United Arab Emirates

الهيئـــة الــعـامـــة للطيـــران الـمـدنـــي
GENERAL CIVIL AVIATION AUTHORITY

Air Accident Investigation Sector

Serious Incident

- Final Report -

AAIS Case No. AIFN/0007/2011

Failure of Undercarriage AFT Crosstube

Operator: Falcon Aviation Services
Type: Bell 412EP
Registration: A6-FLV
Location: PC03 Wellhead Tower, Helideck, Zakum Field
State of Occurrence: United Arab Emirates
Date of Occurrence: 16 March 2011

رؤيـتـنـا: مـنـظـومـة طيـران مـدنـي آمـنـة ورائـدة ومسـتـدامـة
OUR VISION: A LEADING, SAFE, SECURE AND SUSTAINABLE CIVIL AVIATION SYSTEM

Air Accident Investigation Sector
General Civil Aviation Authority
The United Arab Emirates

Serious Incident Brief

GCAA AAI Report No.:	07/2011
Operator:	Falcon Aviation Services
Aircraft Type and Model:	Bell 412EP
Registration Mark:	A6-FLV
MSN:	36514
No. and Type of Engines:	One PT6T-3DF Twin-Pac Turboshaft Assembly
Date and Time (UTC):	16 March 2011, 07:20 UTC
Location:	PC03 Wellhead Tower, Helideck, Zakum Filed
Type of Flight:	Non – scheduled air transport
Persons On-board:	11
Injuries:	None
Nature of Damage:	Failed undercarriage aft crosstube

Notes:

1. Whenever the following words are mentioned in this Report with first Capital letter, they shall mean the following:

   (Aircraft)- the aircraft involved in this Serious Incident.
   (Investigation)- the investigation into this Serious Incident
   (Incident)- this investigated Serious Incident
   (Report)- this Serious Incident final report
   (Team)- the GCAA AAIS Investigation Team

2. Unless otherwise mentioned, all times in this Report are Coordinated Universal Time (UTC), (UAE Local Time minus 4).

3. Photos used this Report are taken from different sources and are adjusted from the original for the sole purpose to improve the clarity of the Report. Modifications to images used in this Report are limited to cropping, magnification, file compression, or enhancement of color, brightness, contrast, or addition of text boxes, arrows or lines.

OBJECTIVE

This Investigation was performed pursuant to the UAE Federal Act No 20 of 1991, promulgating the Civil Aviation Law, Chapter VII, Aircraft Accidents, Article 48, and in compliance with the UAE Civil Aviation Regulations, Part VI, Chapter 3, and in conformity with Annex 13 to the Convention on International Civil Aviation and in adherence to the Air Accidents and Incidents Investigation Manual.

The sole objective of this Investigation is to prevent aircraft accidents and incidents, by identifying and reducing safety-related risk. The GCAA AAIS investigations determine and communicate the safety factors related to the transport safety matter being investigated.

All GCAA Investigations Reports are publicly available from:

http://www.gcaa.gov.ae/en/epublication/pages/investigationreport.aspx

It is not a function of the GCAA AAIS to apportion blame or determine liability.

SYNOPSIS

The aircraft, a Bell 412EP, registration A6-FLV, operated by Falcon Aviation Services, made an uneventful approach and landing on the helideck of Wellhead Tower PC03 at Zakum Field, United Arab Emirates, at approximately 0720UTC on 16th March 2011. It was intended to embark ten passengers and some equipment. After nine passengers had boarded, the aircraft suddenly settled and adopted a nose high attitude. The engines were shut down and the passengers and crew disembarked.

Subsequent examination of the aircraft by the crew showed that the undercarriage aft crosstube had failed.

This report is based on data gathered and provided to the Investigation Team during the course of this investigation[1].

The information contained in this final report is published to inform the aviation industry and the public of the general circumstances of the occurrence.

This factual report supersedes all previous Preliminary and Interim reports concerning this investigation.

The GCAA lead the investigation and assigned the Investigator in Charge (IIC). Additionally accredited representative from CANADA were invited and provided comments to this investigation report. Furthermore, the Operator and the GCAA's

[1] Landing Gear Manufacturer report FA-D412-664-1,
Landing Gear Manufacturer Instructions for Continued Airworthiness ICA-D212-664 Rev 7,
Landing Gear Manufacturer Service Bulletin SB07-1 Rev A,
Landing Gear Manufacturer Service Bulletin SB10-1 Rev A,
Landing Gear Manufacturer Service Bulletin SB11-2 Rev C,
Laboratory 1 Fracture Surface Evaluation G115166 Issue 2,
Laboratory 1 Fracture Surface Evaluation G115167 Issue 1,
Laboratory 2 Group Quantitative Assessment Project No. 128-11-2894,
Laboratory 2 Group Quantitative Assessment Project No. 128-12-127,
FAA Production Certificate No 100,
FAA TYPE CERTIFICATE DATA SHEET NO. H4SW Revision 27, January 4, 2006,
The Operator's incident report, dated 21 March 2011.

Safety Affairs Sector were invited to provide comments, as they are considered interested parties as per UAE CAR PART VI[2].

Having established all of the relevant factors, this final report provides two safety recommendations intended to prevent reoccurrence.

The GCAA AAIS made every possible effort to reflect the facts as presented to the Investigation Team.

The GCAA lead the investigation and assigned the Investigator in Charge (IIC). Additionally accredited representatives from Canada, as the State of Manufacturer and the USA, as the State of Design, were invited and provided comments to this investigation report. Also, the Operator and the Safety Affairs Sector of the GCAA were invited to provide comments, in accordance with UAE CAR PART VI.

The Report

This report was prepared in accordance with the International Civil Aviation Organization Standards And Recommended Practices, the GCAA CAR Part VI Chapter 3 and has the following format:

1. **Factual Information**

   Provides factual information that is relevant to understanding the chronology and circumstances of this occurrence. Part 1, Factual Information, has nineteen (19) sub-headings detailing each aspect of the investigation to be reported.

2. **Analysis**

   Reviews, evaluates and analyses the factual information presented in the part one, Factual Information of the investigation. This varies from theoretical analysis to laboratory and full scale testing

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[2] Definitions
Interested Party- Any person, government authority/department, institution, organization, aviation society, air operator, aircraft owner, property owner, ministry or any other body the GCAA finds appropriate to have their limited participation in the investigation or receive comments on the GCAA's draft reports (CAR PART VI page 10, issue 0 dated October 2012).

3. Conclusions

Based on the analysis of the factual information, presents the Findings and the Causal factors.

A. Findings are statements of all significant conditions, events or circumstances in the accident sequence. The findings are significant steps in the accident sequence, but they are not always causal of indicate deficiencies.
B. Causes are actions, omissions, events, conditions, or a combination thereof, which led to this accident.
C. Contributing factors are actions, omissions, events, conditions, or a combination thereof, which, directly contributed to the Accident and if eliminated or avoided, would have reduced the probability of this Accident occurring, or mitigated the severity of its consequences.

4. Safety Recommendations

Based on the findings of the investigation, recommends safety actions required to be taken to eliminate or mitigate safety deficiencies, and records the main actions already taken or being taken by the affected entities involved through the process of immediate Prompt Safety Recommendations.

This report does not contain any safety recommendations as the safety action taken during this investigation enhance safety by effectively mitigate the unsafe condition created.

Safety Actions already taken

Below is a summary of the safety actions taken by the landing gear manufacturer, the Federal Aviation Administration, the Transport Canada Civil Aviation and the aircraft Operator, because of this occurrence.

The Landing Gear Manufacturer

I. The fatigue analysis that was performed on the D412-664-203 crosstube was revised.
II. A life limit of 10,000 landings and added an LPI after 7500 landings was established.
III. This information was released to the customer base via Service Bulletin SB 11-2

IV. A revision to the ICA followed to include the life limit and the LPI inspection

V. Coordination was performed so TCCA to issue an Airworthiness Directive

VI. During the draft final report comments period the Team was informed via the Accredited Representative of Canada that the landing gear manufacturer following research and development "received a TCCA approval for the improved 412 aft Crosstube which is manufactured from a more fatigue resistant material."

Transport Canada Civil Aviation

Transport Canada issued an Airworthiness Directive for the crosstube (AD-CF-2012-14R1).

Federal Aviation Administration

The USA Federal Aviation Administration issued an Airworthiness Directive for the crosstube (Docket No. FAA-2013-0145; Directorate Identifier 2012-SW-059-AD; Amendment 39-17554; AD 2013-16-16), which adds a life limit of 10,000 landings to the crosstube and removes from service any crosstubes with more than 10,000 accumulated landings.

