3, centre frame rear cluster fitting had failed in fatigue. The fatigue initiated in the upper lug from a sharp notch or defect at the web/lug radius. The effect of the sharp notch or defect increased the stress level beyond the fatigue limit resulting in the initiation of a fatigue crack. In the opinion of the metallurgist who had conducted the associated examination, the fracture would have been visible during daily inspections for about six flights before that accident occurred.

Prior to the publication of this report the AAIB was notified of a fatal accident on 1 November 2002 to a Hughes 269A helicopter, registration N8885F, in Oklahoma, USA. The helicopter was reported as having broken-up in the air at about 500 ft whilst in level cruise flight. The initial examination has revealed a fatigue failure of the upper clevis lug of the original design (BSC) left aft cluster fitting. It is reported that a dye penetrant inspection, as specified in the FAA Emergency AD 2001-25-52, had been carried out in March 2002 and no cracks were found. There was no evidence of any repairs to the failed clevis lug. This accident is being investigated by the National Transportation Safety Board together with the helicopter's manufacturer and the FAA.

The AAIB did not identify any previous accidents which had involved the failure of a clevis lug that had been weld repaired.

1.18.18 Safety actions taken

1.18.18.1 By the CAA

Following the initial investigation findings concerning the failed left centre frame rear cluster fitting, the CAA were briefed. A Letter to Owner/Operators (LTO), No 2018, was then issued by the CAA on the 17 March 2000 (Appendix 13). This LTO recommended 'one-time' visual inspections to be carried out, by appropriately licensed aircraft engineers, to identify any weld repairs of the cluster fittings on all Schweizer (Hughes) 269A, 269A-1, 269B, 269C and 269C-1 series helicopters. This visual inspection covered the centre frame rear cluster fittings, the tailboom support fitting, the support struts and the centre attachment fitting. Any parts found to have weld repairs were to be assessed for compliance with the appropriate Schweizer Service Information.

However, the LTO quoted part number 269A2234, which was the original design of left centre frame rear cluster fitting and Service Notice N220 which applied

only to the re-designed cluster fittings part numbers 269A2234-3 (LH) and 269A2235-3 (RH).

This LTO also requested that all associated findings should be reported to the CAA. Subsequently, more than a year later, two reports of non-approved weld repairs were received by the CAA, one dated in April and the other in June 2001.

Shortly after issuing LTO No 2018, the CAA had also issued a letter on the 30 March 2000 that suspended the JAR 145 approval for the maintenance facility of the aircraft sales organisation that had sold G-AYLX (G-ZAPS) to the new owner. That suspension was subsequently confirmed in a letter from the CAA dated 17 April 2000.

On the 4 April 2000 the CAA carried out an audit of the aircraft records and the related control of maintenance on aircraft at the maintenance facility of this aircraft sales organisation.

On the following day, the 5 April 2000, the CAA issued a letter that suspended the Engineering License of the LAE who had been responsible for the weld repair of the clevis lug on the left centre frame rear cluster fitting of G-AYLX (G-ZAPS).

Following this audit, the CAA issued LTO 2026 on the 12 April to the owners/operators of seventeen helicopters that had been maintained by this organisation because of doubts raised following the audit concerning the continued airworthiness of these helicopters. This LTO provisionally suspended the Certificates of Airworthiness of these helicopters pending specific inspections and any rectification work required following those inspections.

1.18.18.2 By the FAA

In December 2001 the FAA issued Emergency AD 2001-25-52 which required an initial 10 hour dye-penetrant inspection and thereafter a 50 hour dye-penetrant of the clevis lugs of the original design centre frame rear cluster fittings and where cracks were found to replace the cluster fitting with the re-designed –3 type fitting. This Emergency AD superseded AD 76-18-01. The FAA issued an amended AD on the 8 May 2002 (Appendix 14).

1.18.18.3 By the helicopter manufacturer

On 6 September 2002 Schweizer Aircraft Corporation issued mandatory SB B–278 (Appendix 15) that introduced an FAA approved Aft Cluster Fitting Modification Kit for the Hughes 269 model helicopters that are fitted with the 269A2234 BSC and 269A2235 BSC Aft Cluster Fittings. Compliance with this

SB is required within the next 400 hours time in service or within two years from the date of the SB. The fitting of the modification kit specified in this SB is considered an alternative means of compliance for the 50 hour repetitive dye penetrant inspection mandated by the FAA AD 2001-25-52.

On 13 September 2002 Schweizer Aircraft Corporation issued Service Letter L–177 recommending the installation of the modification kit that is specified in SB B-278 to all Schweizer/Hughes 269 model helicopters that have 269A2234-3 and 269A2235-3 re-designed Aft Cluster Fittings to provide enhanced cluster fitting durability.

1.18.19 Non-approved welds and cracks found on other UK registered Hughes 269 helicopters

1.18.19.1 Hughes 269B, G-BPPY

G-BPPY had been manufactured in 1971 under serial number 0448, imported into the United Kingdom from the United States of America in 1989 and had been in storage at an aircraft maintenance organisation's facility for the previous three years.

In February 2001, while carrying out an inspection as part of a pre-purchase survey, a LAE (who was not employed by the organisation where the helicopter was stored) found an original right centre frame rear cluster fitting that had a non-approved welded patch repair of the lower clevis lug (Appendix 3, Photograph 4).

There were no entries in its USA or UK Airframe Log Books to indicate that this non-approved repair had been carried out. It is possible that this welded patch repair could have been carried out prior to G-BPPY having been imported into the UK.

There were no Airframe Log Book entries to indicate that the maintenance facility, the specialist welding company or the LAE, that had been responsible for the non-approved welded patch repair on G-AYLX (G-ZAPS) had been involved with G-BPPY.

When asked why the LTO No 2018 issued by the CAA in March 2000 had not been carried out on this helicopter at the time that the LTO was issued, the maintenance organisation where the helicopter had been in storage responded by saying that they had interpreted the LTO as referring only to helicopters that had a current Certificate of Airworthiness, and did not apply to those in storage.

At the time of its import into the UK, G-BPPY had accumulated 6,034 airframe hours which then increased to a total of 6,380 hours. Examination of both the UK Airframe Log Book and worksheets indicated that the manufacturer's SIN N-82 had never been carried out. FAA AD 76-18-01 had been carried out at 6,035 hours, just after this helicopter had been imported into the UK, but a 200 hour Inspection in accordance with the manufacturer's HMI had never been carried out during the period that G-BPPY had been on the UK register.

None of the worksheets that were referred to in the Airframe and Engine Log Books of G-BPPY were held by the owner, but the AAIB retrieved them from those maintenance organisations that had undertaken work on this helicopter during the time that it had been on the UK register. These worksheets had Certificates of Release attached which related to components that were still fitted to this helicopter. One of these maintenance organisations was about to destroy their worksheets for this helicopter and other aircraft that they had maintained, as permitted by JAR 145.55 which states that such records can be destroyed two years after completion of related work.

1.18.19.2 Hughes 296C, G-BMWA

During inquiries following the discovery of the welded patch repair to the clevis lug on G-BPPY, an aircraft maintenance organisation brought to the attention of the AAIB an original left centre frame rear cluster fitting from Hughes 269C, G-BMWA, which had been found to have a cracked lower clevis lug. This crack was detected during a dye-penetrant inspection in accordance with FAA AD 76-18-01, and had not been apparent during visual inspection of the lug before, or after, removal of the protective paint layer.

None of the worksheets that were referred to in the Airframe and Engine Log Books were held by the owner of G-BMWA.

1.18.19.3 Hughes 269C, G-BWWJ

In May 2001 Hughes 269C, G-BWWJ, which had been manufactured in 1974 under serial number 0256, was taken out of storage where it had been since 1996. It was then surveyed by an aircraft maintenance organisation to assess the maintenance requirement to enable re-issue of its Certificate of Airworthiness.

