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FINAL INVESTIGATION REPORT OF ACCIDENT TO M/S PHL DAUPHIN SA 365 N3 HELICOPTER VT-PWA AT BOMBAY HIGH ON 13th JANUARY 2018

AIRCRAFT ACCIDENT INVESTIGATION BUREAU
MINISTRY OF CIVIL AVIATION
GOVERNMENT OF INDIA

FOREWORD

This document has been prepared based upon the evidences collected during the investigation and opinion obtained from the experts. The investigation has been carried out in accordance with Annex 13 to the convention on International Civil Aviation and under Rule 11 of Aircraft (Investigation of Accidents and Incidents), Rules 2017 of India. The investigation is conducted not to apportion blame or to assess individual or collective responsibility. The sole objective is to draw lessons from this accident which may help in preventing such accidents in future.

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ABBREVIATIONS

AFCS	Automatic Flight Control System
AH	Airbus Helicopter
AIP	Aeronautical Information Publication
AIS	Automatic Identification System
AP	Auto Pilot
ATC	Air Traffic Control
BA	Breath Analyzer
BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile, France
CAM	Continuing Airworthiness Manager
CAR	Civil Aviation Requirements
CHPL	Commercial Helicopter Pilot License
CMD	Chairman & Managing Director
CRM	Crew Resource Management
CSMU	Crash Survivable Memory Unit
CVFDR	Cockpit Voice/Flight Data Recorder
DECU	Digital Electronic Control Unit
DGM	Deputy General Manager
ERP	Emergency Response Plan
FDR	Flight Data Recorder
FOQA	Flight Operations Quality Assurance
HDG	Heading
HPT	High Pressure Turbine
IAS	Indicated Air Speed
IIC	Investigation in Charge
METAR	Metrological Aerodrome Report
MFD	Multifunction Display
MGB	Main Gear Box
MSM	Master Service Manual
NAL	National Aerospace Laboratories
NDB	Non Directional Beacon
NSOP	Non Schedule Operator
ONGC	Oil and Natural Gas Commission

PF	Pilot Flying
PFD	Primary Flight Display
PM	Pilot Monitoring
PT	Power Turbine
RFM	Request for Manifest
ROC	Rate of Climb
ROD	Rate of Descent
SAP	System Application Products
SB	Service Bulletin
SOP	Standard Operating Procedure
UTC	Universal Time Coordinated
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	VHF Omni Directional Range

INVESTIGATION REPORT OF ACCIDENT TO M/S PHL DAUPHIN SA 365 N3 HELICOPTER VT-PWA ON 13 JANUARY 2018 AT BOMBAY HIGH

1.	Aircraft Type	Dauphin SA 365 N3
2.	Nationality	INDIAN
3.	Registration	VT - PWA
4.	Owner	Pawan Hans Ltd.
5.	Operator	Pawan Hans Ltd.
6.	Pilot – in –Command	CHPL Holder
7.	Extent of Injuries	Fatal
8.	Co-Pilot	CHPL Holder
9.	Extent of Injuries	Fatal
10.	Place of accident	Bombay High
11.	Last point of Departure	Juhu
12.	Intended place of Landing	NQO Platform (ONGC)
13.	Date of accident	13.01.2018
14.	Passengers on Board	05
15.	Extent of Injuries	Fatal
16.	Phase of Operation	Cruise
17.	Type of Accident	Loss of Control + Disorientation

1.1 HISTORY OF FLIGHT

Dauphin N3 helicopter was involved in an accident on 13.01.2018, while operating a sortie for Oil and Natural Gas Commission (ONGC). This was the first sortie of the day for the crew. The flight was from Juhu to NQO installation under the command of a CHPL holder with another CHPL holder as Co-Pilot. There were a total 07 persons on board including 02 flight crew members. As per the passenger manifest provided by ONGC, the total weight of 05 passengers was 357 kgs (actual) and Cargo + baggage weight of 93 kgs. All the 07 persons on board received fatal injuries and helicopter was destroyed during the accident.

A flight plan was filed with ATC Juhu indicating planned takeoff time of 0330 UTC. The helicopter was parked at ONGC dispersal and had requested for startup which was approved by ATC. Visibility of 3000 meters was passed on to the flight crew. The flight crew then requested for special VFR operation which was also approved. The flight crew was asked to revise expected time of departure. Departure time was revised to 0445 UTC.

Departure instructions were passed to helicopter clearing it for destination NQO on radial 289 via K017 and at an altitude of 3000 ft. The departure instructions were repeated by the helicopter. The helicopter took off at 0443 UTC. At around 0454 UTC, the helicopter changed over from Juhu frequency (124.35) to Mumbai off shore frequency (118.2). Later, near reporting point "P", the contact with the helicopter was lost.

As the helicopter was to report at point 'P' at 0504 UTC and there was no call from the helicopter till 0508 UTC, the Platform B193 (Next Radio Station) called the helicopter but there was no response. Thereafter, repeated calls were given but there was no response. The last position reported was 19º24.9723 N / 072º26.575 E. The helibase/ Platform requested the Pilot in Command of another helicopter flying in the area to call the accident helicopter. There was no response from the accident helicopter even to the call made by another helicopter. At 0522 UTC, helibase requested another helicopter to look for the accident helicopter in the area.

ONGC alerted the operations desk at 0510 UTC and initiated the Emergency Response Plan (ERP) by coordinating with Maritime Rescue Coordination Centre (MRCC) and Coast Guard for necessary Search and Rescue Operation. On the day of accident itself, the wreckage was sighted and rescue operation started. It was unfortunate that there were no survivors. All bodies were recovered and wreckage also taken out from the sea.

1.2 INJURIES TO PERSONS

INJURIES	CREW	PASSENGERS	OTHERS
FATAL	02	05	Nil
SERIOUS	Nil	Nil	Nil
MINOR / NONE	Nil	Nil	Nil

1.3 DAMAGE TO AIRCRAFT

The helicopter was cruising at a flight level of little above 3000 ft from where it plunged into the sea. The helicopter was destroyed as a result of the impact with water. Most of the wreckage was recovered from the sea. Scattered wreckage parts were found within 80 m on the sea floor. Some pieces were recovered as these were floating.

In addition to IIC and Indian investigator, the BEA (France) investigators, Safran Helicopter Engine Technical Advisors & Airbus Helicopter Technical Advisors also participated in the wreckage examination. The damage to the systems components (hydraulic, electrical generation, etc.…) was severe and has been covered in detail under “**wreckage and impact information**”.

1.4 OTHER DAMAGE

Nil

1.5 PERSONNEL INFORMATION

1.5.1 PILOT – IN – COMMAND

Age	57 years
License	CHPL holder
Date of Issue	14.02.1989
Valid up to	12.07.2021
Class	Single/Multi Engine
Category	Helicopter
Endorsements as PIC	Dauphin N & N3
Med. Exam valid upto	17.12.2018
FRTO License.	Valid
Total flying experience	13420 hours approx
Experience on Type as PIC	8729 hours approx
Total flying experience during last 180 days	198:59 hours
Total flying experience during last 90 days	128:13 hours
Total flying experience during last 30 days	19:25 hours
Total flying experience during last 07 Days	08:40 hours
Total flying experience during last 24 Hours	03:42 hours
Rest Before Duty	14:10 hours

The PIC was off flying for the following period

From - To	**Period**
February 2015 to May 2015	04 months
November 2015 to March 2016	05 months
July 2016 to November 2016	05 months
April 2017	01 month
August 2017	01 Month
December 2017	01 Month

The Pilot Flying (PF) had frequent breaks while flying with the operator. As per the operator records, these breaks were on medical grounds and personal reasons. He had earlier flown with the organization and left in between to join a private company where he had flown "On Shore". He was acting as PM while flying a helicopter which was involved in an accident earlier.