The Aircraft Operator

Following the event the Operator proactively imposed a 2500 landings LPI, which was significantly lower that the manufacturer's 7500 landing LPI limit. The 10,000 landings life limits remained.

ABBREVIATIONS AND DEFINITIONS

AAIS	The Air Accident Investigation Sector
ADC	Aerodrome Controller
AFM	Airplane Flight Manual
AMM	Aircraft Maintenance Manual
ATPL	Air Transport Pilot License
BHTC	Bell Helicopter Textron Canada
BHTI	Bell Helicopter Textron Incorporated
CAS	Calibrated Air Speed
CAVOK	Ceiling and Visibility are OK
C.G.	Centre of Gravity
cm	Centimeter
CoA	Certificate of Airworthiness
CoR	Certificate of Registry
CPL	Commercial Pilot License
CVR	Cockpit Voice Recorder
CSN	Cycles Since New
DOI-OAS	Department of Interior of the United States- Office of Aircraft Services
EAS	Equivalent Air Speed
ETD	Estimated Time of Departure
E.W.	Empty Weight
FAA	The Federal Aviation Administration of the United States
FAR	The Federal Aviation Regulations
FD	Flaps Down
FDR	Flight Data Recorder
ft	Feet (distance unit)
GCAA	General Civil Aviation Authority of the United Arab Emirates
GD	Gear down

GMC	Ground Movement Controller
GNS	Global Navigation System
GU	Gear Up
Hp	Horsepower (power unit)
hPa	Hectopascal (pressure unit)
hrs	Hours
IAS	Indicated Air Speed
ICA	Instructions for Continued Airworthiness
Investigation	The investigation into this occurrence
IFR	Instrument Flight Rules
kts	Knot(s)
lb	Pound(s) (weight unit)
LG	Landing Gear
LH	Left Hand
LT	Local time of the United Arab Emirates
LPI	Liquid Penetrant Inspection
M	Meter(s)
MAC	Mean Aerodynamic Chord
METAR	A format for reporting weather information
MSN	Manufacturer Serial Number
MLG	Main Landing Gear
NLG	Nose Landing Gear
NM	Nautical Miles (distance unit)
No.	Number
NTSB	The National Transportation Safety Board of the United States
OAT	Outside Air Temperature
PIC	Pilot-in-Command
PPL	Private Pilot License
psi	Pounds per square inch (pressure unit)

QNH	The barometric altimeter setting that will cause the altimeter to read airfield elevation when on the airfield.
QFE	The barometric altimeter setting that will cause an altimeter to read zero when at the reference datum of a particular airfield.
RH	Right Hand
RPM	Revolution Per Minute
RWY	Runway
s	Second(s)
SEM	Scanning Electron Microscope
SPIFR	Single Pilot Instrument Flight Rules
STC	Supplemental Type Certificate
TAS	True Air Speed
TAWS	Terrain awareness and warning system
TC	Type Certificate
TCCA	Transport Canada Civil Aviation
TTSN	Total Time Since New
TSLO	Time Since Last Overhaul
TSN	Time Since New-flight hours
TWY	Taxiway
UAE	The United Arab Emirates
UTC	Coordinated Universal Time
VFR	Visual Flight Rules

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1. FACTUAL INFORMATION

1.1 HISTORY OF FLIGHT

The aircraft transited from PN49 empty (no passengers or freight) to Wellhead PC03 of the Zakum field, which is approximately 80 kilometers north-west of Abu Dhabi city, to pick up ten passengers and some equipment. The Captain was the Pilot Flying (PF) and the aircraft landed at approximately 0718hrs UTC. The aircraft was landed using minimal power (given the lightweight and the wind conditions at the time) and was positioned in the center of the helideck prescribed markings.

Fuel onboard, on landing, was approximately 940lbs giving an All Up Weight (AUW) of approximately 9150-9200lbs. Calculations for a takeoff weight (TOW) with 10 passengers (2000lbs) onboard result in a weight of approximately 11,400lbs, some 500 to 600lbs below the maximum takeoff weight (MTOW).

During the loading process, the engines were running with the throttles in the ground idle position. The passengers first loaded the equipment onboard. Nine of the passengers then boarded the aircraft. The 10th passenger was attending to the tail boom luggage compartment when a noise was heard and there was an associated movement of the aircraft skids. The noise was louder than that normally associated with the spreading of the skids, as occurs when additional weight is added to the helicopter. There was also a sudden downward movement of the aircraft and the aircraft adopted a significant nose high attitude. The Crew immediately shut down the engines and the passengers and crew then disembarked the aircraft safely.

On inspecting the aircraft, the crew noticed that the undercarriage aft crosstube (supporting the undercarriage skids in the aft) had failed approximately at the mid-point and that both sections of the failed crosstube had pivoted around the rubber absorber mounts. The crosstube failure allowed the aircraft aft fuselage to settle almost onto the surface of the helideck.

The weather conditions at the time of the incident were: CAVOK, wind 330/25-30kts outside air temperature (OAT) approximately 25°C.

With A6-FLV disabled on the helideck an inadequate amount of space remained to land a helicopter on the wellhead to extract the crew and passengers. Due to high winds and high seas, it was also not possible to utilize a boat to return the personnel involved in the incident to the accommodation Platform (ACPT). The only option was to hoist the personnel from the wellhead via helicopter winch.

Operator management personnel requested United Arab Emirates Search and Rescue (SAR) to recover the passengers and crew. The SAR Flight Crew was fully briefed by the operator's Offshore Operations Manager on the extent of the task. Approval was granted for SAR to recover the personnel.

All personnel were safely recovered to the Accommodation Platform and the SAR aircraft returned to Bateen. There were no injuries to either the crewmembers or passengers as a result of the Serious Incident or their recovery. Furthermore, the crew reported that flights prior to the incident flight had been normal and there had been no hard landing on any flight. In addition there were no hard landing recorded in the aircraft maintenance log book.

1.2 INJURIES TO PERSONS

There were no injuries to the passengers or crew.

Injuries to persons						
Injuries	**Flight Crew**	**Cabin Crew**	**Other Persons Onboard**	**Passengers**	**Total Onboard**	**Others**
Fatal	0	0	0	0	0	0
Serious	0	0	0	0	0	0
Minor	0	0	0	0	0	0
None	2	0	9	0	11	0
TOTAL	**2**	0	**9**	0	**11**	0

Table 1. Injuries to persons

1.3 DAMAGE TO AIRCRAFT

Photo 1. A6-FLV following aft crosstube failure

Damage to the aircraft consisted of the failed undercarriage aft crosstube, part number D412-664-203, and resulting damaged fuselage skin panels in the area of the aft crosstube tunnel, near the grounding receptacle, on both sides of the fuselage.

The fracture of the aft crosstube occurred on the starboard side, close to the crosstube pivot point. The crosstube tunnel skin was damaged and the emergency life raft inflation cylinder attachment brackets sustained damage. The rocking beam pivot assembly was detached.

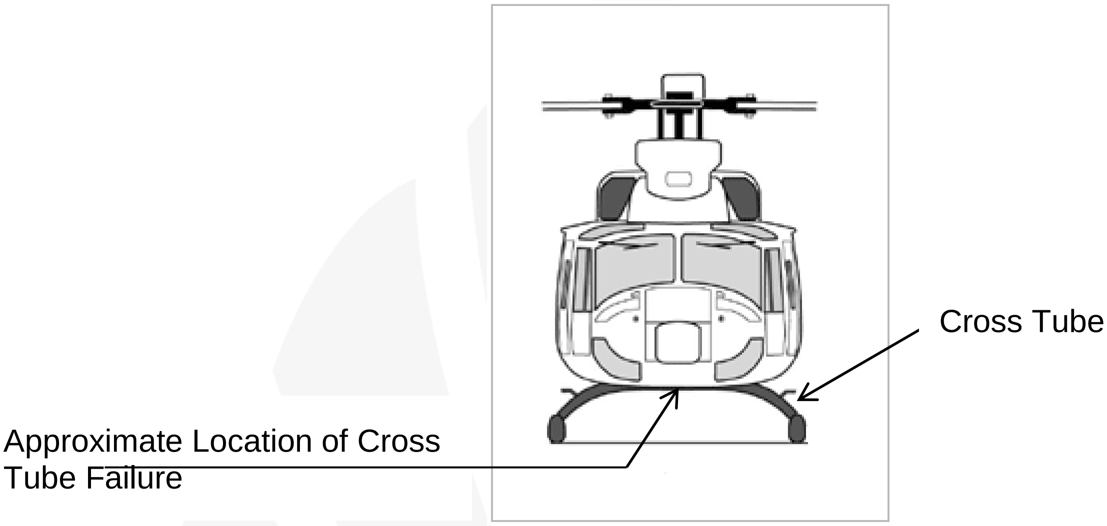

Figure 1. Bell 412 location of Cross Tube Failure

Photo 2. Failed Undercarriage Aft Crosstube A6-FLV (looking aft)