During this survey, it was found that a non-approved weld repair had been carried out on the outboard flange area of a right centre frame rear cluster fitting (Appendix 3, Photograph 5). The cluster fitting was of the original design.

This helicopter had been imported into the UK from the USA in 1986. Examination of the entries in the UK Airframe Log Book did not indicate where, or when, this non-approved weld repair had been carried out.

There were no entries in this Log Book to indicate that the maintenance facility, the specialist welding company or the LAE, who had been responsible for the non–approved welded patch repair of G-ZAPS had been involved with this helicopter.

When asked why the LTO No 2018 issued by the CAA in March 2000 had not been carried out on this helicopter at the time that the LTO was issued, the maintenance organisation where the helicopter had been in storage responded by saying that they had interpreted LTO as referring only to the re-designed –3, left centre frame rear cluster fitting and since this helicopter had original cluster fittings, it was not applicable.

At the time of its import into the UK, G-BWWJ had accumulated 7,896 airframe hours which had then increased to a total of 8,535 hours. Examination of both the Airframe Log Book and the 'Visicard' file indicated that the manufacturer's SIN N-82 had been carried out once, at 8,275 airframe hours. FAA AD 76-18-01 had been carried out twice, at 7,896 and 8,225 hours. One 200 hour Inspection in accordance with the manufacturer's HMI had been carried out at 8,535 hours. It was noted that FAA AD 88-17-04, part c, a 100 hour dye penetrant inspection of the re-designed –3, cluster fittings which was not required after December 1988, had nevertheless been carried out in 1991, 1993, 1994 and 1995 at 8,286, 8,386, 8,460 and 8,535 airframe hours respectively.

None of the worksheets that were referred to in the Airframe or Engine Log Books were held by the owner.

1.18.20 General maintenance standards of Hughes 269 helicopters

Whilst investigating G-ZAPS, G-BPPY, G-BMWA and G-BWWJ a number of other Hughes 269 helicopter Airframe Log Books and worksheets were examined. Generally it was found that there appeared to be considerable confusion and misunderstanding regarding what inspections were required on the original and re-designed –3 centre fame rear cluster fittings. It was also found that none of the helicopter owners or operators had the worksheets that were referred to in the Log Book maintenance entries.

In a number of the Airframe Log Books that were examined it was noted that Part C, the section entitled 'Modifications and other Technical Instructions', was full and that locally produced pages were being used. Not one of the helicopters

had a CAP 543 'Time Limited Task and Component Change Record' as part of their maintenance records, although a number did have a 'Visicard' file containing similar information; however some of that information was incorrect.

1.18.21 Hughes 269 helicopters on the UK register

As at 1 May 2001, there were seventeen Hughes 269A, B and C helicopters on the UK register. Thirteen of these helicopters had been manufactured using the original centre frame rear cluster fittings and two were known to have had these cluster fittings replaced with the re-designed –3 type.

During this investigation, the premises of a number of aircraft maintenance organisations were visited. It was noted that there were a number of used Hughes 269 series helicopter centre frame structures residing in various corners of a number of these premises.

1.19 New investigation techniques

None.

2 Analysis

2.1 The accident flight

On the day of the accident flight, the meteorological conditions had produced strong winds and low level turbulence which had caused the owner to cancel a training flight, and to allow his son and the close friend to use the helicopter for a private flight. Having collected a mutual female friend from a nearby private landing site, the helicopter was flown to Wycombe Air Park where a set of ground handling wheels for the helicopter were collected. As far as could be established, these ground handling wheels appeared to have been carried unsecured on the helicopter's cabin floor.

The helicopter then took off uneventfully from Wycombe Air Park to return to Shoreham with the owner's son flying the helicopter from the left seat position, the right collective lever having been removed to allow the female passenger to occupy the mid position. Whilst flying in the vicinity of Hare Hatch, the left centre frame rear cluster fitting had failed completely and allowed the aft end of the tailboom to move upwards and to the right. The tail rotor and rear of the tailboom had contacted the main rotor blades before the tailboom detached from the helicopter's fuselage. The fuselage had then rapidly pitched down to the inverted position before falling to the ground.

2.2 Technical investigation

2.2.1 Metallurgical examination

The metallurgical examination concluded that the upper clevis lug of the left centre frame rear cluster fitting had failed due to a very high cycle tension fatigue mechanism. The fatigue crack had originated in an area that had been the subject of a non-approved welded patch repair over a previous crack. The fatigue resistance of the non-approved weld repair would have been adversely affected by internal stresses generated by the welding process. Following the failure of the upper clevis lug, all of the load on the left fitting would have been transferred to the lower clevis lug, which had then failed in rapid fatigue. It was the opinion of the metallurgist that the upper clevis lug may have been completely fractured for a period of time prior to the final failure of the lower clevis lug.

During the metallurgical examination, a crack was observed in an approved welded patch repair on the outboard flange of the right centre frame rear cluster fitting. This crack had also been caused by a high cycle fatigue mechanism that was considered to have initiated as a result of stress concentrations caused by discontinuities in the poor quality of the weld attaching the patch repair. There

was no evidence of plastic deformation or overload failure to indicate that any part of this crack had been as a result of the in-flight break-up or the final impact with the ground. In the opinion of the metallurgist, this crack had initiated shortly after this approved welded patch repair had been carried out. As far as could be established, this approved welded patch repair had been carried out some time before the accident and by a welder other than the one who had carried out the non-approved repair to the upper clevis lug of the left cluster fitting (see section 2.2.3).

2.2.2 Presence of cracks prior to the accident flight

The fatigue crack in the upper clevis lug on the left centre frame rear cluster fitting had been propagating for some flying hours prior to the accident and the metallurgist was of the opinion that this lug may actually have been completely fractured for a short, but undefinable period of time, before this accident.

In addition, the metallurgical examination revealed that the fatigue crack in the approved welded patch repair on the outboard flange of the right centre frame rear cluster fitting had also been present for some flying hours prior to the accident. The size of this crack indicated that it should have been readily visible during a visual inspection of this fitting, as indeed should have been the fatigue crack on the upper lug of the left centre frame cluster fitting.

During a 100 hour maintenance inspection which had been carried out on 18 February 2000, 112:20 flying hours after the non-approved welded patch repair had been carried out in April 1999 and some 16 flying hours before the accident, a visual inspection using a 10X magnifier had been recorded on both of these centre frame aft cluster fittings. However, no associated cracking or damage had apparently been observed during that inspection by the Licensed Aircraft Engineer (LAE) (section 1.18.7), who had issued a Certificate of Release to Service.

The manufacturer had also introduced a requirement for specific visual inspections of the centre frame rear cluster fittings for cracks or damage in the Pre-Flight Check in the Pilot's Flight Manual, and the Daily Inspection (A Check) specified in the Handbook of Maintenance Instruction (HMI).

However, the fatigue cracking present on the upper clevis lug of the left centre frame cluster fitting was not observed during any of the Daily and Pre-Flight Inspections conducted before the accident.

2.2.3 Weld repair of the left centre frame rear cluster fitting

The LAE involved in the weld repair of the upper lug of the left centre frame rear cluster fitting in April 1999 had not consulted the HMI, or Schweizer, to establish whether such a weld repair of the clevis lug was approved. If he had done so, he would have found a specific statement in the HMI which stated that no repair of the clevis lug was allowed and that replacement of the cluster fitting was the only option (section 1.18.3).

However, during the course of this investigation two other Hughes 269 helicopters were found to have non-approved weld repairs of their centre frame rear cluster fittings, one of which had a very similar non-approved welded patch repair to a clevis lug (section 1.18.19). It was established that neither of these helicopters had been maintained by the maintenance facility where the LAE had arranged the non-approved welded patch repair to G-AYLX (G-ZAPS).