1.5.2 CO-PILOT

AGE	53 years
License	CHPL holder
Date of Issue	23.05.2014
Valid up to	22.05.2019
Class	Multi Engine
Category	Helicopter
Date of Med. Exam.	17.05.2017
Med. Exam valid upto	16.05.2018
FRTO License	Valid
Total flying experience	6850hours approx
Total flying experience on type	4360 hours approx
Total flying experience on type as PIC	2144 hours approx
Total flying experience during last 180 days	256:58 hours
Total flying experience during last 90 days	126:31 hours
Total flying experience during last 30 days	60:02 hours
Total flying experience during last 07 Days	19:40 hours
Total flying experience during last 24 Hours	03:42 hours
Rest before duty	14:10 hours

1.6 AIRCRAFT INFORMATION

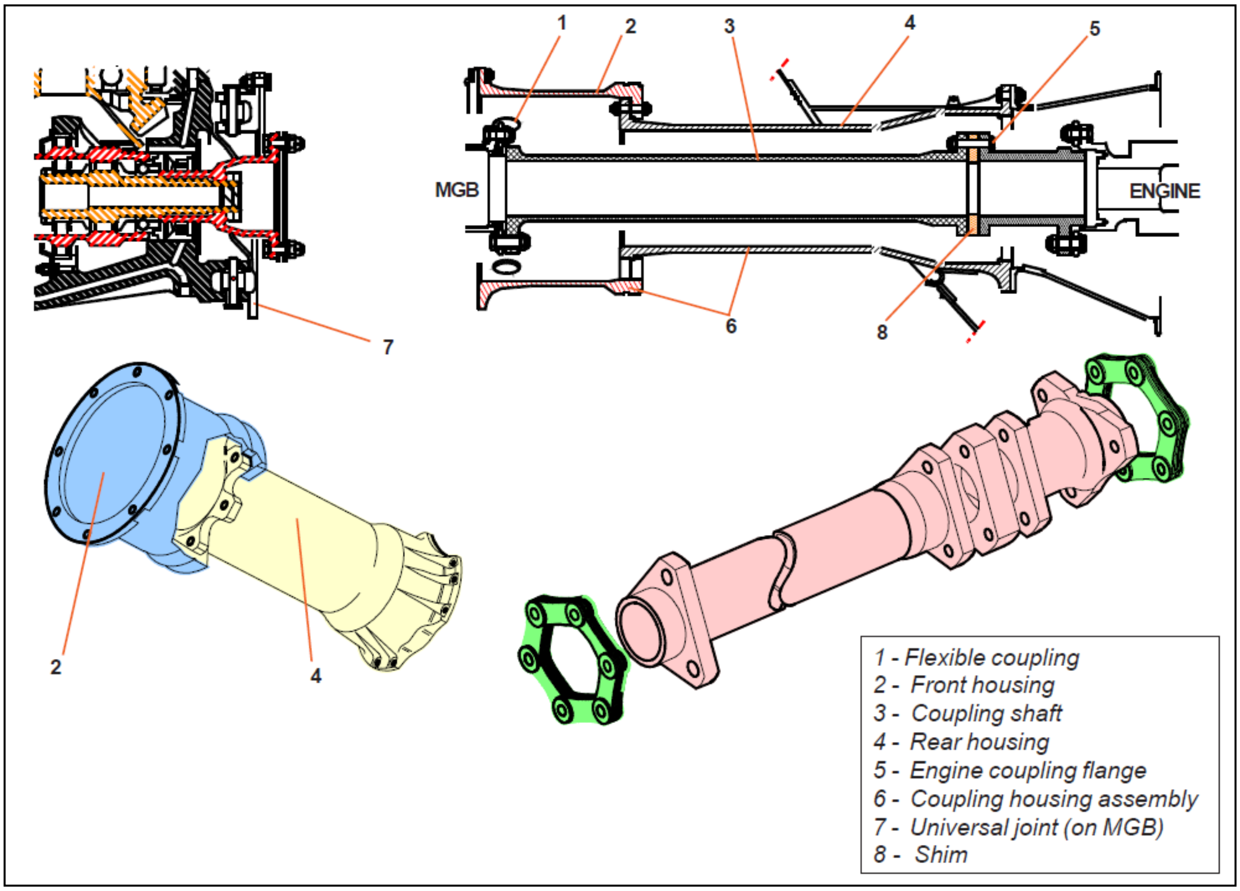
1.6.1 HELICOPTER

The involved Dauphin N3 was a twin-engine helicopter bearing serial number 6929. It was manufactured by Eurocopter, France in the year 2010 and was ONGC AS4 compliant. It was operated under Non-scheduled operator's Permit No. 02/1998 which was valid on the date of accident. The helicopter was fitted with all the equipment required for IFR and offshore flying as per DGCA requirements. The helicopter had undergone 600 hrs / 02-year inspection at Mumbai followed by a test flight. The inspection including test flights was completed on 06.01.2018. The accident flight was the first revenue flight after 600 hrs inspection.

The helicopter was accorded approval in Normal category under Passenger Sub-division. Certificate of Registration No. 4196, under Category – A was issued on 28.02.2011. The Certificate of Airworthiness Number 6305 was issued by DGCA on 23.03.2011 specifying minimum number of flight crew as two. Last Airworthiness Review Certificate was issued by the DGCA on 09.05.2017 at Mumbai. The maximum take-off weight was 4300 kgs. The helicopter and the engines were being maintained under continuous maintenance program consisting of calendar based and Flying Hours/ Cycles based maintenance. The helicopter was last weighed on 01.05.2017 at Mumbai. As per the approved weight schedule, the Empty weight was 2857.40 kgs. Empty weight CG was 4.142 meters aft of datum in off-shore configuration. As there had not been any major modification affecting weight & balance since last weighing, the weighing was valid up to 30.04.2022. Turn around inspections were carried out as per approved 'Turn Around Inspection schedules'. All the higher inspections including checks were carried out as per the manufacturer 's guidelines specified in — MSM (Master Servicing Manual).

Details of some of the relevant components/ attachments/ systems of Dauphin N3 type of helicopter are given below:-

(A) Engine to Main Gear Box Coupling

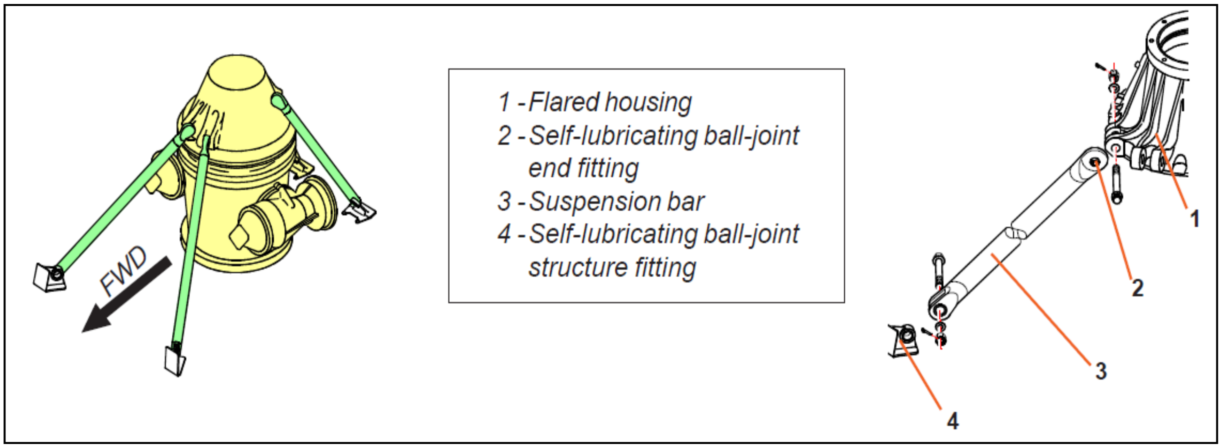


The "engines-to-main gearbox" coupling

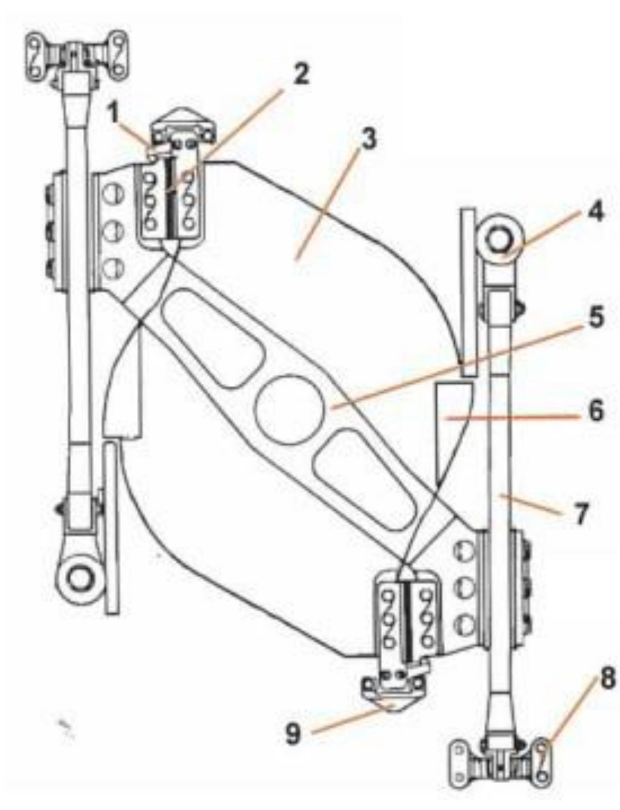
- transmits the engine torque to the main gearbox (coupling shaft - 3)
- supports the engines (Engine front attachments) and links them dynamically to the main gearbox (through coupling housing - 6).

(B) Main Gearbox Support

Four suspension bars, secured at one end to rotor shaft casing and at the other end to the structure absorb the lift forces and moments generated by the rotor.