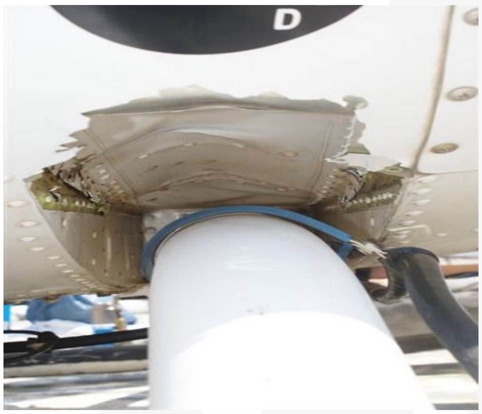	
Photo 3. Damage to Fuselage Skin Panels and Aft Crosstube Tunnel Skin Panels (detail).	**Photo 4. Damage to Fuselage Skin Panels and Aft Crosstube Tunnel Skin Panels.**

Photo 5. Fracture surface exhibited beach marks / striations originating from the surface of the inner radius of the bend.

1.4 OTHER DAMAGE

There was no other damage.

1.5 PERSONNEL INFORMATION

The Commander:

Date of birth	May 06, 1967
Class & Validity of medical	Class: One Valid until 31 May 2011
Total all flying hours	8300.00
Total flying hours on B412	1450.00
Total last 28 days	45.00
Line & Proficiency check	Line Check valid till - Dec 2011 Proficiency Check valid till (OPC)– Sept 30 2011
English Language Proficiency	Level 4

Table 2. Commander Flying Experience as of 16 March 2011

First Officer

Date of birth	November 23 1956
Class & Validity of medical	Class: One Valid until September 30, 2011
Total all flying hours	9458:05
Total flying hours on B412	3100
Total last 28 days	43:05
Line & Proficiency check	Line Check valid till - March 30 2012 Proficiency Check valid till (OPC)– Feb 23 2012
English Language Proficiency	Level 6

Table 3. First Officer Flying Experience as of March 16 2011.

1.6 AIRCRAFT INFORMATION

1.6.1 Aircraft General Information

Bell Helicopter is an American rotorcraft manufacturer headquartered in Hurst, Texas, near Fort Worth. A division of Textron, Bell manufactures military helicopter and tiltrotor products in and around Fort Worth, as well as in Amarillo, Texas. The commercial rotorcraft products are manufactured in Mirabel, Quebec, Canada. The Type Certificate Details[3] are the following:

Type Certificate	:	H4SW
Issued by	:	Federal Aviation Administration
Manufacturer	:	Bell Helicopter Textron (212 s/n 35001 and 412 s/n 36001 on)
Model(s)	:	212, 412, 412EP
Engine	:	PT6T-3, -3B Twin Power Section (Model 212)
		PT6T-3B, -3BE, -3D, -3BF or -3BG (Model 412)
		PT6T-3D, -3DE or -3DF (Model 412EP)
MCTOW	:	11,200 lb. (212)
		11,600 lb. (412 s/n 33001 thru 33107)
		11,900 lb. (412/412EP s/n 33108 thru 33213, and 36001 and on)
Noise Standard	:	Not Applicable (212)
		FAR 36, Subpart H dated Feb 5, 1988, Amend 36-14 (412/412EP)

In accordance with the FAA Production Certificate[4] to Bell Helicopter Textron, INC. amended September 29, 2011, the Type Certificate of the 412EP is H4SW[5], as per

[3] FAA TCDS No H4SW, revision 27 dated January 4, 2006.
[4] FAA Production Certificate No 100 dated July 2, 1960.
[5] FAA Production Certificate No 100 dated July 2, 1960, page 3 of 4 [FAA FORM 8120-3 (7-67)] Initial production date authorized July 5, 1995

License Agreement between Bell Helicopter Textron Incorporated (BHTI) and Bell Helicopter Textron Canada (BHTC) dated December 2, 1996.

1.6.2 Aircraft General Information

The Bell 412EP is a medium sized, twin turbine powered, helicopter, powered by the Pratt and Whitney PT6T-3DF Twin-Pac gas turbine engine, a crew of two pilots and can carry 13 passengers. It has a maximum speed of 140Kts and a range of 290nm (see below table 4).

Make and model (as shown in the CoA)	Bell 412EP
MSN	36514
Max. TO/LDG Mass	11,900lbs / 11,900lbs
Last C of A inspection	12 August 2010
C of A Category	Transport (Passenger)
Aircraft Station License	AMO/190/06
Insurance Validity Period	16 November 2011
Last CMR Date / Next Due CMR	09 March 2011 / 08 July 2011
TTSN	2003.25 Hours
Total Landings	12598
Cross tube assembly Serial number	LT-09-002581

Table 4. General information A6-FLV.

The aircraft was manufactured in Canada and all of the operator’s Bell 412EP helicopters are equipped with a High Cross Tube Undercarriage which is required to enable the installation of a skid mounted Emergency Floatation System with automatically deployable life raft. This installation is approved by Transport Canada (Supplemental Type Certificate (STC) SH01-9), EASA (STC IM.R.S.01304) and the FAA (STC SR01298NY).The same Operator experienced another crosstube failure (D412-664-203), on another Bell 412, registration A6-FLZ, 12 days after the first crosstube failure, which is under the investigation of the GCAA.

1.7 METEOROLOGICAL INFORMATION

Table 5 shows the METAR Report at the time of the Incident.

METAR Report	
Wind:	320°/24kts
Weather	CAVOK
OAT	25 °C

Table 5. Meteorological Information

There were no significant meteorological conditions in the area at the time of the Incident.

The following were the METARs from Abu Dhabi International Airport, before and after the event:

SA 11/03/2011 08:00-> METAR OMAA 110800Z 17012KT 8000 NSC 34/06 Q1014 A2994 NOSIG=

SA 11/03/2011 07:00-> METAR OMAA 110700Z 16013KT 140V230 7000 NSC 32/06 Q1014 A2995 NOSIG=

SA 11/03/2011 06:00-> METAR OMAA 110600Z 16013KT 5000 DU NSC 29/07 Q1015 TEMPO 3000 RMK A2997=

In addition, there were neither short TAF nor large TAF reports for Abu Dhabi International Airport.

1.8 AIDS TO NAVIGATION

No navigation aids were used during the time of the occurrence.

1.9 COMMUNICATIONS

The communication with the appropriate Air Traffic Control units was normal, without any problems.

1.10 AERODROME INFORMATION

No information was made available to the investigation as to the condition of the Wellhead Tower PC03 helideck at the time of the incident.

1.11 FLIGHT RECORDERS

The aircraft was equipped with recorders as per the GCAA regulations. Flight data was not recovered.

1.12 WRECKAGE AND IMPACT INFORMATION

The aircraft was intact with the exception of the fractured undercarriage aft crosstube and minor fuselage skin panel damage. The helideck of Wellhead Tower PC03 sustained no damage as a result of the Incident.

1.13 MEDICAL AND PATHOLOGICAL INFORMATION

The toxicology testing that was performed on the collected samples of the PIC did not reveal significant psychoactive substances that might have affected his performance. No other medical or pathological related information was provided to the Investigation.

1.14 FIRE

There was no evidence of fire in flight or after the crosstube fracture.

1.15 SURVIVAL ASPECTS

There was no failure of seats or seat belts and after the crosstube fracture, all persons onboard vacated the helicopter without any difficulty.

1.16 TESTS AND RESEARCH

1.16.1 A6-FLV Aft Crosstube Failure tests in the UAE

The failed undercarriage aft crosstube of A6-FLV was subjected to metallurgical examination in the United Arab Emirates[6]. Tests were carried out in order to verify the

crosstube material and to determine the nature of the failure mechanism. The following tests and evaluations were undertaken;

a) Material Identification
b) Visual Examination

1.16.1.1 Material Identification

Material identification of the crosstube was carried out using a Nitron X-Ray Alloy Analyzer (Model: XL3t) to confirm the crosstube material identification.

1.16.1.2 Visual Examination

The tube surface and the fracture surfaces of the cracks were visually examined under different magnifications up to 50X using an OLYMPUS binocular (Model: SZ-PT) for any pre-incident surface damage such as impact, scoring, deep scratches, Corrosion pitting etc.