As a result of these findings the following Safety Recommendation is made to the CAA:

> The CAA should forward an information notice to all Licensed Aircraft Engineers, and all approved aircraft and component maintenance organisations, reminding them of the requirement that all repairs, including weld repairs, can only be carried out to an approved repair scheme and of their responsibilities to ensure that there is an appropriate repair scheme in the manufacturer's maintenance or repair manual, or related approval is granted by the manufacturer, before any repair is authorised. (Safety Recommendation No 2001-80)

An experienced senior person from the welding company inspected the area of the crack and assessed that a welded patch repair could be made. This assessment was based on his extensive welding experience, and that welding of the cluster fitting appeared acceptable since the fitting was welded to the tubular fuselage structure at three joints (section 1.17.1).

A patch repair was duly prepared and a few days later the repair welding was carried out by a person who held a CAA Welders Approval Certificate employed by this specialist welding company (section 1.17.1). Neither this specialist welding company nor the person who held the CAA Welders Approval Certificate sought approval for the welded patch repair, nor was there any requirement for them to do so in BCAR, sub-section A8, Chapter 10 entitled 'Approval of Welders'. As a result of these findings regarding the authorisation of welded repairs to aircraft and the role of persons holding CAA Welders Approval Certificates, the following Safety Recommendation is made:

> The CAA should tighten the approval process for persons granted CAA Welders Approval Certificates to ensure that before they carry out any welding repairs to aircraft or aircraft components, written assurance is obtained from the authorising Licensed Aircraft Engineer that such repairs are in accordance with an approved repair scheme. (Safety Recommendation No 2001-81)

Following the non-approved welded patch repair, the welding company provided the aircraft maintenance organisation with a 'Welding Certificate of Conformity' for the repair.

This Welding Certificate of Conformity did not, however, contain any provision for recording details of the aircraft type, aircraft registration, component or serial number, or the approval to which the repair was carried out (section 1.17.3).

In addition, the LAE did not raise a worksheet, or make an entry in the Aircraft Log Book, CAP 398, in accordance with the related requirements in the Air Navigation Order, Schedule 6.

As a result of these worksheet and Log Book omissions, the fact that this particular Welding Certificate of Conformity pertained to the non-approved welded patch repair which had been carried out on this helicopter could not be deduced from these maintenance records.

The evidence of how this non-approved weld repair had occurred thus stemmed solely from the early declarations of the associated LAE, augmented by those other individuals involved.

In view of this finding that such Welding Certificates of Conformity do not require any details of aircraft type, registration or repair approval, the following Safety Recommendation is made:

> The CAA should take early action to introduce a requirement that Welding Certificates of Conformity must state details of the applicable aircraft registration, type, component, part number, serial number and approval for the related weld repair. (Safety Recommendation No 2001-82)

2.2.4 Weld repair of the right centre frame rear cluster fitting

The metallurgical examination of the approved welded patch repair on the outboard flange of the right centre frame cluster fitting on G-ZAPS found that it had developed a fatigue crack in the patch which had propagated along a similar path to the original fatigue crack in the flange that had necessitated the repair

(section 1.12.4.2). The fatigue crack in the patch repair had originated from an area of poor quality weld. The standard of this weld was of a much lower quality than that of the welding of the patch repair to the upper clevis lug of the left cluster fitting, and there was no associated Welding Certificate of Conformity.

The difference in weld quality suggested that these repair welds had not been carried out by the same welder. The poor standard of the weld on the right fitting, combined with no associated Welding Certificate of Conformity, suggested that the weld repair to the outboard flange of the right cluster fitting on G-ZAPS may not have been carried out by a person holding a CAA Welders Approval Certificate.

2.3 Clevis lug fatigue cracking and previous accidents

2.3.1 Clevis lug fatigue cracking

The original design of the centre frame rear cluster fittings, as fitted to G-ZAPS, had been found to develop cracks in the clevis lugs (section 1.18.2). In 1970, Hughes Helicopters had issued Service Information Notice (SIN) N-82 which required inspection of the centre frame rear cluster fittings for evidence of cracks. This SIN required a daily visual inspection which was incorporated into the Daily Inspection (A Check) in the manufacturer's HMI, and into the Pre-Fight Inspection in the Pilot's Flight Manual.

In 1976, the FAA issued Airworthiness Directive 76-18-01 which mandated a 200 hour periodic dye penetrant inspection of these cluster fittings in accordance with the procedures contained in an updated SIN N-82.

The manufacturer's inspection and repair procedures had an approved repair scheme that specified how a welded patch repair could be carried out on the outboard flange of an original cluster fitting. The procedure specifically stated that cracks in clevis lugs were not repairable (section 1.18.3).

As a result of the cracking of the original cluster fitting design, Hughes had also re-designed the cluster fittings by almost doubling the thickness of the steel clevis lugs. The re-designed cluster fittings were identified by the addition of '–3' after the part numbers.

The part number was in the form of slightly raised numbers and letters imprinted on the bodies of the cluster fittings which, once they had been welded into the fuselage structure, were painted for corrosion protection. A number of other Hughes 269 helicopters were examined and it was observed that the combination of the paint thickness and the accumulation of grime and oil made visual

examination for cracks extremely difficult and the identification of the cluster fittings by part numbers virtually impossible.

However, despite the improvements to the original design, some of the re-designed –3 centre frame rear cluster fittings were found to develop cracks in the areas where the cluster fitting was welded into the fuselage tubular frame. Such cracks had been caused by heat treatment problems at manufacture which was resolved as described in section 1.18.2. As a result of this, in January 1988 Schweizer issued 'mandatory' SINs N-217, N-220 and N-221 which were later the subject of FAA AD 88-17-04, issued in August 1988. This AD and SIN N-221 introduced similar action to that which had previously been taken on the original cluster fittings (in 1976) - ie a daily visual inspection and a 100 hour dye penetrant inspection. In addition, in 1995 Schweizer issued 'mandatory' Service Bulletin B-263 which required a 'one time' visual inspection using 10X magnification of the re-designed –3 centre frame rear cluster fittings.

There were no permitted weld repair schemes for the re-designed –3 cluster fittings; replacement of such fittings was (and is) the only option (section 1.18.3).

Note: Although the above SINs and SB B-263 were stated to be 'mandatory' by Hughes and Schweizer in the text of these documents, only the relevant regulatory agency has the authority to make such documents legally 'mandatory' and thus binding upon the owners/operators of aircraft. In the case of SINs N-217, N-220 and N-221, these therefore only became legally mandatory when the FAA issued AD 88-17-04. The current system thus relies heavily upon the regulators recognising the importance, from a flight safety standpoint, of certain inspections and modifications recommended by manufacturers in order that associated Airworthiness Directives can be issued to ensure compliance, as far as legally possible.

Schweizer stated the following in this context:

> 'Schweizer Aircraft Corporation strongly emphasises that Red Border Service Notices and Service Bulletins are mandated by SAC and must be complied with as specified within the directives. Compliance with FAA AD Notices is required by law. It is the operator's responsibility to ensure that all applicable Red Border Service Notices, Service Bulletins and FAA AD Notes have been complied with prior to the first flight of the day (FAR 91.403). Any pilot who operates a 269 Series Helicopter against which mandatory Service Notices, Service Bulletins or FAA AD Notes are outstanding, does so at his own risk.'

2.3.2 Previous accidents caused by clevis lug failures

This investigation identified six previous accidents involving this helicopter type where the failure of a clevis lug on the centre frame rear cluster fitting had been identified as the initial failure (Appendix 12). All these failures were of original centre frame rear cluster fittings. In all these accidents the initial failure had occurred in the left clevis lug attachment, with the upper clevis lug positively identified as the primary failure in three of the accidents. The other three investigations had not identified which of the two lugs on the left cluster fitting had been the primary failure.