(C) Suspension Components (MGB Support)



1- Negative torque safety device (prevents separation of elastomer material when tension stressed: Rotor braking or autorotation)

2- Laminated elastomer stop

3- MGB bottom

4- Fixed ball-joint end fiotting

5- Diagonal cross-member

6- Torque stop (secured to the bottom of MGB)

7- Roving bar (glass wires)

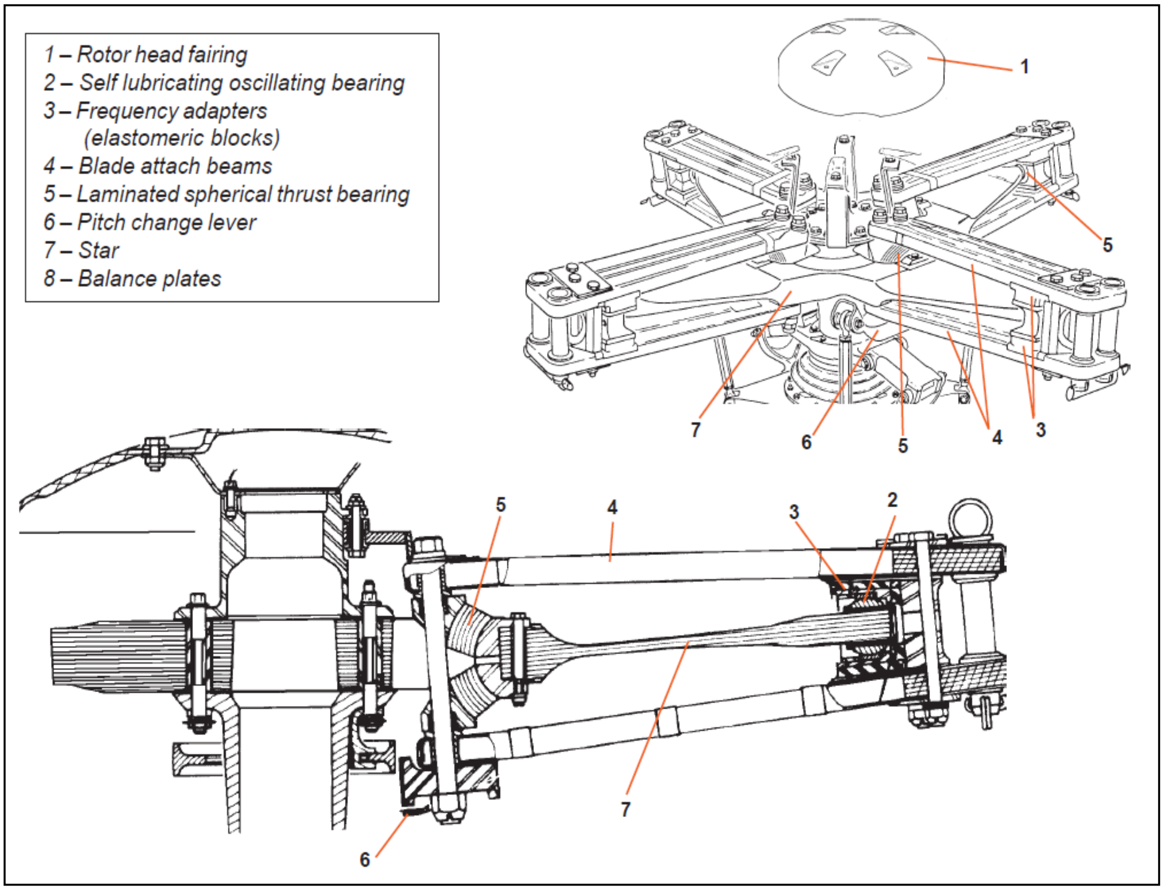
8- Sliding ball-joint end fitting

9- Adjustable stop

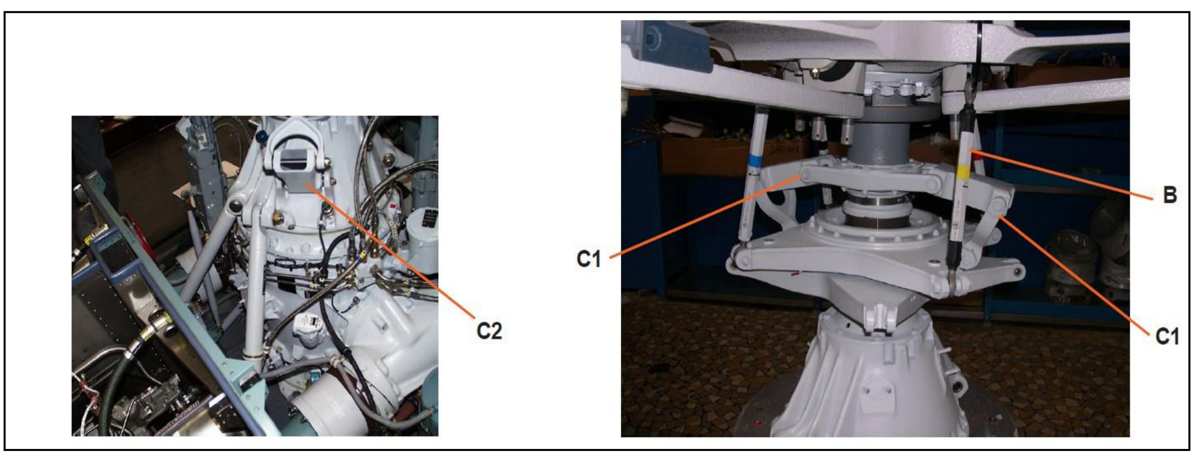
Laminated elastomer stops (2) and roving bars (7) constitute the suspension components which can be subjected to distortions. Laminated materials are rigid in compression and flexible in sharing; roving bars are flexible in bending.

(D) Main Rotor Head

The components of the main rotor head are as given below:

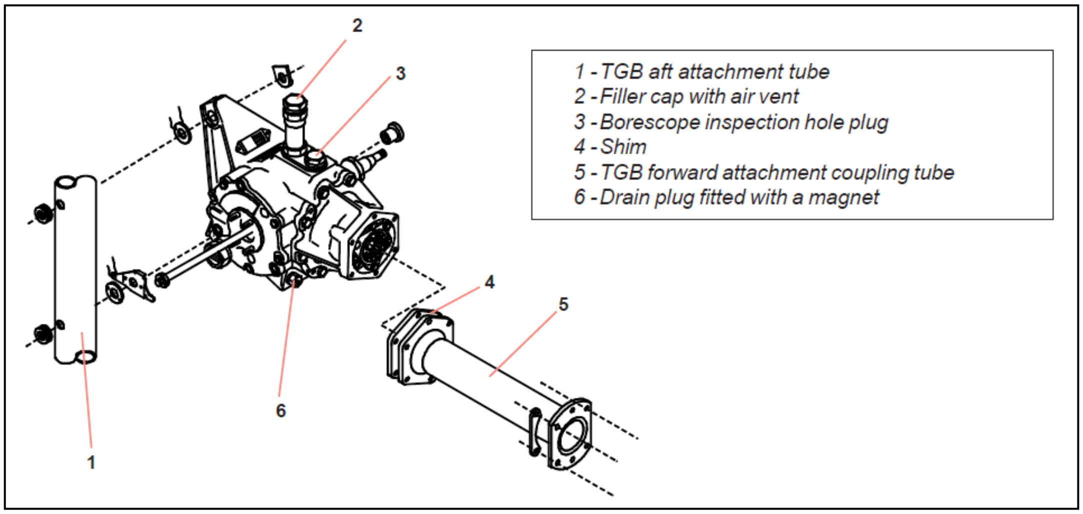


(E) Rotor Mast

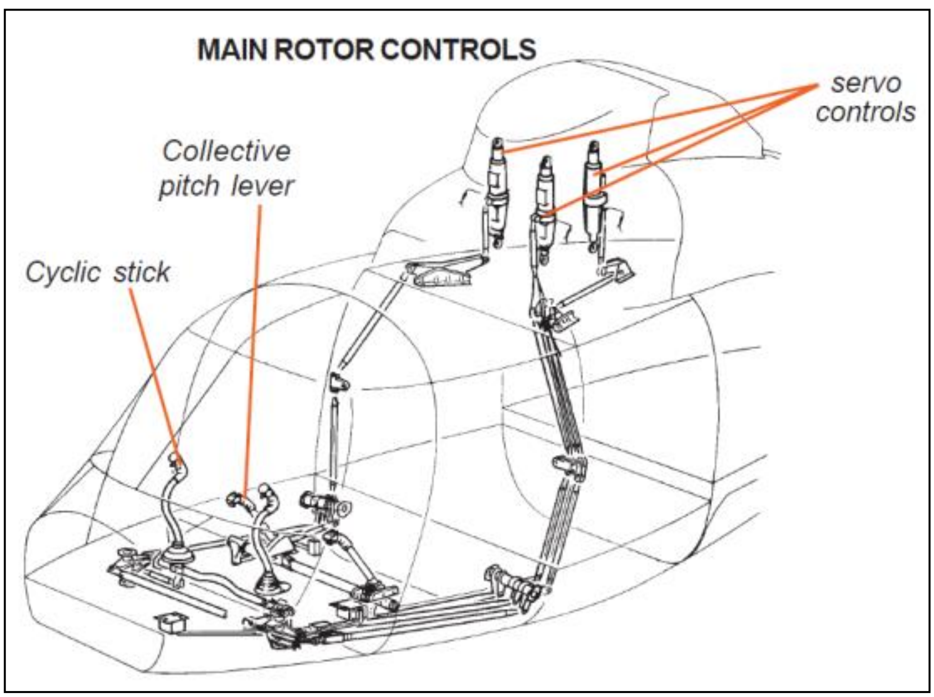


The PITCH CHANGE RODS (B) transmit swash plate motion to the main rotor head attach beams. The STATIONARY SCISSORS (C2) prevents the lever swash plate from rotating. The ROTATING SCISSORS (C1) drive the upper swash plate in rotation.