Photographs were taken at locations of areas of interest in this evaluation. Fracture surfaces were studied in detail, especially the areas showing evidence of crack origin. Visual examination of a section on the fractured tube was also carried out after paint stripping stated in Para 2.2.2.4 below.

[6] Test was performed at the ADAT Metallurgical Laboratory, Abu Dhabi, UAE, April 2011(F- 1239).

1.16.2 A6-FLV Aft Crosstube Failure tests performed by the landing gear manufacturer

The landing gear manufacturer arranged for two independent laboratories to perform analysis on the failed crosstube with the following results:

1.16.2.1 Test performed on the 23rd of September 2011

As per the test report the test method used to test the fracture faces was visual and then and using stereomicroscope MII NO B05649. Following rinsing with alcohol in order to remove any contamination and/or dust, further damage was prevented. Multiple crack origins were detected, along with some impact damage at the crack area. The inspection revealed that the fatigue portion of the fracture surface was bright with semicircular beach marks. "*The fatigue portion of the fracture surface was examined using a Jeol JSM-5600 scanning electron microscope (SEM), MII NO B05028. The width of the fatigue fracture zone from initiation site to final fracture was measured to be 5.84 mm using the scanning electron microscope's micrometer.*

The width of the fatigue fracture zone was then divided into 10 equally sized zones from the middle of which striation counts were taken at magnifications up to 6000X.

Fatigue striations were counted over defined distances on each field where present and the striations spacing was then calculated for each field from which the number of stress cycles (striations) per field were calculated.

The numbers of fatigue striations for each of the 10 fields were added up, with the total being the estimated number of cycles to failure number of fatigue striations per field associated with this damaged region was assumed to be the same as for the field immediately adjacent to it.

The test results are presented in the Table below. Refer to Figures 3, 4 and 5 for representative images of the observed fatigue striations. In many areas the fatigue striations were poorly defined with superimposed finer parallel features. These were presumed to be slip lines due to slip along the crystallographic planes at the crack front when the crack was propagating and were ignored in the evaluation. Slip lines can be difficult to distinguish from fatigue striations. after crack initiation. It should be noted that the fracture surface in the vicinity of the crack origin was heavily oxidized, obscuring the fatigue striations at this location.

The number of fatigue striations per field associated with this damaged region was assumed to be the same as for the field immediately adjacent to it. The test results are *presented in the Table below. In many areas the fatigue striations were poorly defined with superimposed finer parallel features.*

These were presumed to be slip lines due to slip along the crystallographic planes at the crack front when the crack was propagating and were ignored in the evaluation. Slip lines can be difficult to distinguish from fatigue striations."

Distance from crack origin (mm)	Location	Striation Spacing (microns)	Field Size (mm)	Estimated Number of Striations per Field
0	Crack origin	-	-	-
0.29	Field 1	0.63[7]	0.584	927
0.88	Field 2	0.63	0.584	927
1.46	Field 3	0.91	0.584	642
2.04	Field 4	1.16	0.584	503
2.63	Field 5	1.11	0.584	526
3.21	Field 6	1.20	0.584	487
3.80	Field 7	1.18	0.584	495
4.38	Field 8	1.41	0.584	414
4.96	Field 9	1.75	0.584	334
5.55	Field 10	1.75		334
5.84	final fracture zone to fatigue zone interface	-	-	-
	Total Load Cycles Based on Measured Striations	-	total width of fatigue fracture zone: 5.84 mm	5, 589 Estimated Total Striations

Table 6. Total Load Cycles Based on Measured Striation Spacings

[7] No well-defined striations observed due to oxidation damage. Striation spacing assumed the same as for Field 2.

The report indicates that although various factors may affect the measured striation spacing, one of which, is the abrasion damage, during the occurrence failure that might obscure the finer fracture surface detail.

Furthermore the method used cannot account for the number of load cycles prior to crack initiation.

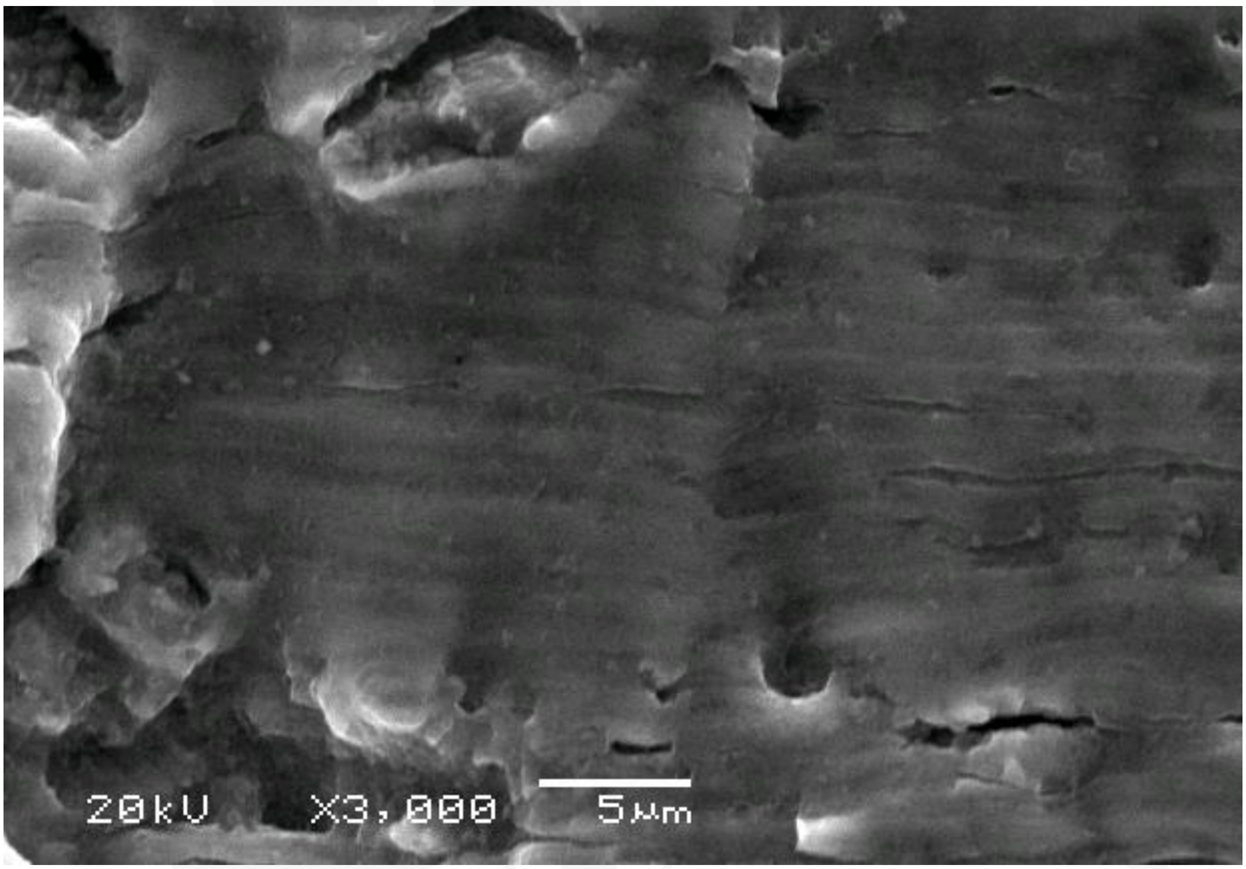

Image 1 Showing fatigue striations (parallel features) at the middle of the fatigue fracture zone.