The report by the Australian BASI on a fatal accident to a Hughes 269C in 1995 concluded that the upper clevis lug on the left re-designed –3 centre frame rear cluster fitting had failed in fatigue. In the opinion of the metallurgist who had conducted the associated examination, that fracture would have been visible during Daily Inspections for some time before the accident occurred.

The report of the fatal accident to Hughes 269A, registration N8885F, on 1 November 2002 in Oklahoma, USA (section 1.18.17) which initially indicates a fatigue failure of the upper clevis lug of an original design (BSC) left aft cluster fitting is of great concern. As this accident is still very much in the early stages of investigation it is felt that any comment in this repot would be inappropriate.

The AAIB did not identify any previous accidents which had involved the failure of a clevis lug that had been weld-repaired.

2.4 Operation and maintenance of G-ZAPS

2.4.1 Log Book and Technical Log

Following the purchase of the helicopter, G-AYLX, by the owner in November 1999 and re-registry as G-ZAPS, it was used by a number of pilots, including the owner, his son and a close friend for a mixture of training and private flights. The daily care of the helicopter was often vested in the close friend who had custody of the Log Books. No contract had been arranged for the future regular maintenance of the helicopter, although maintenance was carried out by the maintenance staff of the aircraft sales organisation from which the owner had purchased the helicopter. This maintenance was carried out when requested by the owner, or the close friend.

No entries had been made in the helicopter's Log Books since it was purchased in November 1999 (section 1.18.8) and the Log Books were not made available to the maintenance organisation before, during or after maintenance had been carried

out. The Technical Log sheets recorded the flying undertaken by the helicopter, but only one Daily Inspection had been signed as having been carried out, that on 5 March 2000 (section 1.18.11). The following Safety Recommendation is therefore made to the CAA:

> The CAA should remind all Licensed Aircraft Engineers and aircraft maintenance organisations that maintenance should not be undertaken on aircraft without access to the associated Log Books and Technical Log (if applicable), and that all work should be recorded as required. (Safety Recommendation No 2001-83)

2.4.2 CAA Survey of this helicopter under its previous registration

Before the current owner had purchased the helicopter towards the end of 1999, it had been surveyed by a CAA Surveyor in October 1999 (section 1.18.7) in preparation for the granting of an Export Certificate of Airworthiness for an intended sale of the helicopter, then registered as G-AYLX, which did not in fact materialise.

That survey had been conducted after the non-approved weld patch repair of the left clevis fitting in April 1999, but the presence of the non-approved weld patch repair was not detected.

Despite the history of fatigue cracking, inspections and modification of these clevis fitting attachments on such helicopters, these specific areas of structure were not included in those areas to be inspected during such CAA Surveys.

The CAA responded to this aspect with the following:

> 'The areas surveyed together with the recorded findings detailed in the Survey Report are commensurate with the level of CAA activity expected. It is important to recognise that the CAA survey of aircraft is not for inspection purposes to determine the standard of airworthiness of specific parts of the aircraft. The absence of a legally required record for the work carried out on G-ZAPS, including the weld repair (albeit to a non-approved standard), the absence of a Certificate of Release to Service, combined with the blending in of the repair by painting reduced the likelihood of the weld repair being detected.'

This CAA Report was presented to the maintenance organisation which then applied for an Export Certificate of Airworthiness, which was granted.

As a result of these findings, the following Safety Recommendation is made:

> In order to better justify assumed airworthiness assurance arising from CAA Survey Reports the CAA should require, before any aircraft or helicopter is surveyed by a CAA Surveyor for the purpose of issuing a Survey Report, that the service history of the type be carefully audited by the Surveyor to identify any critical structural areas which have been the subject of special inspections / Airworthiness Directives to ensure that such areas are closely inspected, if reasonably accessible, during these surveys. (Safety Recommendation No 2001-84)

2.4.3 Daily Inspections (A Check)

There was a requirement in the Pilot's Flight Manual, the manufacturer's HMI and the CAA/LAMS/H/1999 issue 1 (CAP 412) for a Daily Inspections (A Check) to be carried out on the helicopter (sections 1.18.4, 1.18.5 and 1.18.12).

Because G-ZAPS had a Certificate of Airworthiness in the Transport (Passenger) Category, there was a requirement to maintain a Technical Log. This had been kept but there was only one entry, on the 5 March 2000, to indicate that a Daily Inspection (A Check) had been carried out (section 1.18.11). There was no entry to record that a Daily Inspection (A Check) had been carried out on the day of the accident flight.

The preface to the Pre-Flight Check in the Pilot's Flight Manual stated that the pilot must determine that a Daily Inspection in accordance with the HMI has been accomplished within 24 hours prior to the first flight of each day (section 1.18.12). On the day of the accident, the helicopter was being flown on a private flight by a pilot who was not the helicopter's owner and who held a Private Pilot's License. Examination of the Air Navigation Order, CAA/LAMS/H/1999 issue 1 and CAP 520 did not reveal any statement which authorised a private pilot of a private flight to conduct a Daily Inspection. In addition, there was no statement regarding the initial training and continuity training required by pilots of aircraft flown on private flights to allow them to conduct Daily Inspections.

Furthermore, if the helicopter had a Certificate of Airworthiness in the Private Category, there would have been no requirement to maintain a Technical log. This raised the question of how the pilot of an aircraft with a Private Category Certificate of Airworthiness is expected to determine, in accordance with the requirements specified in the CAA approved Pilot's Flight Manual, that a Daily Inspection has been carried out.

As a result of these findings, the following Safety Recommendation is made:

The CAA should specify who is authorised to carry out and certify a Daily Inspection (A Check), in addition to describing the initial training and continuity training required for such authorised persons, how that training should be recorded and monitored, and where the authorised person should sign to certify that a Daily Inspection (A Check) has been carried out satisfactorily. (Safety Recommendation No 2001-85)

2.4.4 Pre-Flight Checks

Amongst the helicopter wreckage was found a locally produced Pilot's Check List which included a Pre-Flight Inspection. This Pre-Flight Inspection did not include the manufacturer's specific requirement to visually inspect the centre frame rear cluster fittings, or the associated warning that if cracking of cluster fittings was suspected then dye penetrant inspection was required before the next flight (section 1.18.12).

As far as could be established during this investigation it appeared to be standard practise, both amongst the pilots who had flown G-ZAPS and those who flew other similar helicopters, to use locally produced Pre-Flight Check Lists to perform the Pre-Flight Inspection in preference to that contained within the Pilot's Flight Manual.

The Pilot's Flight Manual is a CAA approved and controlled document, and as such is amended as required. Locally produced Pilot's Check Lists are not CAA approved, or controlled, and therefore may not be updated with required amendments. As a result of these findings, the following Safety Recommendation is made:

The CAA should require that all pilots use a Pre-Flight Check List from the CAA approved Pilot's Flight Manual whenever a flight is conducted for training, conversion or testing so that only approved and fully amended Check Lists are used. (Safety Recommendation No 2001-86)

In addition, it was noted that the Pre-Flight Check List in the Pilot's Flight Manual only stated the requirement to inspect the left centre frame rear cluster fitting during the Pre-Flight Inspection. There was no specific similar requirement to inspect the right centre frame rear cluster fitting; therefore, the following Safety Recommendation is also made:

The Schweizer Aircraft Corporation should amend the Pre-Flight Check List contained within the Pilot's Flight Manual for the Hughes/Schweizer 269 and 300 helicopters to include in the Pre-Flight Inspection a visual check of the right centre frame rear cluster fitting for cracks and damage, and to include

the warning that if cracking of cluster fittings is suspected then dye penetrant inspection is required before flight. (Safety Recommendation No 2001-87)

The Schweizer Aircraft Corporation has indicated to the AAIB that it will issue an amendment to the Pre-Flight Check List in the Pilot's Flight Manual to include a visual check of the right centre frame rear cluster fitting.