(F) Tail Gear Box



(G) Main Rotor Controls

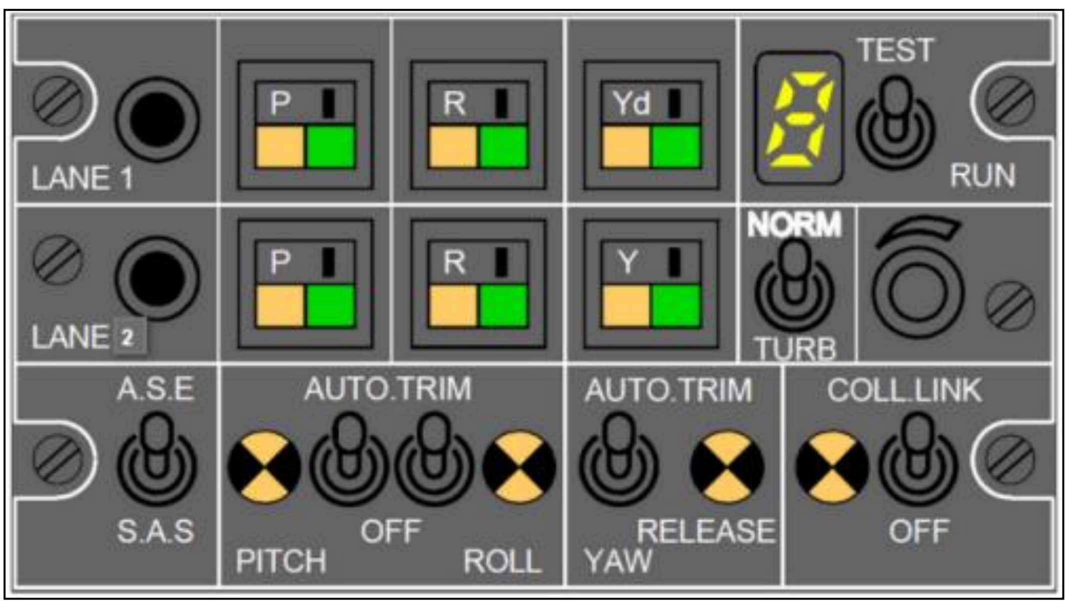


(H) Automatic Flight Control System (AFCS) Architecture

The AFCS installed on the helicopter is a 3-axis autopilot system based on AP155 computer and flight coupler CDV85. The AP155 computer is a dual computer design and provides basic stabilization by holding the attitude and heading. It is composed of 2 lanes (lane 1 and 2) and permits engaging/ disengaging the 3 axis viz. Pitch, Roll and Yaw independently. It performs monitoring between the 2 lanes at 3 levels:-

- Sensors
- Computed law and
- Series actuators.

(I) AP155 Control Unit



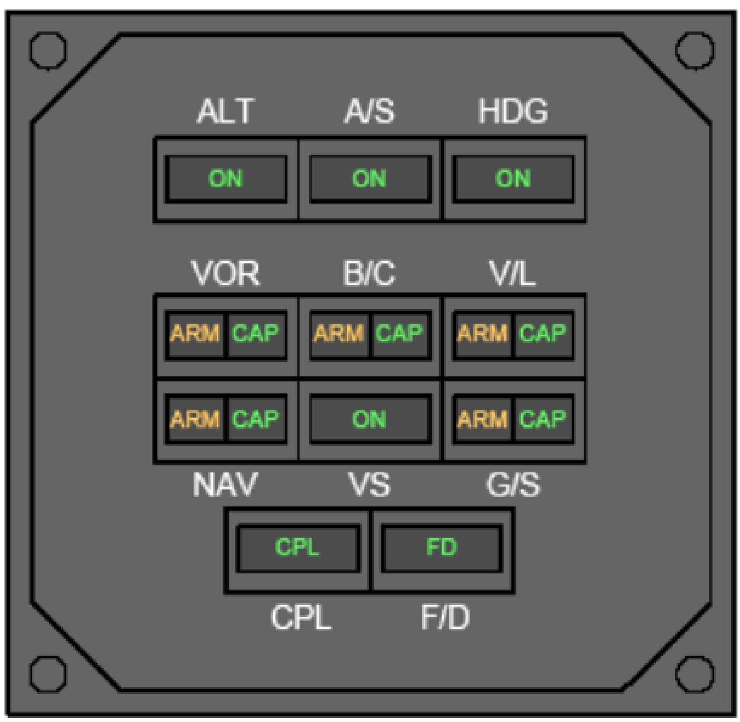
In case of discrepancy, an amber light of the concerned axis comes ON. In that case, the pilot must reconfigure the axis to the safe lane after evaluating the behavior of the helicopter. The AP155 computer also performs monitoring of pitch roll and yaw TRIMs. In case of any TRIM light coming up, the pilot should switch off the concerned AUTO TRIM function. Other function performed by the computer is monitoring of axis decoupling function (COLL LINK).

As far as the FDR recording is concerned, the Auto Pilot is engaged when light is green. From the analysis point of view, the discrepancies observed (amber warning) are as follows :-

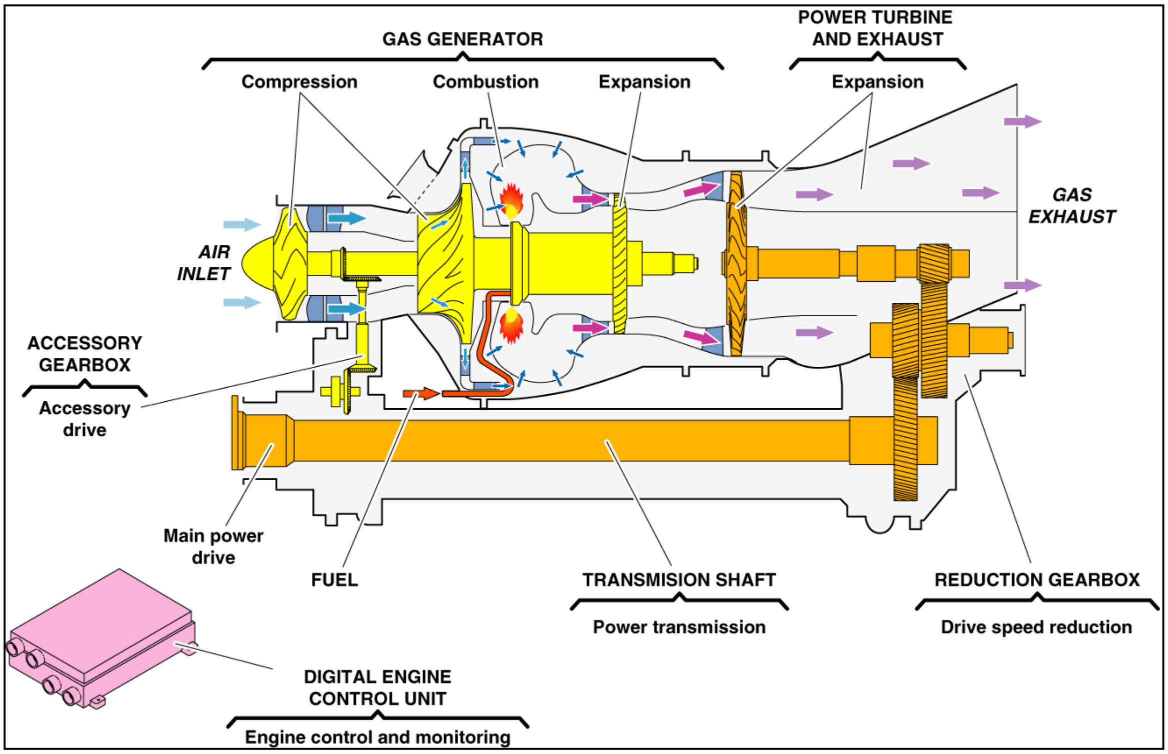
C1 warning	indicates discrepancy at sensor level
C2 warning	indicates discrepancy computed law level
C3 warning	indicates discrepancy at parallel actuators (TRIM) level
C4 warning	indicates discrepancy at decoupling level
C5 warning	indicates discrepancy at series actuators level

CDV85 manages upper modes (A/S, V/S, ALT, NAV, ILS…) and provides orders to AP155 which transmits commands to actuators.