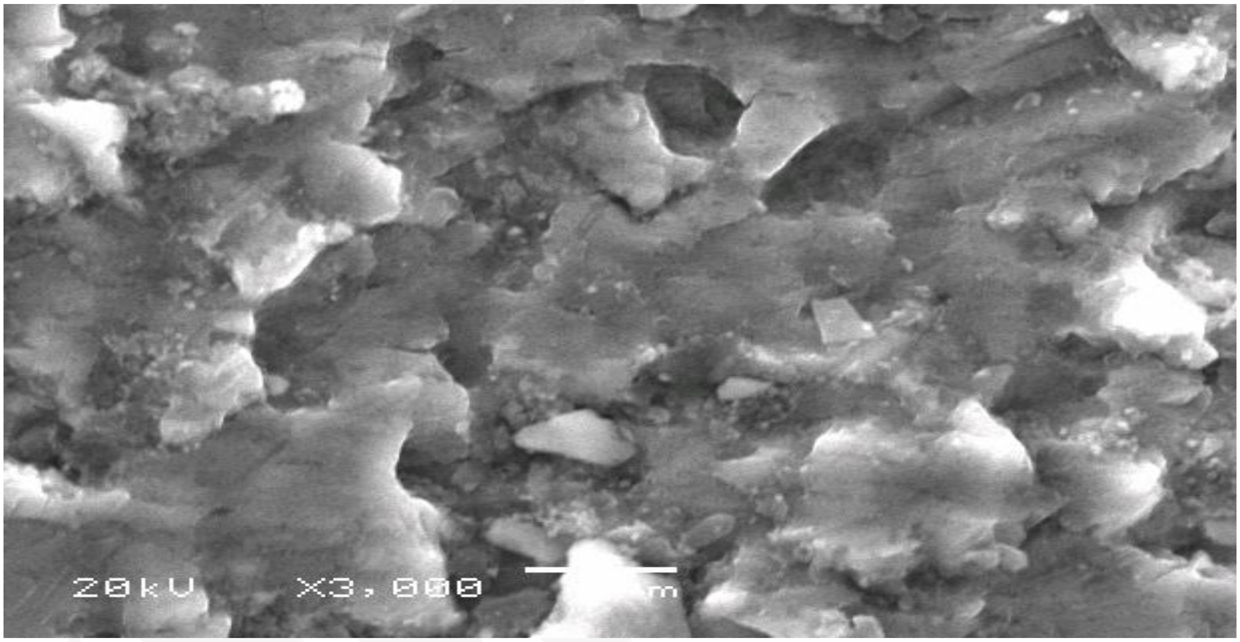

Image 2 Showing faint fatigue striations (parallel features) of a field near the crack origin.

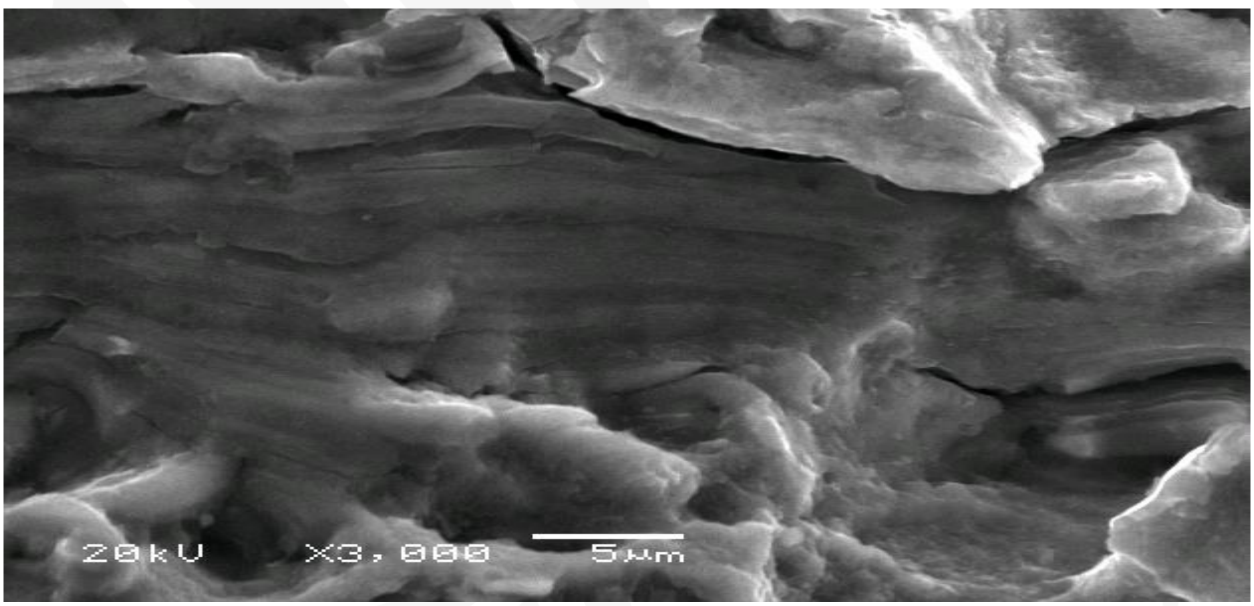

Image 3 Showing fatigue striations (parallel features) adjacent to the final fracture zone.

1.16.2.2 Second Test performed by the landing gear manufacturer [8]

Following the first test, the landing gear manufacturer accomplished an additional test, which was performed by another independent laboratory, which was employed to "*assess the fatigue crack growth quantitatively by employing striation counting*[9]".

The laboratory after performing a visual examination and measuring the section of the crosstube received , which was found to be approximately 90.4 mm (~3.56 inches) in diameter, 164 mm (~6.46 inch) in length (the longest portion) and had 16.4 mm (~0.65 inch) wall thickness. In addition it was mentioned that the observed beach marks suggested a fatigue crack initiation, which had colour differentiation with bright grey signifying the cracked benchmarks and the dull grey signifying the remaining area (see photo 5 and 6).

The laboratory indicated that the figure 2 "*shows the thumbnail area removed from the mating fracture surface. All the measurements were made on this sample. The thumbnail region was photographed under the stereo microscope and measurements were made on the picture. Image analysis measurements were verified prior making the measurements*".

In addition the section was further cleaned with alcohol in ultrasonic bath for approximately half an hour and replica rubber material was used to clean further the thumbnail, which was used to measure the striations. Thereafter the cleaned section was placed in a scanning electron microscope (SEM)[10] chamber, with a working distance height of 15mm and a tilt of 0°.

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[8] Report dated 04 Dec 2012, under project number 128-11-2984.
[9] Report dated 04 Dec 2012, under project number 128-11-2984 "*Introduction and Scale*".
[10] A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. From : http://en.wikipedia.org/wiki/Scanning_electron_microscope

The SEM is an instrument that produces a largely magnified image by using electrons instead of light to form an image. A beam of electrons is produced at the top of the microscope by an electron gun. The electron beam follows a vertical path through the microscope, which is held within a vacuum. The beam travels through electromagnetic fields and lenses, which focus the beam down toward the sample. Once the beam hits the sample, electrons and X-rays are ejected from the sample. From : http://www.purdue.edu/rem/rs/sem.htm