2.5 CAA LTO 2018 and non-approved welding repairs

Following briefings on the cause of this accident by the AAIB, the CAA issued Letter to Operators (LTO) 2018 on the 17 March 2000 to all owner/operators of Hughes/Schweizer 269 series helicopters (section 1.18.18). This LTO requested a 'one time' visual inspection to be carried out for in service weld repairs of the centre frame rear cluster fittings, the tailboom support fitting, the support struts and the centre attachment fitting. In addition, this LTO requested that all associated findings be reported to the CAA.

However, this LTO referred only to the part number for the original left centre frame rear cluster fitting and to a manufacturer's Service Information Notice N-220 which applied only to the re-designed –3 centre frame rear cluster fitting. This lapse caused some confusion within the aircraft maintenance companies involved and reportedly resulted in the required inspection not being carried out on at least two helicopters.

The investigation of the non-approved welded patch repair to the lower clevis lug of the right centre frame rear cluster fitting on G-BPPY did not reveal when, or where, that non-approved repair had been carried out (section 1.18.19). It was possible that this repair may have been implemented before this helicopter had been imported into the UK.

During this investigation a number of used Hughes/Schweizer 269 series helicopter centre frames were seen in the corners of premises of a number of aircraft maintenance organisations. LTO 2018 did not apply to these centre frame assemblies or helicopters that did not have a current Certificate of Airworthiness. In addition, LTO 2018 and its associated visual inspections will not apply to any helicopter of this type that is imported into the United Kingdom in the future.

It was established that, at the time of the accident to G-ZAPS, there were 12 Hughes/Schweizer 269 helicopters on the UK Register that had the original centre frame rear cluster fittings (section 1.18.21). Of these 12 helicopters, 2 were subsequently found to have non-approved weld repairs to a centre frame rear cluster fitting. Thus, if G-ZAPS is included then 3 of these 12 helicopters had non-approved weld repairs, representing 25% of the UK fleet. In addition,

although the dye-penetrant test conducted on the left centre frame rear cluster fitting of G-BMWA had successfully detected the cracked lower clevis lug, it is generally accepted within the aviation industry that such penetrant testing is not completely reliable for crack detection.

The success of such dye penetrant testing can depend upon the technique used and the experience of the person conducting the test. For example, crack indications may be mistaken for red dye retention along the edge of weld bead profiles, or penetrant dye seepage from a crack may be obscured by excessive deposits of the white powder 'developer' used to highlight the seepage.

Past general experience within the AAIB has included accidents where components, such as helicopter tail rotor blades, have failed and caused fatal accidents due to undetected fatigue cracks which had not been found during required repetitive dye-penetrant testing, despite such testing having left evidence of the red penetrant dye used upon the associated fatigue fracture surfaces of failed tail rotor blades, when inspected on site after the related accidents.

2.6 AAIB safety action during this investigation

2.6.1 Reasons for AAIB Safety Recommendation 2001-41:

In view of the serious implications of undetected fatigue cracking of these clevis lugs for tailboom detachment in flight, it was considered that dye-penetrant testing of these cluster fittings could not be sufficiently relied upon to detect such potentially critical cracking on Hughes and Schweizer 269/300 helicopters.

This situation appeared further compromised by the apparent confusion in service as to the standard, original or re-design, of such cluster fittings, and therefore which particular inspections were required (section 1.18.20).

It was also notable that certain weld repairs were authorised on the original type of cluster fitting, while others were not authorised. By contrast, no welding repairs were authorised at all on the re-designed –3 cluster fitting.

As a result of the above findings and concern that there may have been other Hughes/Schweizer 269/300 helicopters, or used centre frames, which had cracked cluster fittings or had been subject to non-approved weld repairs of these fittings, but had not been identified by the CAA's LTO 2018 inspection request (section 1.18.19), the following urgent Safety Recommendation was made to the CAA and to the FAA in a related AAIB Safety Recommendation Document on the 11 April 2001:

'In view of the finding of non-approved welding repairs to the clevis lugs of the Centre Frame Rear Cluster Fittings on two Hughes 269 helicopters, failure of one of which caused a catastrophic in-flight separation of the tailboom assembly, it is recommended that the Civil Aviation Authority and the Federal Aviation Administration take early action to issue Airworthiness Directives to require immediate visual inspections of these fittings on all Hughes/Schweizer 269 and 300 helicopters in order to check for any non–approved welded repairs to the clevis lugs, and to ground any affected helicopters until such repaired Centre Frame Rear Cluster Fittings have been replaced with new fittings. (Safety Recommendation No 2001-41, made 11 April 2001)'

2.6.2 CAA response to AAIB Safety Recommendation 2001-41:

The CAA responded to this Safety Recommendation on the 22 May 2001 as follows:

'The CAA does not accept this Recommendation.

Following the accident to G-ZAPS and the advice received from the AAIB concerning a non-approved weld repair which may have contributed to the accident, the CAA issued a Letter to Operators (LTO) No 2018 in March 2000. This LTO raised the awareness of the failure due to the non-approved repair and recommended a 'one time' inspection of the affected structure on Hughes 269 series helicopters for evidence of in service non-approved repairs. At that time, subsequent to the issue of LTO 2018, no reports of in service non-approved repairs on operating aircraft were submitted to the CAA. During April 2001 the CAA received a report of non-approved repair to the clevis lugs concerning a helicopter which had been out of service and did not hold a current C of A. This aircraft had been out of service since 1977 and the non-approved repair was identified during an inspection carried out on behalf of a prospective purchaser. The CAA consider that the issuance of the LTO has alerted operators and maintenance organisations of the need to inspect affected aircraft for non-approved repairs and the need to follow the service information published by the manufacturer of Hughes 269 series helicopters.'

2.6.3 FAA response to AAIB Safety Recommendation 2001-41:

The FAA, on 14 December 2001, issued Emergency AD 2001-25-52 which required an initial 10 hour dye-penetrant inspection and thereafter a 50 hour dye-penetrant of the clevis lugs of the original design centre frame rear cluster fittings and where cracks were found to replace the cluster fitting with the re-designed –3 type fitting. The FAA issued an amended AD on the 8 May 2002 (Appendix 14).

2.6.4 Reasons for AAIB Safety Recommendation 2001-45:

During this investigation a number of Hughes 269 helicopters were inspected, along with their maintenance documentation, and it became clear that there was an apparent misunderstanding within the UK aviation maintenance industry regarding the difference between the original and the re-designed –3 centre frame rear cluster fittings, and which Airworthiness Directives, manufacturer's Service Information Notices and Service Bulletins applied to which standard of cluster fitting.

There was also apparent confusion regarding what welding could and could not be carried out on each standard of cluster fitting.

In addition, the AAIB had accessed information concerning six previous accidents to Hughes 269 series helicopters which had involved the primary failure of the clevis lugs of the original centre frame rear cluster fitting (section 1.18.17).