CDV85 Control Unit



1.6.2 ENGINE



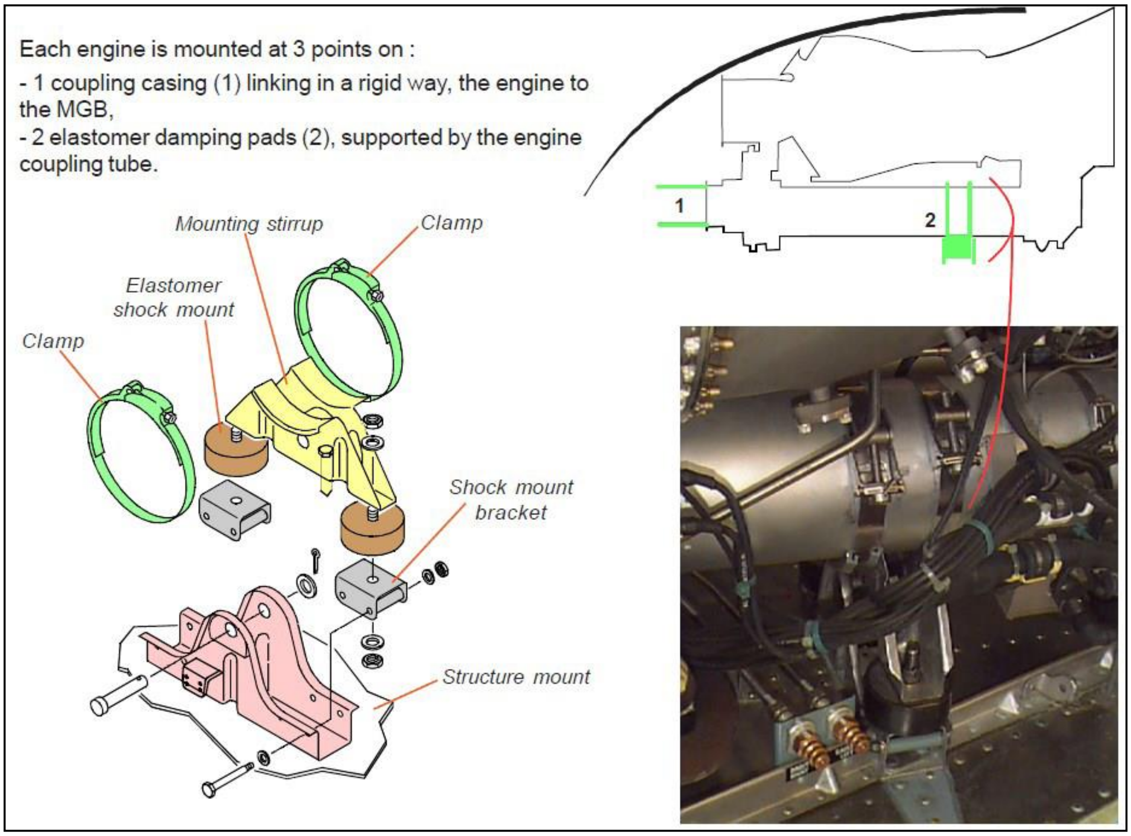
GENERAL SCHEMATIC (ARRIEL 2C ENGINE)

The Dauphin SA 365 N3 helicopter is powered by two Arriel 2C engines. These are turboshaft engines with a single-stage axial compressor, a single-stage centrifugal compressor, an annular combustion chamber, a single stage high pressure turbine (HPT), a single stage power turbine (PT), and a reduction gearbox with a nominal output at 6000 rpm. The engine is rated at 712 shp (take-off power). The dimensions of the engine are 1.181 m long, 0.497 m wide and 0.616 m high. Its dry weight is 131 kgs. The ignition system includes one high-energy generator, two injectors and two igniters. Engine start is via an electro-valve.

These engines have modular construction consisting of 5 modules i.e. Accessories Gear Box and Turbine Shaft; Axial Compressor; Gas Generator; Power Turbine; and Reduction Gear Box.

The engines installed on the helicopter bore Manufacturers serial number 24533 (hours flown since new – 4641) & 24195 (hours flown since new – 7584).

(A) Engine Mounting

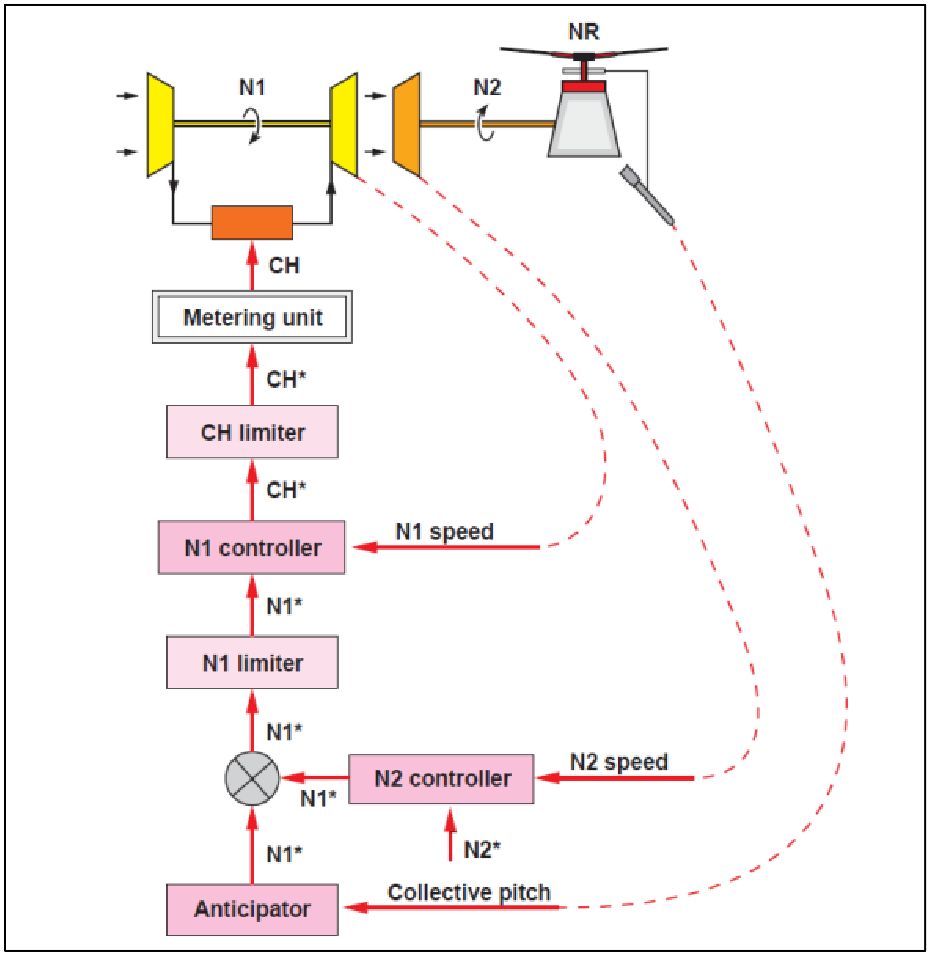


(B) Digital Electronic Control Unit (DECU)

The Digital Electronic Control Unit (DECU) aims to maintain the Power Turbine speed (N2) and hence the rotor speed (NR) at normal value. It does so by controlling the speed (N1), and hence the power, delivered by the Gas Generator. The target N1 (N1* on diagram) is obtained by modifying the fuel flow (CH) to the engine.

Actions on the collective pitch lever and/ or aircraft flying conditions (attitudes, speed, ambient conditions) act on the power requirements expected from the engines and can influence NR and N2.