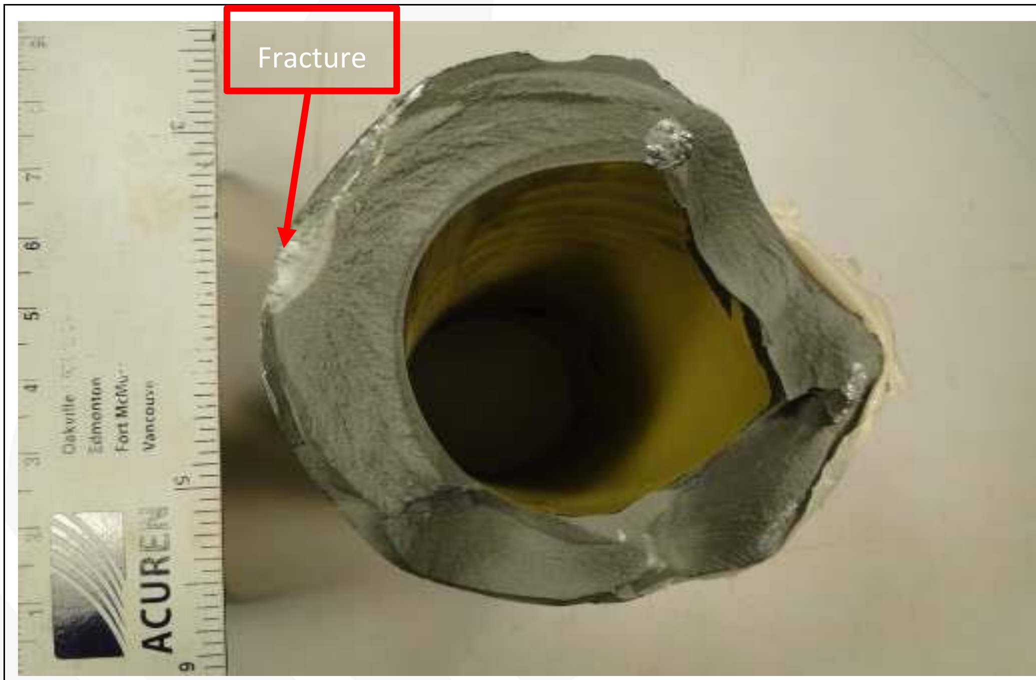

Photo 6. **Fractured surface**

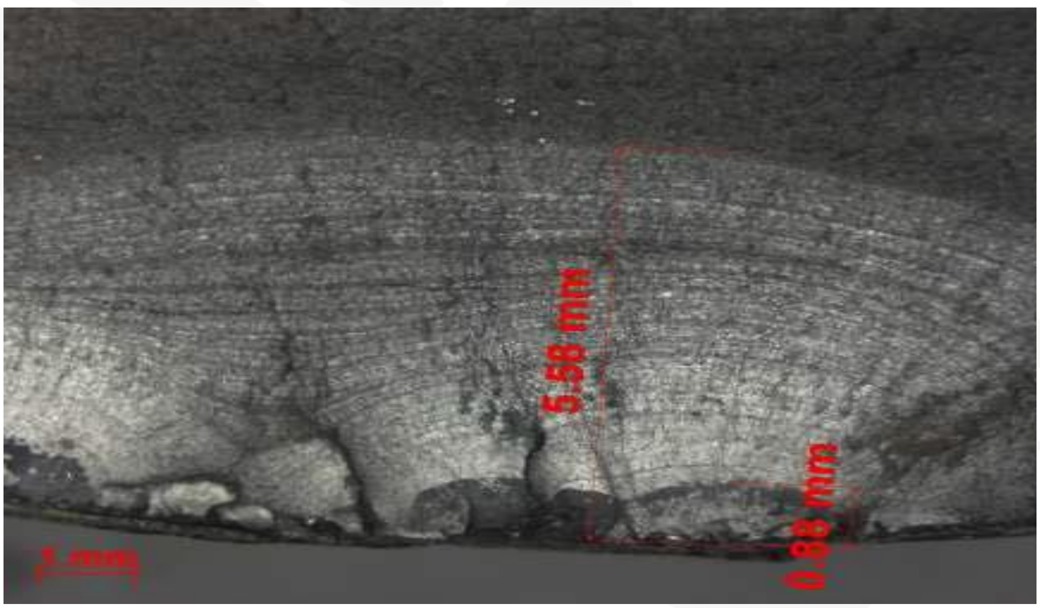

Figure 2 **Fatigue Cracked Area**

The report indicates that the "*acceleration voltage was 20 kV (10 kV and below the image did not appear good)*." The path measured in Figure 2 was divided into five approximately equal distances and pictures were taken after the initial 0.88 mm from the initiation point.

The striations observed were counted at a measured distance and tabled. The following table shows the distance from the crack origin to the area where striations counted and the average striation spacing in that area (see table 7). In addition the laboratory showed the striation spacing at each distance (see figure3) and calculated the total number of *striations over the 5.58 mm length counted to be approximately 8,314.*

Distance From Origin, mm	**Striation spacing, µm**
1.76	0.65677966
2.76	0.46610169
3.6	0.91101695
4.52	0.67796610
5.44	0.64406780
Average	0.67118644

Table 7 Striation spacing in different areas

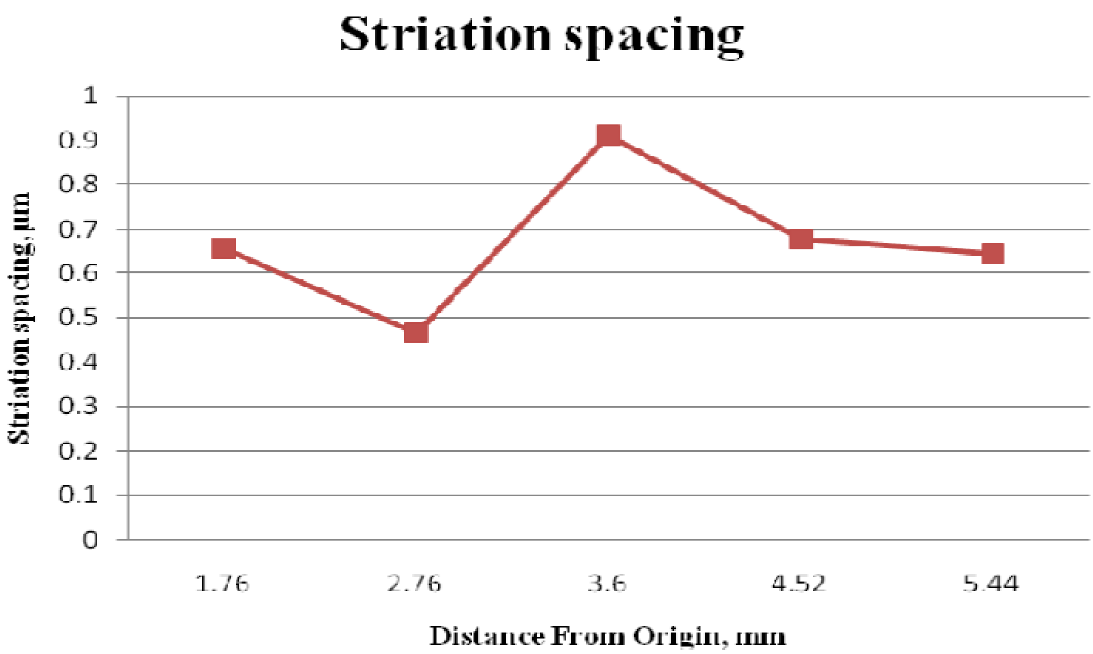

Figure 3 Variation in Striation spacing.

1.17 ORGANIZATIONAL AND MANAGEMENT INFORMATION

The operator is a charter airline and commenced operations in 2006 and is based in Abu Dhabi, Al Bateen Executive Airport, United Arab Emirates. The operator is certified for the carriage of passengers by the UAE General Civil Aviation Authority (GCAA) and operates a fleet of helicopters and business jets.

1.18 ADDITIONAL INFORMATION

1.18.1 Flight Crew Statements and Interviews

1.18.1.1 Statement of Captain

Following the Incident the Captain provided this statement;

At 11:18 am we took off from PS49 empty w/o passengers to PC03 to pick up 10 passengers to be moved to ACPT. We landed at PC03 normally. We rolled the throttles to idle waiting for the 10 passengers to board the aircraft, 9 passengers boarded the aircraft and the last passenger was outside the aircraft closing the tail boom door when suddenly the aircraft settled in the rear part of the fuselage with significant nose high attitude (10) degrees nose up and a loud noise indicating some abnormal condition had occurred. I opened the door and looked outside and noticed the helicopter was sat down on the bottom part of the fuselage. The aircraft was immediately shut down. The passengers evacuated from the aircraft and we called to operations communicating the incident.

We looked at the bottom of the helicopter and we found the cross rear landing gear tube was broken in half. The aircraft coming to rest on the RHS rear jacking point and the tail stinger on the safety barrier outer support tubing.

Note: During the morning flight, operation was smooth without any hard landing at all.

1.18.1.2 Statement of First Officer

The First Officer, who holds the rank of Captain, provided this statement;

The aircraft transited from PN49 empty (no pax or Frt) to Nth PC003 to pick up 10 pax and gear. Capt X was the flying pilot at the time. The aircraft was landed approx. 11:20 am in an uneventful fashion using minimal power (given lightweight and wind conditions at the time) and positioned in the center of the marked helideck prescribed markings. Fuel on board at the time was approx. 800lbs giving AUW of approx 9150-9200lbs on landing.

The throttles were wound back to ground idle to facilitate loading of 10 x pax plus equipment. The pax loaded the equipment and 9 of the pax got on board. The 10th pax was still down attending to the tail boom luggage hold when there was a noise and associated movement of the skids. The noise was certainly louder than the normal spreading of skids as occurs when additional weight is added to the helicopter but the downwards jolt and significant nose high attitude certainly grabbed ones attention quickly.

My very initial thought was that this is a big movement compared with “normal” skid spread as A/c are loaded. Then the unusually high nose up attitude grabbed my attention as being “definitely not normal”. I looked back at the cabin and the passengers and saw abnormally large eyes looking back at me and anxious looks and instinctive movement of the pax. The RHS cargo door was still open and I noted the cargo door sill and pax appeared to be sitting at an unusual nose high attitude and looked closer to the ground.

At the same time I was doing this, Capt X had opened his door to assess what was going on. I looked back out the front now beginning to think we have had a tail boom problem and that maybe we have had a tail rotor problem. At this point I said to Capt X “shut it down”, before it did possibly start to rotate. This was at the very same moment that Capt X began initiating the shut down.

The rotor brake was applied after <40% Nr and while Capt X looked after the throttles and rotor, I switched off the fuel switches and instructed the Pax to remain in the aircraft and seated until the rotors had come to a stop. Capt X also directed the Passenger still outside on the RHS to stay close to the aircraft and not go under the disc while it was being shut down.