As a result of these findings, the following urgent Safety Recommendation was also made to the CAA and to the FAA in the AAIB Safety Recommendation Document on the 11 April 2001:

> 'In view of the potential for catastrophic in flight tailboom detachment on Hughes/Schweizer 269 and 300 helicopters due to fatigue fracture of the clevis lug attachments on the Centre Frame Rear Cluster Fittings, and the difficulty in reliably detecting by dye-penetrant testing all such fatigue cracking in service before related lug fracture occurs, it is recommended that the Civil Aviation Authority issues an Airworthiness Directive requiring the mandatory replacement, on all affected helicopters of these types on the UK Register, of all original Centre Frame Rear Cluster Fittings, part numbers 269A2234 and 269A2235, with the manufacturer's re-designed Cluster Fittings, part numbers 269A2234-3 and 269A2235-3; it is further recommended that the Federal Aviation Administration should implement similar mandatory modification action for all affected helicopters of these types abroad. (Safety Recommendation No 2001-45, made 11 April 2001)'

2.6.5 CAA response to AAIB Safety Recommendation 2001-45:

The CAA responded to this Safety Recommendation on the 22 May 2001 as follows:

> 'The CAA does not accept this Recommendation.
>
> There is no evidence from the UK fleet that the pre-modified centre frame aft cluster fittings are unsafe when maintained in accordance with the appropriate approved service information. The aviation industry is well aware of the limitations of dye penetrant inspection, and it is used in a manner to mitigate these limitations. This is clearly illustrated in the maintenance of the cluster fitting where a dye penetrant inspection is used repeatedly every 200 hours in combination with other inspections. The maintenance specified by the manufacturer provides multiple opportunities for detection of cracks in the clusters before growth to a critical length and has shown to be effective in detection of cracked clusters on G-ZAPS and G-BMWA.'

2.6.6 FAA response to AAIB Safety Recommendation 2001-45:

The FAA indicated to AAIB that it proposes to issue a Notice of Proposed Rule Making (NPRM) mandating the requirement to replace all of the original design centre frame rear cluster fittings with the re-designed cluster fittings.

2.7 Regulatory requirements

2.7.1 Retention requirements for maintenance documentation

During the investigation difficulty was experienced by the AAIB in obtaining worksheets which were referred to in the Airframe Log Books (CAP 398) of those helicopters that were inspected. None of the worksheets that were located were in the possession of the respective current owner/operators, but were found in the archives of various maintenance organisations.

Some of the earlier worksheets for G-ZAPS (when it was registered as G-AYLX) were never located, and those maintenance organisations that had carried out the work had ceased trading at some time in the past (section 1.18.10).

One maintenance organisation initially stated, when approached by the AAIB, that their maintenance records had been destroyed in accordance with the JAR 145 requirement that they could be destroyed two years after the associated work had been completed; these worksheets were in fact later found.

It was noted that it was common practise for maintenance and component overhaul organisations to attach component Certificates of Release to worksheets.

It was thus apparent that the above requirements, as they apply to the retention of Log Books and maintenance records, were more stringent for aircraft operators than for maintenance organisations.

Operators are required to comply with the ANO which requires them to keep such records for a period of two years after their aircraft have been permanently withdrawn from service, whereas maintenance organisations comply with the JAR 145.55 requirement which only requires them to keep records for a minimum of two years after the aircraft, or component, has been released after related maintenance work.

There is no more important reason for maintenance records to be accessible after an accident than when that accident has caused fatalities and has occurred specifically due to non-approved maintenance practices. The absence of relevant records in such accident investigations undermines the prime reason for requiring maintenance records to be kept at all. In view of these findings, the following Safety Recommendation is made:

> The CAA should conduct a review of JAR 145.55 with the aim of proposing to the JAA the improved harmonisation of maintenance document retention time requirements with those specified in the ANO, so that maintenance Worksheets and component Certificates of Release that are referred to in Aircraft, Engine and Propeller Log Books are retained until the aircraft, engine or propeller has been destroyed or scrapped. (Safety Recommendation No 2001-88)

2.7.2 The CAA Light Aircraft Maintenance Schedule

The manufacturer's HMI specified, in detail, the inspections and maintenance required to ensure the safe operation of this type of helicopter (section 1.18.4).

The maintenance requirements specified in the CAA/LAMS/H/1999 issue 1 were general, and not specific to helicopter type (section 1.18.5).

In addition, all of the periodic maintenance inspection checks specified in CAA/LAMS/H/1999 issue 1 were also specified in the manufacturer's HMI, but the latter also specified many more checks. The CAA/LAMS/H/1999 issue 1 only specified inspections at intervals up to 100 hours, whereas the HMI specified maintenance inspections at 200, 300, 400, 600, and 1200 airframe hour intervals.

It was very noticeable from the worksheets and the Aircraft Log Books for G–ZAPS (and previously G-AYLX) that regular maintenance checks in accordance with CAA/LAMS/H had been carried out from 1980 onwards, but those maintenance checks specified in the manufacturer's HMI and FAA AD 76-18-01 had only been carried out spasmodically. Indeed the latter AD, which required a periodic dye penetrant inspection of the centre frame rear cluster fittings for cracks every 200 flying hours, had last been accomplished on this helicopter on the 16 August 1990 at 3,263 flying hours, some 816 hours before this accident on the 8 March 2000.

It thus appeared questionable as to what was gained by operating a helicopter to the CAA Light Aircraft Maintenance Schedule if this was less specific and comprehensive for a type than the manufacturer's Maintenance Manual. It is the case that the CAA requires that any additional inspections and maintenance requirements in the manufacturer's maintenance manual must be added to the LAMS requirements, but this merely reinforces the question of what is gained by using any maintenance schedule other than that provided by the manufacturer specifically for its product. In this context, it was notable that the CAA had previously taken action to stop the use of LAMS for gas turbine helicopters.

Furthermore, this case demonstrated that the inadvertent use of the basic LAMS could lead to a situation where regular inspections to the LAMS were being carried out, but certain manufacturer's inspections were not being implemented as required.

This 'double standard' approach to aircraft maintenance can thus lead to confusion, the presentation of an apparent compliance with the required routine inspections checks and the granting of successive Certificates of Airworthiness while omitting, for almost a decade, critical inspections required by the manufacturer and the primary certificating authority (in this case, the FAA).

As previously referred to in section 1.18.6, Part 3 of CAP 520, entitled 'Light Aircraft Maintenance Schedules' stated, towards the end of paragraph 2:

> 'The LAMS should therefore be considered as a schedule defining the minimum level of scheduled maintenance, taking into account the aircraft type design organisations recommendations.'

Whilst the above extract from CAP 520 does qualify the first phrase statement by adding 'taking into account the aircraft type design organisations recommendations', this sentence could be taken to infer that the basic LAMS defines 'the minimum level of scheduled maintenance', to which must be added the recommendations of the aircraft type design organisation (or manufacturer).

However, the basic LAMS cannot be regarded as 'defining the minimum level of scheduled maintenance' because it may not include, as in this case, critical inspections of key structural elements which service experience has highlighted as potential primary causes of catastrophic in-flight structural failure.

In short, this approach of using the CAA LAMS general maintenance schedule still requires augmentation with additional required inspections from the manufacturer's maintenance manual, and if such augmentation is not done provides a ready 'human factor' lapse mechanism for the unintended omission of key inspections and airworthiness directives. In view of these findings and considerations, the following Safety Recommendations are made:

> In order to avoid inadvertent omission of manufacturer's inspections during maintenance, it is recommended that the CAA withdraw the option to use the generalised CAA Light Aircraft Maintenance Schedule for Hughes/Schweizer 269 and 300 series helicopters so that they may only be maintained to the manufacturer's Handbook of Maintenance Instructions (HMI). (Safety Recommendation No 2001-89)
>
> and:
>
> The CAA should conduct a review of the manufacturer's maintenance manual requirements for all helicopter types on the UK register which are currently maintained to CAA/LAMS/H/1999 issue 1 and where there are significant additional 'specific-to-type' maintenance requirements in the applicable maintenance manuals, require such helicopters to be maintained only to the manufacturer's maintenance manual. (Safety Recommendation No 2001-90)

2.7.3 Upper torso restraints

No upper torso restraint was found fitted to this helicopter for the middle passenger seat (section 1.12.2), and no associated exemption certificate had been issued in accordance with Schedule 4 of the ANO, although a lap strap had been fitted (section 1.18.15).

Although the middle seat was physically capable of being occupied and had a lap strap fitted, without an upper torso restraint fitted to this seat and no exemption granted the helicopter was not authorised to carry more that two people.