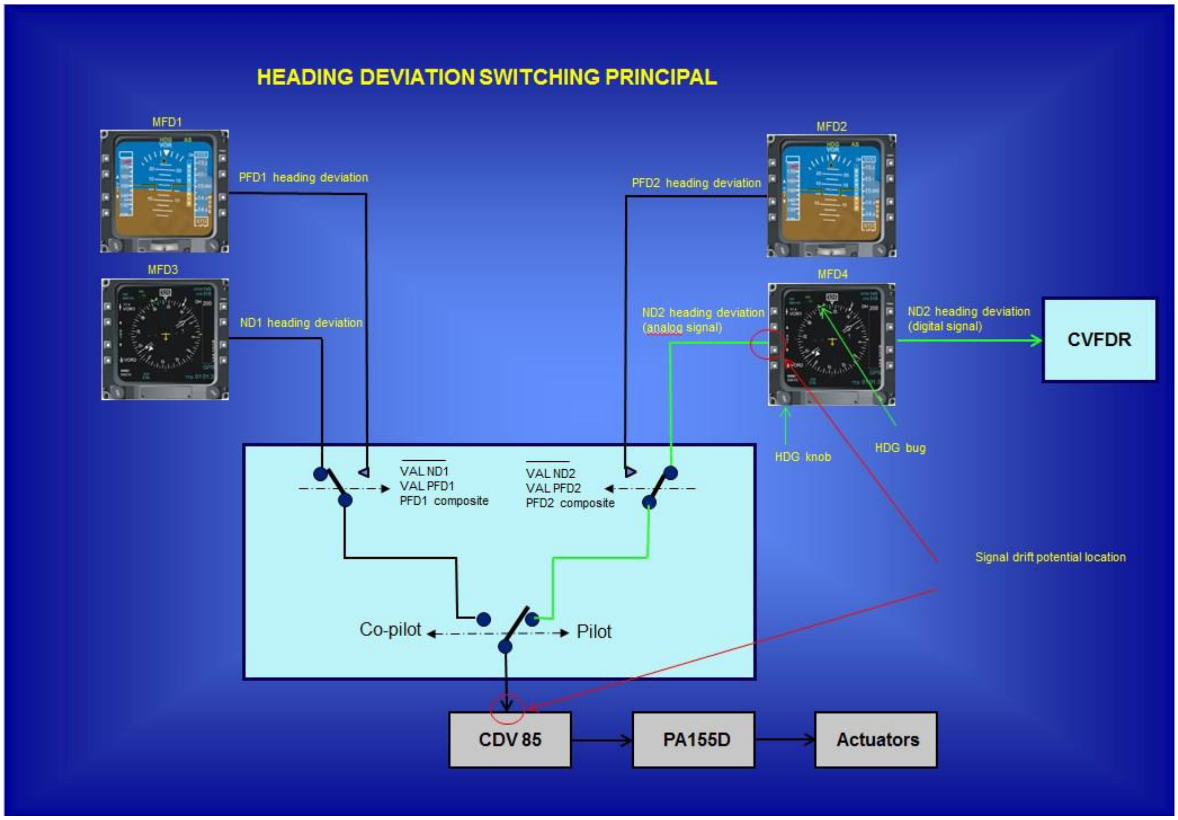
If N2 moves away from the target N2 (noted N2* on diagram), then the control system recalculates the target N1 and fuel flow to match.



(C) Heading Deviation Signal Switching Principal

The pilot can set HDG reference (HDG bug) used by HDG upper mode by rotating the master HDG knob. Then, the corresponding MFD provides heading deviation signal (analog signal) to the CDV85. The CDV85 acquires heading deviation signal from either ND2, PFD2 (composite mode), ND1 or PFD1 (composite mode).

In nominal configuration (all MFD valid), the heading deviation signal comes from ND2 or ND1 depending on Co-Pilot/pilot selection. In case of ND (1 or 2) failure, the PFD (1 or 2) can be switched to composite mode. In this case, the PFD selected provides heading deviation signal to CDV85.



During accident flight, heading deviation signal came from MFD4 meaning that selector was set to pilot flying position. The heading deviation drift is supposed to come from either MFD4 output defect or CDV85 input defect. (The CVFDR does not record analog signal. It records digital signal coming from MFD which is not affected by the drift).

1.7 METEOROLOGICAL INFORMATION

The following METARs were issued for Juhu Airport from where the helicopter had taken off.

Time (UTC)	Visibility (meter)	Wind	Clouds	Temp (º C)	QNH
0430	3000	110/11	SCT 2000 ft/ BKN 10000 ft	32	1014
0500	4000	100/12	FEW 2000 ft/ BKN 10000 ft	33	1014
0530	4000	100/10	FEW 2000 ft/ BKN 10000 ft	36	1013

On query, the crew of another helicopter which was operating 10 minutes ahead of the accident helicopter informed that the weather en-route was hazy with poor slant visibility. No horizon was visible once climb was initiated from 700 ft upwards. However, vertical visibility was good.

1.8 AIDS TO NAVIGATION

The helicopter was equipped with VHF, VOR, NDB, ATC transponder, Radio altimeter, weather radar and GPS. In addition, the helicopter was equipped with AIS for monitoring purposes as per the requirements of ONGC.

1.9 COMMUNICATIONS

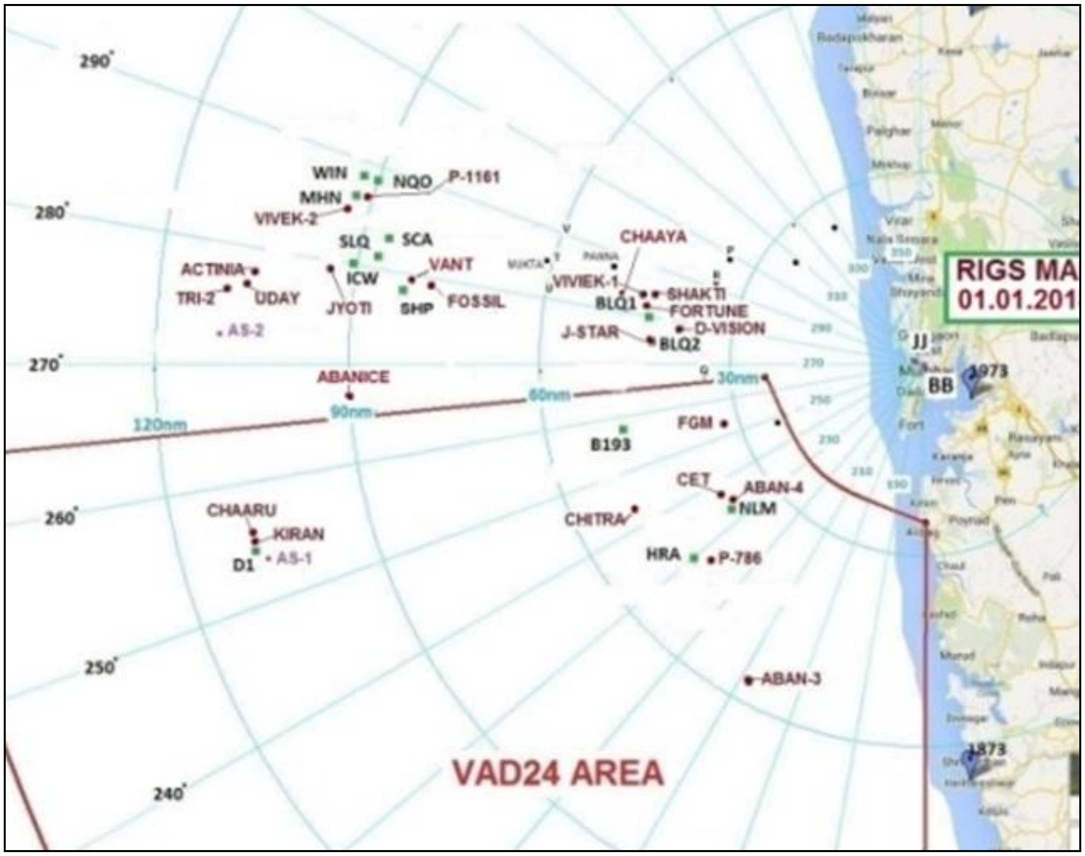
The flight crew never faced any problem in maintaining two-way communication between the helicopter and ground station. The intra cockpit conversation has not indicated any problems faced by the flight crew in communicating with the ground stations during the flight.

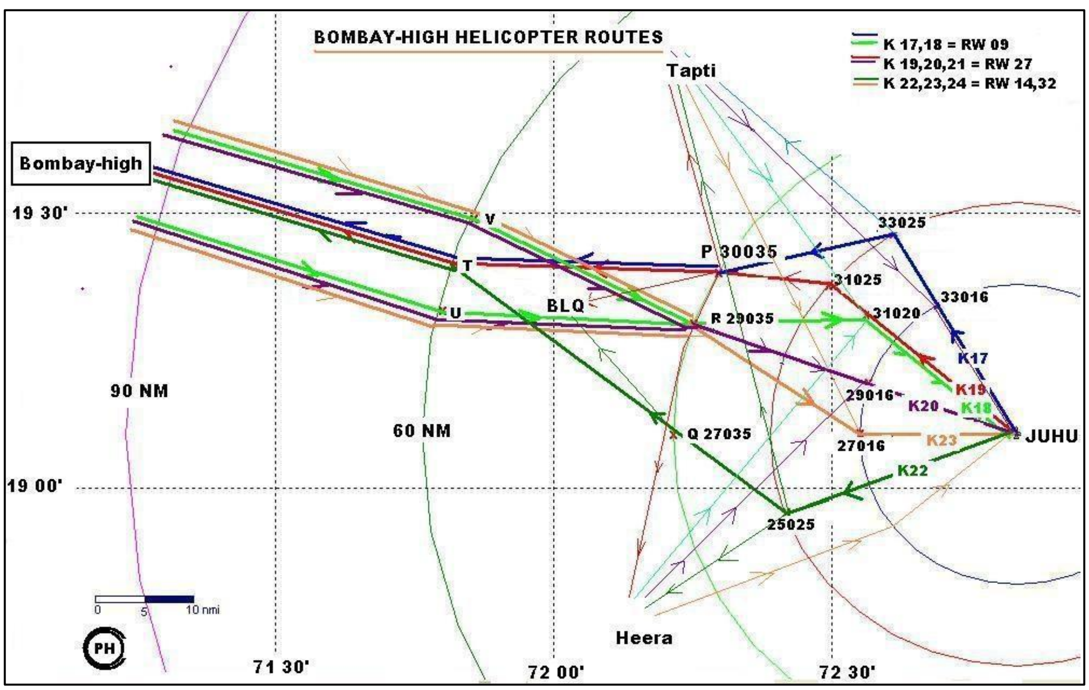
1.10 AERODROME INFORMATION

Juhu airport is owned and maintained by Airports Authority of India (AAI). It is a single runway airport. Most of the helicopters Operators (NSOP) are stationed at Juhu. ONGC also has got their infrastructure at Juhu for embarking and disembarking of passengers. The facility has got security arrangements.