All this would have been compacted within a period of 4-5 seconds. After/during latter stages of the aircraft being shutdown, Capt X called Zakum and advised them of our predicament. While he was doing this and as the rotor slowed, I hopped out to assess the situation to advise Capt X more precisely of the problem. I observed a somewhat more squat attitude with the aircraft decidedly lower toward the back end with the tail stinger resting on the outer support bar of the horizontal safety net. Luckily the tail rotor had not contacted any part of the well head structure. I initially thought that the aircraft lower fuselage was resting on the liferaft inflation bottles. The rear crosstube had obviously failed. I initially thought that it was the saddles joining the crosstubes to skids and told Capt X that the rear crosstube had failed.

As it turned out, the aircraft had come to rest with the tail stinger supporting the tail boom on the outer safety net support bar and the RHS rear jacking point tie down ring appeared wedged solid in the vertical position on the deck with the remainder of the rear fuselage weight being supported on the crushed remains of the crosstube.

The aircraft shutdown was completed and electrical power turned off after Zakum had been advised of the situation. We got the pax out of the aircraft after the rotor had stopped and confirmed that there were no injuries. We directed them to unload their equipment and vacate the helideck downstairs.

After I had another look from the front of the aircraft, it was then clear to see the very center or apex of the crosstube had failed with both halves of the crosstube pivoting around the rubber absorber mounts and the bend radius of each half crosstube inflicting panel damage on the fuselage in the crosstube tunnel area near the grounding receptacle on both sides of the aircraft.

1.18.2 The Landing gear manufacturer.

The landing gear manufacturer has manufactured 188 of the D412-664-203 high gear aft crosstube for the Bell 412. In 2007 a Gulf of Mexico Operator, utilizing crosstubes from two landing gear manufacturers, experienced failures, which occurred on an offshore configured Bell 412EP's, which was considered to be operating at a relative high gross weight in the offshore environment. In addition, the helicopters due to their specific operating conditions they were subjected to higher than normal landings. Following the landing gear failure, in the Gulf of Mexico, the manufacturer performed an investigation, which determined that the operating environment was severe and maintenance practices were questionable. Per SB07-1, the inspection criteria was clarified and operators were reminded to use the gross weight towing strap, replace worn out wearplates, and properly maintain landing surfaces. There were no changes in the engineering design and production as a result.

There have been additional failures of DAS D412-664-203 high aft crosstube for the Bell 412EP under similar operating conditions. Two other Operators encountered a failure at 10,495 landings and at 21,057 landing cycles.

Therefore, as summarized in Table below there have been 5 failures on D412-664-203 crosstubes.

Registration	D412-664-203 B/N	Failure Location	Landings at Failure	Striation Count
XA-UGA	B26675	Off Center	14127	Unavailable
VT-AZO	B25550	Center	21057	6200
unknown	B41153	Center	10495	6700
A6-FLV	LT-09-002581	Center	12598	5589/8314
A6-FLZ	LT-09-004674	Off-Center	11314	7238/6021

Table 8. Summary of all known crosstubes failures

All failures appear to be low cycle fatigue failures. This particular part is designed to yield in service to prevent higher loads from being transferred into the airframe and consequently operates under extremely high stress. Repeated landings at high weight and on slippery surfaces contributes to high stress in this part.

In March of 2011, failures, with the UAE based Operator were experienced. The landing gear manufacturer "*immediately began to investigate the failures. The fatigue analysis for the D412-664-203 aft crosstube was re-performed with a higher load spectrum and a retirement life of 10,000 landings was verified with a knockdown factor of 8, which is extremely conservative for a metal structure. Furthermore, a crack growth analysis was performed and it was demonstrated that the crosstube could withstand over 4000 cycles to failure after detection of a crack. As a result of this analysis, a retirement life of 10,000 landings was established for the D412-664-203 aft crosstube with a mandatory LPI at 7500 landings as outlined in SB11-2*".[11]

The landing gear manufacturer submitted the tubes to independent labs for striation counts, which came back with the count contained in table 8 above. Based on these high striation counts, the landing gear manufacturer indicated that "*is confident that if the crosstube is not found to be cracked after 7500 landings, it will be safe to continue operating for 2500 cycles until the crosstube is replaced at 10,000 landings.*

Since the introduction of these stringent airworthiness limits, no abnormalities or incidents have been reported. After consultation with Transport Canada, the content from SB11-2 was incorporated into ICAD212-664 at Rev. 7."[12]

Service Bulleting (SB) 11-2

SB 11-2 was issued by the landing gear manufacturer on the 25th April 2011 informing the operators that : "*Due to unexpected failures of 0412-664-203 high gear aft crosstubes at a low number of landing cycles, a life limit of 10000 landings has been established for all 0412-664-203 high gear aft crosstubes. Crosstubes that already exceed the life limit must be replaced immediately*".

In addition if all landing gears accumulated more than 7500 landing should be removed stripped of paint, and LPI inspected. In case crosstube found not be cracked it could have be refinished and re-installed.

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[11] Failure Analysis report dated 22 February 2012 (FA-D412-664-1) page 4.
[12] Failure Analysis report dated 22 February 2012 (FA-D412-664-1) page 5.

1.18.3 Previously Reported Bell 412EP Undercarriage Aft Crosstube Failures

The Investigation Team reviewed two incidents of failure of the same manufactured aft cross tube have been reported prior to the occurrence involving A6-FLV, which are discussed in more detail below; additionally during the investigation of the A6-FLV event, the same Operator experienced another crosstube failure, registration A6-FLZ, which is under the investigation of the GCAA .

1.18.3.1. Failure of Undercarriage Aft Cross Tube of Aircraft XA-UGA

In the case of aircraft XA-UGA the aft crosstube failed at three locations; RBL 30, RBL 10 and LBL 30. The site of the primary failure location is unknown. Examination of the fracture surfaces showed evidence of thumbnail-shaped regions of flat transverse fracture i.e. beach marks, at the fracture origins. This aircraft operated in the Gulf of Mexico transporting passengers to and from oil rigs. No injuries resulted from the incident.

The investigation found that the operator was not using the gross weight towing strap and that the wear plates were badly worn. In addition, the landing surface was slippy. Resulting from this incident the manufacturer published Service Bulletin 07-1.

1.18.3.2. Failure of Undercarriage Aft Cross Tube of Aircraft VT-AZO

A second Bell 412EP, VT-AZO, carrying out operations related to the off-shore oil industry in India, suffered an undercarriage aft cross tube failure.

The undercarriage aft cross tube failed near the centre support. There was evidence of 0.8 cm deep thumbnail shaped beach marks at the fracture site. The aircraft had just landed at Tapti Oil Rig when the cross tube failed. No injuries occurred either to passengers or crew as a result of this incident.

The investigation report produced by the Indian DGAC recommended that more thorough visual inspection of the cross tube was required during maintenance. The manufacturer published Service Bulletin 10-1.

1.18.3.3 Further Cross Tube failures

Three further reports of undercarriage aft cross tube failures have been reported involving cross tubes manufactured by a different supplier. In these cases, the failures occurred at 10723, 11894 and 15336 landings.

1.18.4 Transport Canada Airworthiness Directive number CF-2012-14R1

Transport Canada issued an Airworthiness Directive under the title "*Crosstubes – Life Limitation*" with an effective date 22nd of May 2012 which established the life limitation of 10,000 landings.

1.19 USEFUL OR EFFECTIVE INVESTIGATION TECHNIQUES

There were neither useful nor effective investigation techniques used during the investigation.

2. ANALYSIS

2.1 GENERAL

No previous similar failure of the undercarriage aft cross tube had occurred in the operators' experience, although two prior similar failures had been reported involving other operators.

All of the operator's Bell 412EP helicopters are equipped with a High Cross Tube Undercarriage which is required to enable the installation of a skid mounted Emergency Floatation System with automatically deployable life raft. This installation is approved by Transport Canada (Supplemental Type Certificate (STC) SH01-9), EASA (STC IM.R.S.01304) and the FAA (STC SR01298NY).

The Captain was Pilot Flying [PF] and the First Officer was the Pilot Monitoring [PM]. The Captain's report stated that the aircraft took off from PS49 at 1118 local time without passengers and flew to Wellhead Tower Helideck PC03 of the Zakum field to pick up 10 passengers who were to be flown to the Accommodation Platform, uneventful, which is confirmed by all other information sources.