However, the severity of this accident was such that even had an upper torso restraint been fitted, the middle seat passenger would not have survived. Notwithstanding this, if this seat had been rendered physically unusable then the third person would not have been aboard the helicopter at the time of the accident. In view of these findings, the following Safety Recommendation is therefore made:

It is recommended to the CAA that where an aircraft seat requires an upper torso restraint in accordance with Schedule 4 of the Air Navigation Order but no upper torso restraint has been fitted and no exemption certificate issued, then the seat position should be required to be made unusable for the carriage of a passenger. (Safety Recommendation No 2001-91)

3 Conclusions

(a) Findings

1 The pilot was properly licensed and medically fit to conduct the private flight.

2 The helicopter suffered a critical in-flight structural failure which allowed the aft end of the tailboom to contact the main rotor blades; during the ensuing rapid pitch down as the tailboom detached, the mid seat female passenger was ejected through the cockpit canopy and received fatal injury from contact with the main rotor blades, before the helicopter wreckage and two remaining occupants fell to earth.

3 The tailboom detachment was initiated by a pre-existing fatigue fracture of the upper clevis lug on the left centre frame rear cluster fitting, which induced a rapid fatigue failure of the associated lower lug and consequent separation of the tailboom left lower support tube from this cluster fitting; this allowed the aft end of the tailboom to suffer relative displacement into the plane of rotation of the main rotor disc.

4 The fracture of the upper clevis lug on the left centre frame rear cluster fitting had occurred as a result of propagation of a very high cycle tension fatigue crack which had originated at the weld bead edge of a non-approved welded patch repair to this lug.

5 The welding of the patch repair to this upper clevis lug had been carried out in April 1999 to repair a previous crack in this lug, and had been called up by the Licensed Aircraft Engineer of the aircraft dealership which had later sold the helicopter (then registered as G-AYLX) to the current owner in November 1999.

6 The LAE had not consulted the helicopter's Handbook of Maintenance Instruction (HMI), or sought advice from the manufacturer regarding this weld repair, and was not aware at that time that no weld repairs of these clevis lugs were permitted by the manufacturer.

7 Although all personnel who conduct welding repairs to aircraft or their components in the UK must hold a CAA Welders Approval Certificate, such personnel have not thus far been required to obtain written assurance from authorising aircraft engineers to confirm that requested weld repairs are in accordance with approved repair schemes. This system can thus result in personnel holding CAA Welders Approval Certificates carrying out non-approved welding on aircraft, as occurred in this case.

8 Although the CAA requires the completion of a Welding Certificate of Conformity after any welding repairs to aircraft in the UK, such certificates have not thus far been required to state any details of the associated aircraft type, registration, or weld repair authorisation/approval. The lack of such pertinent information can lead to non-approved welding, and also prejudice the identification of those organisations which may have inadvertently carried out non-approved weld repairs if these have not been recorded in the associated Log Books and documentation.

9 Since no worksheet was raised or Aircraft Log Book entry made to record this welded patch repair to the left centre frame rear cluster fitting on G-AYLX in April 1999, this investigation would have experienced difficulty in identifying the circumstances of this non-approved weld repair, if the associated LAE had not declared his involvement after the accident.

10 No fatigue cracking had been detected on this repaired left upper clevis lug as a result of subsequent Pre-Flight Inspections, Daily Inspections or other inspections, including a visual inspection which required 10X magnification and had been conducted on the 18 February 2000, 112:20 flying hours after this non-approved repair and some 16 flying hours prior to this accident.

11 Although the manufacturer had included in the Pre-Flight Inspection within the Pilot's Flight Manual a specific visual inspection of the centre frame rear cluster fittings for cracks, the pilot had used a locally produced Pilot's Check List which contained a Pre-Flight Inspection that did not include a visual inspection of these fittings.

12 Despite a requirement in the Pilot's Flight Manual and in the CAA Light Aircraft Maintenance Schedule/Helicopters (CAA LAMS/H) 1999, issue 1, for a Daily Inspection (A Check), there was only one record in the operator's Technical Log of such an Inspection having been carried out since the helicopter had been acquired in November 1999, and that was on the 5 March 2000; there was thus no record of any Daily Inspection having been carried out on the day of the accident flight.

13 Although this helicopter had been inspected by a CAA Surveyor in October 1999 for the purpose of granting a Certificate of Airworthiness to G-AYLX for intended export, the non-approved weld repair of the upper clevis lug on the left centre frame rear cluster fitting had not been detected, and a Certificate of Airworthiness was duly granted by the CAA; despite the history of cracking on such original design lugs in service, and the associated FAA Airworthiness Directive 76-18-01, these areas of structure were not amongst those listed for inspection during that CAA Survey.

14 The last recorded compliance with FAA AD 76-18-01, which required dye penetrant inspection of the original standard of centre frame rear cluster fittings for cracking at 200 hour intervals, was on the 16 August 1990 at 3,263 flying hours, some 816 hours before the accident.

15 During the investigation, other instances of cracking on the original standard of clevis lugs, associated non-approved welded patch repair, and a non-approved welding repair of the outboard flange area were found on other Hughes 269 helicopters in the UK, indicating that the non-approved welding repair found on G-ZAPS was not an isolated occurrence on this helicopter type.

16 Hughes Helicopters had previously responded to the cracking problem on the clevis lugs of these centre frame rear cluster fittings with additional periodic inspections and a re-designed –3 type of cluster fitting, but it became apparent during this investigation that there was confusion within UK personnel responsible for the maintenance of Hughes 269 helicopters regarding the difference between the original and re-designed –3 standards of these centre frame cluster fittings, and which inspections applied to which standard of fitting.

17 Six previous accidents to this type of helicopter were identified which had been caused by fatigue failure of clevis lugs on the original standard of centre frame rear cluster fitting; all six accidents had stemmed from fatigue cracking of the left clevis lugs. In addition, one fatal accident had occurred in Australia in 1995 due to fatigue failure of an upper clevis lug on a re-designed –3 centre frame rear cluster fitting. No previous accidents were identified which had occurred due to failure of a clevis lug that had been weld-repaired.

18 This accident, and those which had also occurred previously due to fatigue failure of these clevis lugs on helicopters of this type, demonstrated that such clevis lug fatigue cracking could remain undetected, despite frequent opportunities and requirements for in service inspections of these readily viewed fittings, until eventual failure of such weakened lugs caused accidents. Such findings questioned the regulatory reliance placed upon such inspections to detect fatigue damage of these clevis lugs before catastrophic tailboom separation occurred.

19 A lack of logical standardisation was apparent with respect to the timespans that maintenance records and associated documentation must be kept by aircraft operators and maintenance organisations. The ANO requires operators to retain aircraft Log Books for two years after related aircraft have been permanently withdrawn from service, but JAR 145.55 only requires

maintenance organisations to retain work records for a minimum of two years after the aircraft to which they refer have been released on completion of related maintenance work. In effect, the potential advantages to investigations of retaining Log Books for the life of an aircraft can thus be nullified by the absence of the detailed maintenance records to which the Log Books refer, if the related work of interest has been completed more than two years before an aircraft suffers a maintenance related accident.

20 Although the mid seat position on this helicopter should not have been occupied because it was not equipped with upper torso restraint, and no related Exemption Certificate in compliance with the ANO Schedule 4 had been issued by the CAA, this accident was non-survivable for all occupants.

(b) Causal factors

The investigation identified the following causal factors:

1 A pre-existing fatigue fracture of the upper clevis lug on the left centre frame rear cluster fitting, which induced a rapid fatigue failure of the associated lower lug and consequent separation of the tailboom left lower support tube from this cluster fitting; this allowed the aft end of the tailboom to displace into the plane of the main rotor disc before the tailboom detached completely.