The helicopter took off from Juhu airport which is a controlled airport and was cleared for flight to NQO platform in the Mumbai offshore area. The helicopter crashed into the sea while cruising to point ‘P’.

Airports Authority of India has issued an AIP Supplement 09/2010 regarding helicopter routing Mumbai/ Juhu. In this AIP, helicopter VFR rules are established to streamline the flow of helicopter movement within Mumbai control zone to various helipads and Bombay High.


290°
280°
270°
260°
250°
240°
WIN
NQO
P-1161
MHN
VIVEK-2
SLQ
SCA
ICW
VANT
ACTINIA
TRI-2
UDAY
JYOTI
SHP
FOSSIL
AS-2
CHAAYA
VIVIEK-1
SHAKTI
BLQ1
FORTUNE
D-VISION
J-STAR
BLQ2
ABANICE
120nm
90nm
60nm
30nm
B193
FGM
CET
ABAN-4
NLM
CHAARU
KIRAN
D1
AS-1
CHITRA
HRA
P-786
ABAN-3
RIGS MA
01.01.201
JJ
BB
1973
1873
VAD24 AREA


BOMBAY-HIGH HELICOPTER ROUTES
K 17,18 = RW 09
K 19,20,21 = RW 27
K 22,23,24 = RW 14,32
Tapti
Bombay-high
19 30'
19 00'
V
T
U
BLQ
P 30035
33025
31025
33016
R 29035
31020
K17
K19
29016
K20
K18
JUHU
K23
Q 27035
27016
K22
25025
90 NM
60 NM
Heera
71 30'
72 00'
72 30'
0
5
10 nmi
PH

The procedures for offshore flying (beyond 30 nm in the offshore and in the uncontrolled airspace), were formulated in April 2010, after agreement by the helicopter operators operating from Juhu and operating offshore. These procedures covered the altitude, radial, ROC, ROD etc. to be followed while flying inter/intra field traffic (north, south field). These procedures were integrated with the routings given in AIP from Juhu.

1.11 FLIGHT RECORDERS

The combo CVFDR unit was retrieved from the sea and after taking all necessary precautions was brought to Delhi for downloading the data. The unit was found intact with Underwater Locator Beacon (ULB) in position. There was no damage to the unit as seen from outside.

1.11.1 RETRIEVAL OF DATA CARDS

An external visual examination was performed. The recorder showed no physical damage. However, it had stayed in sea water for more than a day before it was recovered. Therefore, it was decided to remove the Crash Survivable Memory Unit (CSMU) from the chassis and extract the memory boards.

The memory support is composed of two electronic boards containing the memory components and surrounded by a red colored sealant. The white thermal protective powder inside the CSMU was wet indicating that the memory support had got exposed to water. The electronic boards were separated to check the status of the memory components between the boards.

The boards were in good condition. Only a pin of the connector on one card was slightly bent. The boards were cleaned with water and then with alcohol. A visual examination of the components of the cards was performed. No crack on the memory components was seen.

1.11.2 DOWNLOAD OPERATIONS

Impedance measurements were made on the input connector of the electronic board. The measured values were consistent with the reference values either provided by the manufacturer or measured by the BEA on other similar cards.

Download was performed on a golden chassis with the manufacturer ground station (RPGSE), using BEA interconnection board and BEA customizable connector. The download was successful.

1.11.3 CVFDR READOUTS

The raw CVFDR data was retrieved after taking out the data cards from the CVFDR unit. The raw data was in the form of ".dlu files" which was converted to engineering units by BEA and a few parameters were provided to the investigation which indicated that the retrieved data was good and meaningful. The investigation tried to get some more parameters from the raw data (.dlu file) with the help of NAL Bangalore but it was not successful because of non-availability of the definitions with NAL. The evidences available were correlated which gave a clear picture of the sequence of events. BEA was asked to provide detailed analysis of the accident flight as well as some previous flights. CVFDR data analysis, FDR data analysis for engine behavior, Engine examination report, AFCS behavior during accident flight and previous flights and Summary of simulation study performed by Airbus Helicopters were received from BEA. The analysis carried out by BEA in these reports has been extensively used to conclude the investigation.

1.12 WRECKAGE AND IMPACT INFORMATION

A. General

The helicopter was cruising at a flight level of little above 3000 ft from where it plunged into sea. Most of the wreckage was recovered from the sea. The wreckage examination was performed at Mumbai and included the observation on the dynamic assemblies, airframe and flight controls.

Wreckage examination report was received through BEA (France) which included damage analysis to the systems components (hydraulic, electrical generation, etc…). Impact damage to the structural and rotating components was analysed to find out the attitude of the helicopter at the time of impact.

Lower part of the cabin floor, doors, lower part of the 9° frame, tail boom parts, horizontal stabilizer, right hand and nose landing gear, parts of the tail fenestron, could not be recovered. Radome, tail fin, and both outboard fins were recovered near the water impact point. The landing gear was retracted at the time of impact.

Damage to the front and right side part of the MGB cowling

B. Overhead Control Levers

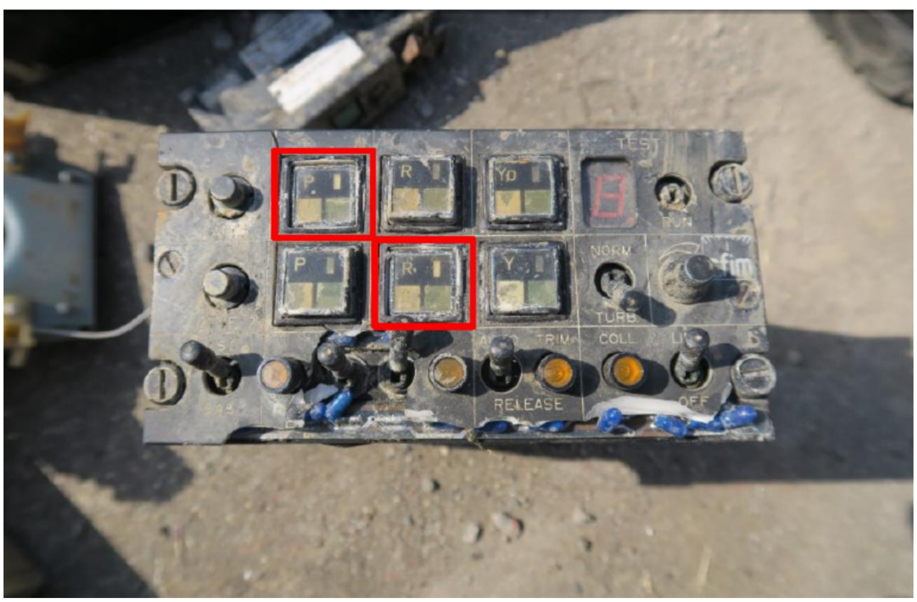
The positions of the overhead control levers were found as follows:-

Lever	***Position***
Engine 2 fuel shut-off cock lever	*Not actuated (forward position)*
Engine 2 fuel flow lever	*Forward position*
Rotor brake lever	*Not actuated (forward position)*
Engine 1 fuel flow lever	*Forward position*
Engine 1 fuel shut-off cock lever	*Not actuated (forward position)*
Heating system P3 valve lever	*Destroyed*
Cabin ventilation flap lever	*Forward position*

During accident or retrieval, there might have been distortions resulting in change in positions.

C. Control and Indication Units

The cockpit was destroyed. Most of the control and indication units were severely damaged. The position of the pushbuttons of the Autopilot Control Panel was as shown below.