A6-FLV landed normally on the helideck of Wellhead Tower Helideck PC03 and the throttles were selected to ground idle. The passengers commenced boarding. After nine passengers had boarded the aircraft, and while the final passenger was still outside the aircraft closing the tail boom door, the aircraft suddenly settled towards the aft and adopted a significant nose high attitude of approximately 10 degrees. In addition, the crew heard a loud noise indicating that an abnormal condition had occurred. The Captain opened the door and looked outside to try to determine what had occurred. He noticed that the helicopter aft fuselage was in close proximity to the helideck surface. The crew immediately shut down the engines and the passengers and crew safely disembarked the aircraft. There was no other prior indication of failure and the crew was unaware of any other malfunctions or prior indications that could lead them to suspect the failure that they experienced. In addition the engineering and maintenance records did not indicate nor included any maintenance action that could lead to any kind of suspicious activity. Therefore, no indication of the imminent failure was given to the crew or to the maintenance personnel involved in the dispatch of the helicopter.

Later, the crew inspected the lower aft fuselage of the helicopter and they noted that the undercarriage aft crosstube was sheared. The aircraft came to rest on the right hand side (RHS) aft jacking point and the tail stinger on the helideck safety barrier outer support tubing. The sheared aft crosstube sections pivoted about the cross tube mounting points and contacted the fuselage skin, resulting in damage to skin panels near the aft cross tube tunnel.

It is therefore evident that both crewmembers and the maintenance personnel had no earlier indication of the coming fracture and had no possibility of knowing the potential landing gear failure. In addition the Operator followed the manufacturer’s and GCAA’s maintenance instructions and had no prior indication of the failure.

2.2 Pilot and maintenance reports for previous flights.

Both pilots reported that the landing on Wellhead Tower Helideck PC03 was normal. Nothing unusual, such as a hard landing, was reported during the flights immediately prior to the Incident flight, nor was any previous maintenance issue recorded that indicated any potential problem involving the undercarriage. However all other helicopter operators utilizing this landing gear should be aware of this landing gear’s issues and of the tests performed in order to approach the solution to the problem. That is why the GCAA should ensure that all helicopter operators in the UAE are aware of this investigation report, so they may make to appropriate decisions.

2.3 Analysis of previous undercarriage crosstube failures.

The undercarriage crosstube is designed to yield in service to prevent higher loads from being transferred into the airframe and consequently operates under extremely high stress. Repeated landings at high weight and on slippery surfaces contribute to high stress in the crosstube.

There have been three reported failures of the D412-664-203 aft crosstube at 14127, 21057 and 12598 landings. These failures have occurred to aircraft performing landings at high weights on platforms at extremely high frequency.

2.2.3 Material Identification

The material analysis of the crosstube identified it to be manufactured from Aluminium Alloy 7075 T6 of standard composition.

Also the hardness values observed were uniform across the inner and outer radius of the cross tube bend areas.

2.4 Tests / Examination

No external damage, scoring or impacts were noticed on the tube surface. Fractured surfaces exhibited beach marks / striations originating from the inner radius surface of the bend.

Fracture surfaces revealed two distinct regions of failure mode. A thumbnail region of fatigue beach marks/striations and a region of fast fracture. The Investigation team performed test in the UAE that could provide the possibility of revealing the cracks while the landing gear tube was still attached to the aircraft, therefore without removing it from its position. In addition, the Investigation Team's effort, both with paint and without paint, within its capabilities, was to reveal an inspection method that could provide the assurance of an inspection method used in the field with the ability to detect presence of cracks beneath the paint layer. The Investigation Team's effort was undertaken in order to provide solid evidence of a method that could be used in the field of operations without highly specialized personnel, equipment and recourses. However as revealed the Team's efforts, within its capabilities, as described in the relevant section, could not provide guidance for such a method. Therefore, more efforts have to be undertaken by the aircraft and landing gear manufacturer, in order to verify that such a method exists and then ensure that it could be used easily in the field. Nevertheless, the AD issued limiting the lifetime of the landing gear has currently solved the landing gear failures.

However, the aviation industry always benefit from better methods applied. In any case the aircraft, landing gear and component manufacturer could review the possibility of investing resources potential manufacturers should ensure that specified maintenance inspections, intended to detect material fatigue, are practical and effective.

During the course of this investigation the Investigation Team was informed by the landing gear manufacturer was working on the design of an improved aft crosstube; however the investigation team did not receive any information on the issue.

3. CONCLUSIONS

3.1 GENERAL

From the evidence available, the following Findings, Causes and Contributing Factors were made with respect to this Serious Incident. These shall not be read as apportioning blame or liability to any particular organisation or individual.

To serve the objective of this Investigation, the following sections are listed under the "Conclusions" heading:

- **Findings-** statements of all significant conditions, events or circumstances in the sequence of this Accident. The findings are significant steps in this Accident sequence, but they are not always causal or indicate deficiencies.
- **Causes-** actions, omissions, events, conditions, or a combination thereof, which led to this accident.
- **Contributing Factors-** actions, omissions, events, conditions, or a combination thereof, which, directly contributed to this Accident and if eliminated or avoided, would have reduced the probability of this Accident occurring, or mitigated the severity of its consequences.

3.2 FINDINGS

3.2.1 The aircraft was certified, equipped, airworthy and maintained in accordance with existing regulations and approved procedures.

3.2.2 The Flight Crew were properly licensed, medically fit and qualified for the flight and adequately rested in accordance with existing regulations.

3.2.3 The flight crew/pilot/co-pilot was in compliance with the flight and duty time regulations.

3.2.4 The pilots actions and statements indicated that their knowledge and understanding of the aircraft systems was adequate.

3.2.5 The Flight Crew first became aware of a problem when they heard a loud noise as the final passengers boarded and the aircraft suddenly adopted a nose up attitude.

3.2.6 Nothing unusual was reported during the flights immediately prior to the incident, nor was any previous maintenance issue recorded, that indicated any potential problem involving the undercarriage.

3.2.7 The operator complied with the undercarriage manufacturer's STC ICA and other periodic visual inspections.

3.2.8 Prior to the incident the undercarriage aft cross tube Part Number D412-664-203 did not have an assigned airworthiness life limit.

3.2.9 No pre-existing damage (stress riser) was detected by detailed metallurgical examination of the failed cross tube.

3.3 PROBABLE CAUSE

The fracture of the undercarriage aft cross tube was caused by a fatigue failure resulting from repeated stress due to cyclic loading of the crosstube.

3.3.1 Contributing Factors

Existing fatigue cracking of the cross tube was not discovered, prior to failure, by the specified visual inspection as the cracks were hidden underneath the layer of paint on the surface of the undercarriage aft crosstube.

4. SAFETY RECOMMENDATIONS

4.1 FINAL REPORT SAFETY RECOMMENDATIONS

This investigation report does not contain any Safety Recommendations. Normally this section of reports list are proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation, and are based on the Findings listed in Section 3 of this Report. The GCAA expects that all safety issues identified by the Investigation in the Findings are addressed by the appropriate States and organizations.

4.2 Safety Actions already taken

Below is a summary of the safety actions taken by the landing gear manufacturer, the Transport Canada Civil Aviation, the Federal Aviation Administration and the aircraft Operator, because of this occurrence.

4.2.1 The Landing Gear Manufacturer

I. The fatigue analysis that was performed on the D412-664-203 crosstube was revised.

II. A life limit of 10,000 landings and added an LPI after 7500 landings was established.

III. This information was released to the customer base via Service Bulletin SB 11-2

IV. A revision to the ICA followed to include the life limit and the LPI inspection

V. Coordination was performed so TCCA to issue an Airworthiness Directive

VI. During the draft final report comments period the Team was informed via the Accredited Representative of Canada[13] that the landing gear manufacturer following research and development "*received a TCCA approval for the improved 412 aft Crosstube which is manufactured from a more fatigue resistant material.*"

4.2.2 Transport Canada Civil Aviation

Transport Canada issued an Airworthiness Directive for the crosstube (AD-CF-2012-14R1).

4.2.3 Federal Aviation Administration

The USA Federal Aviation Administration issued an Airworthiness Directive for the crosstube (Docket No. FAA-2013-0145; Directorate Identifier 2012-SW-059-AD; Amendment 39-17554; AD 2013-16-16), which adds a life limit of 10,000 landings to the crosstube and removes from service any crosstubes with more than 10,000 accumulated landings.

4.2.4 The Aircraft Operator

Following the two events the Operator proactively imposed a 2500 landings LPI, which was significantly lower that the manufacturer's 7500 landing LPI limit. The 10,000 landings life limits remained.

END

[13] Electronic communication dated 23 May 2014.