2 Initiation of very high cycle tension fatigue crack propagation in the upper clevis lug at the weld bead edge of a non-approved welded patch repair to this lug.

3 An omission by the Licensed Aircraft Engineer, who had instigated the welded patch repair of the previously cracked upper clevis lug in April 1999, to reference the helicopter's Handbook of Maintenance Instruction, or the manufacturer regarding this weld repair combined with a lack of awareness that no weld repairs of these clevis lugs were permitted. The presence of such cracking required replacement of the cluster fitting.

4 Non-detection of the welded patch repair on this left upper clevis lug or associated fatigue cracking as a result of the pilot's Pre-Flight Inspection, the helicopter's previous Daily Inspections and the last recorded specific visual examination of the clevis lugs using 10X magnification which had been carried out by the Licensed Aircraft Engineer on 18 February 2000, 112:20 flying hours after this non-approved repair and some 16 flying hours before the accident.

5 Absence of any requirement to inspect these clevis lugs during a Civil Aviation Authority Survey of this helicopter in October 1999 and the attendant non-detection of the welded patch repair to the left upper clevis lug prior to the issuing of a Certificate of Airworthiness.

6 The regulatory decision not to mandate the fitment of available re-designed strengthened cluster fittings, despite a history of fatigue cracking of the original clevis lug design over some 30 years and six resultant tailboom detachments, combined with unsound reliance upon the effectiveness of a strategy of repetitive inspections and Federal Aviation Administration Airworthiness Directive 76-18-01; such modification had therefore not been made mandatory by the Federal Aviation Administration, the primary certification authority for this type, or the Civil Aviation Authority for such helicopters on the UK Register, and this UK registered helicopter had not had such re-designed clusters fitted.

4 Safety Recommendations

The following safety recommendations were made during the course of the investigation:

4.1 **Safety Recommendation No 2001-80** The CAA should forward an information notice to all Licensed Aircraft Engineers, and all approved aircraft and component maintenance organisations, reminding them of the requirement that all repairs, including weld repairs, can only be carried out to an approved repair scheme and of their responsibilities to ensure that there is an appropriate repair scheme in the manufacturer's maintenance or repair manual, or related approval is granted by the manufacturer, before any repair is authorised.

4.2 **Safety Recommendation No 2001-81** The CAA should tighten the approval process for persons granted CAA Welders Approval Certificates to ensure that before they carry out any welding repairs to aircraft or aircraft components, written assurance is obtained from the authorising Licensed Aircraft Engineer that such repairs are in accordance with an approved repair scheme.

4.3 **Safety Recommendation No 2001-82** The CAA should take early action to introduce a requirement that Welding Certificates of Conformity must state details of the applicable aircraft registration, type, component, part number, serial number and approval for the related weld repair.

4.4 **Safety Recommendation No 2001-83** The CAA should remind all Licensed Aircraft Engineers and aircraft maintenance organisations that maintenance should not be undertaken on aircraft without access to the associated Log Books and Technical Log (if applicable) and that all work should be recorded as required.

4.5 **Safety Recommendation No 2001-84** In order to better justify assumed airworthiness assurance arising from CAA Survey Reports the CAA should require, before any aircraft or helicopter is surveyed by a CAA Surveyor for the purpose of issuing a Survey Report, that the service history of the type be carefully audited by the Surveyor to identify any critical structural areas which have been the subject of special inspections / Airworthiness Directives to ensure that such areas are closely inspected, if reasonably accessible, during these surveys.

4.6 **Safety Recommendation No 2001-85** The CAA should specify who is authorised to carry out and certify a Daily Inspection (A Check), in addition to describing the initial training and continuity training required for such authorised persons, how that training should be recorded and monitored, and where the authorised person should sign to certify that a Daily Inspection (A Check) has been carried out satisfactorily.

4.7 **Safety Recommendation No 2001-86** The CAA should require that all pilots use a Pre-Flight Check List from the CAA approved Pilot's Flight Manual whenever a flight is conducted for training, conversion or testing so that only approved and fully amended Check Lists are used.

4.8 **Safety Recommendation No 2001-87** The Schweizer Aircraft Corporation should amend the Pre-Flight Check List contained within the Pilot's Flight Manual for the Hughes/Schweizer 269 and 300 helicopters to include in the Pre-Flight Inspection a visual check of the right centre frame rear cluster fitting for cracks and damage, and to include the warning that if cracking of cluster fittings is suspected then dye penetrant inspection is required before flight.

4.9 **Safety Recommendation No 2001-41** In view of the finding of non-approved welding repairs to the clevis lugs of the Centre Frame Rear Cluster Fittings on two Hughes 269 helicopters, failure of one of which caused a catastrophic in-flight separation of the tailboom assembly, it is recommended that the Civil Aviation Authority and the Federal Aviation Administration take early action to issue Airworthiness Directives to require immediate visual inspections of these fittings on all Hughes/Schweizer 269 and 300 helicopters in order to check for any non-approved welded repairs to the clevis lugs, and to ground any affected helicopters until such repaired Centre Frame Rear Cluster Fittings have been replaced with new fittings. (Safety Recommendation No 2001-41, made 11 April 2001)

4.10 **Safety Recommendation No 2001-45** In view of the potential for catastrophic in flight tailboom detachment on Hughes/Schweizer 269 and 300 helicopters due to fatigue fracture of the clevis lug attachments on the Centre Frame Rear Cluster Fittings, and the difficulty in reliably detecting by dye-penetrant testing all such fatigue cracking in service before related lug fracture occurs, it is recommended that the Civil Aviation Authority issues an Airworthiness Directive requiring the mandatory replacement, on all affected helicopters of these types on the UK Register, of all original Centre Frame Rear Cluster Fittings, part numbers 269A2234 and 269A2235, with the manufacturer's re-designed Cluster Fittings, part numbers 269A2234-3 and 269A2235-3; it is further recommended that the Federal Aviation Administration should implement similar mandatory modification action for all affected helicopters of these types abroad. (Safety Recommendation No 2001-45, made 11 April 2001)

4.11 **Safety Recommendation No 2001-88** The CAA should conduct a review of JAR 145.55 with the aim of proposing to the JAA the improved harmonisation of maintenance document retention time requirements with those specified in the ANO, so that maintenance Worksheets and component Certificates of Release that are referred to in Aircraft, Engine and Propeller Log Books are retained until the aircraft, engine or propeller has been destroyed or scrapped.

4.12 **Safety Recommendation No 2001-89** In order to avoid inadvertent omission of manufacturer's inspections during maintenance, it is recommended that the CAA withdraw the option to use the generalised CAA Light Aircraft Maintenance Schedule for Hughes/Schweizer 269 and 300 series helicopters so that they may only be maintained to the manufacturer's Handbook of Maintenance Instructions (HMI).

4.13 **Safety Recommendation No 2001-90** The CAA should conduct a review of the manufacturer's maintenance manual requirements for all helicopter types on the UK register which are currently maintained to CAA/LAMS/H/1999 issue 1 and where there are significant additional 'specific-to-type' maintenance requirements in the applicable maintenance manuals, require such helicopters to be maintained only to the manufacturer's maintenance manual.

4.14 **Safety Recommendation No 2001-91** It is recommended to the CAA that where an aircraft seat requires an upper torso restraint in accordance with Schedule 4 of the Air Navigation Order but no upper torso restraint has been fitted and no exemption certificate issued, then the seat position should be required to be made unusable for the carriage of a passenger.

E J TRIMBLE
Inspector of Air Accidents
Air Accidents Investigation Branch
Department for Transport
January 2003

All safety recommendations are required to be taken into consideration and where appropriate, acted upon without delay. Regulation 14 of the Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996 sets out the statutory responsibilities of any undertaking or authority to which a safety recommendation is communicated.