AUTOPILOT CONTROL PANEL

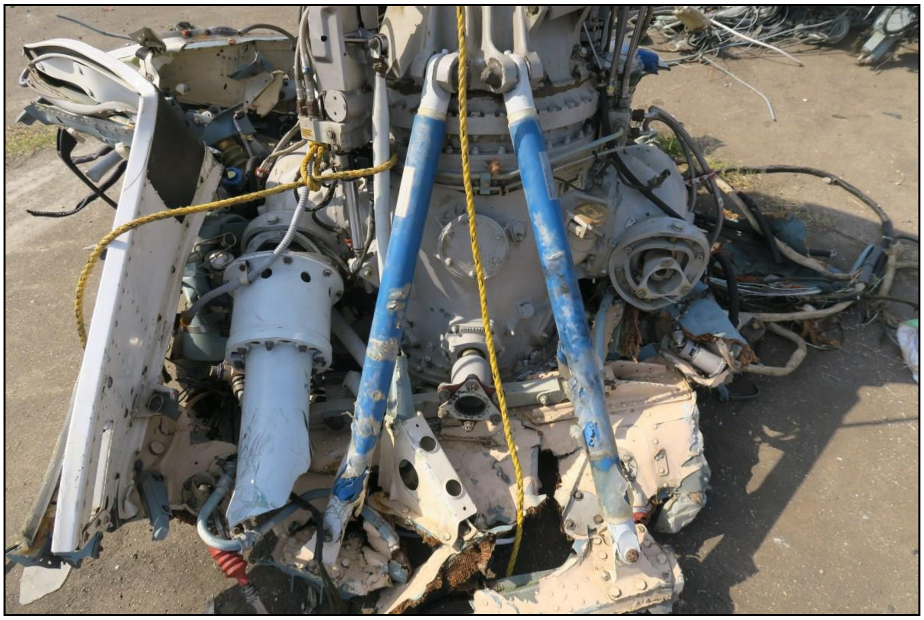
The pushbuttons that are engaged are identified in red: Pitch on lane 1, and Roll on lane 2. During the accident, there might have been distortions resulting in change in pushbuttons positions.

D. Main Rotor Drive System

The main gearbox was complete without any external mechanical damages or evidence of overheating. Some external corrosion evidences were observed which could be because of salty water immersion. It was not possible to turn the MGB by hand, due to the internal corrosion (magnesium casing).

Main Gearbox (MGB)

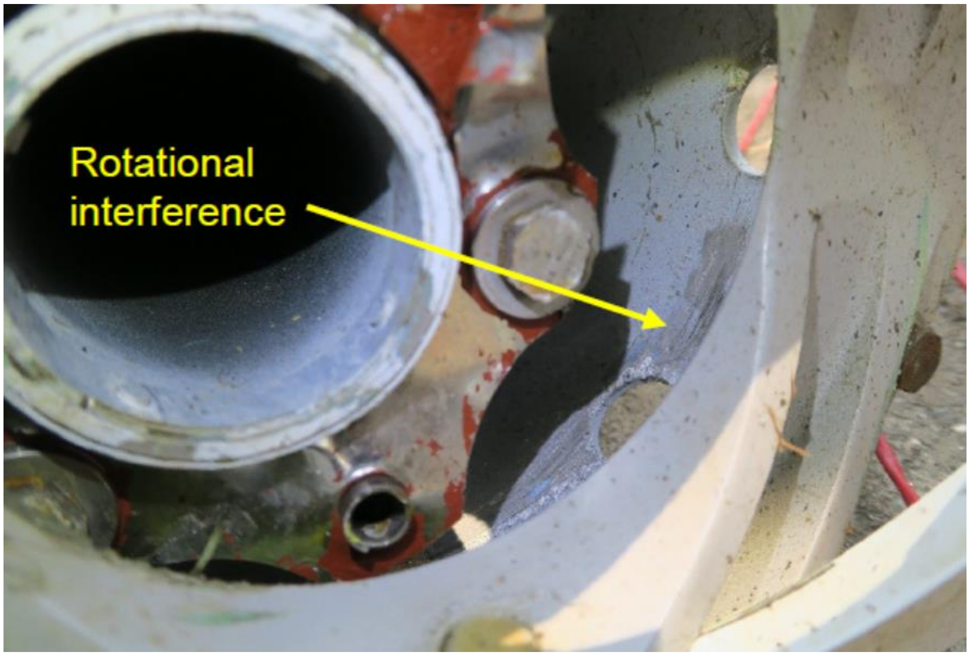
No metallic particle was found on chip detector. Magnesium corrosion powder (nonmagnetic) was found on detector confirming high level of corrosion inside.



The left coupling was found broken at two locations i.e. at the MGB input (flexible coupling and universal joint), and at rear housing (coupling shaft and housing). Rupture of some flexible coupling bolts and evidence of traction loads were observed on the flexible coupling. The ruptures and deformations were due to overload, with no pre-impact damage.

Tearing due to torsional load was observed on the coupling shaft. This observation shows that the left engine was running during the fracture sequence.

The right coupling was found broken at the MGB input (flexible coupling and universal joint). The ruptures and deformations are due to overload, with no pre-impact damage. Rotational interference was observed on the inner surface of the front housing indicating that the right engine was running during the fracture sequence.

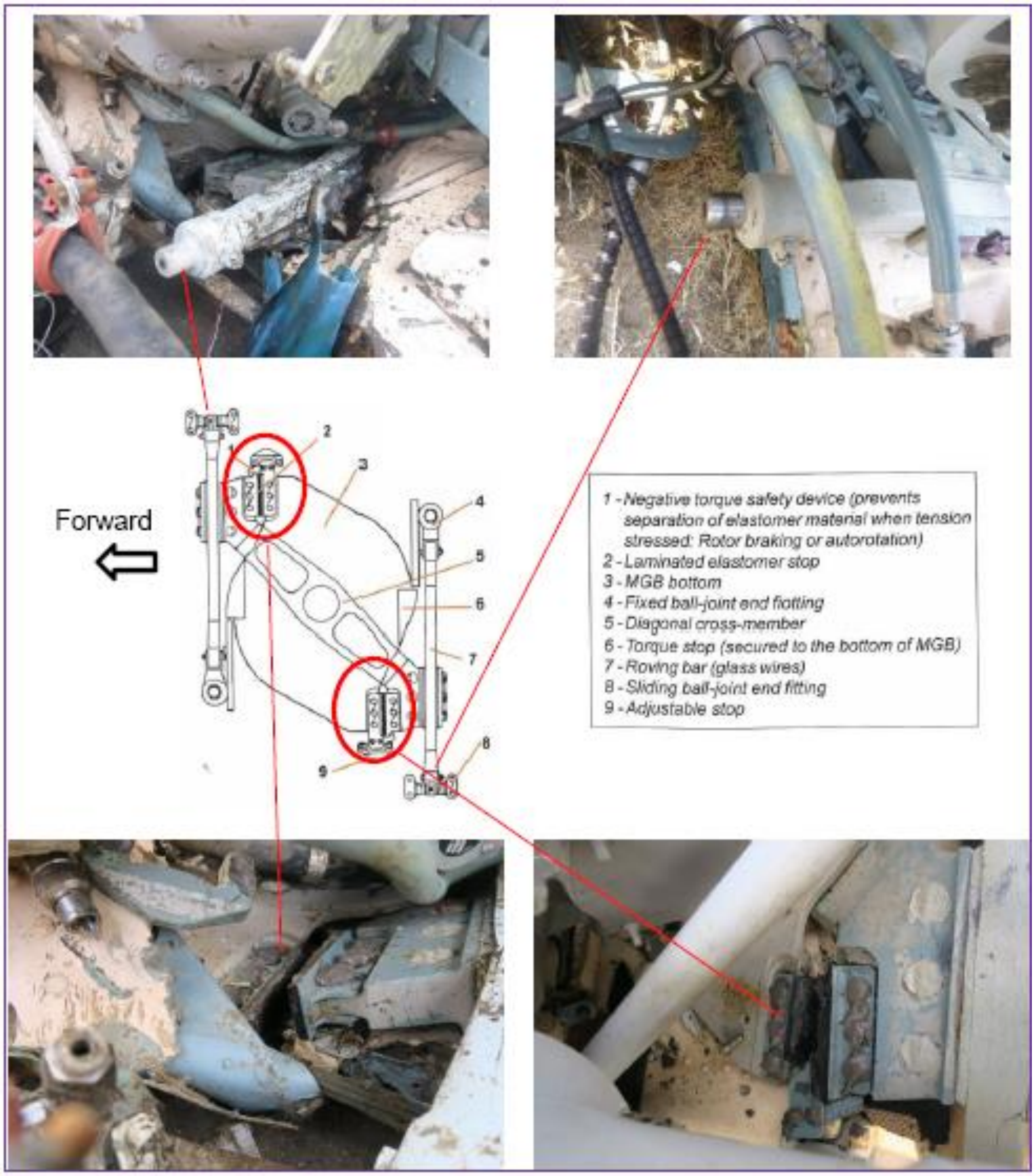


Rotational interference between flexible coupling and front housing

E. Main Gear Box Support

The four suspension bars were still attached to the conical housing and to the ferrule on the mechanical deck. The front right suspension bar was distorted and broken in the middle. The rupture was static. The front left suspension bar was complete with substantial distortion. Both front bars experienced compression loads due impact, with no damage prior to accident. The two aft suspension bars were complete with little distortion.

	
FRONT RIGHT SUSPENSION BAR	FRONT LEFT SUSPENSION BAR



The two laminated elastomer stops were fractured and the two roving bars slided out of their ball-joint end fittings. The main gearbox had turned clockwise in relation to the structure. The damage was because of sudden stoppage of rotating powered main rotor due to impact with water.

F. Main Rotor Head

	
Stationary scissor coupling bolt	**Black pitch change rod**

	
Red Arm	Black Arm
	
Blue arm	Yellow arm

Rotating and non-rotating swash-plates were in a high position with a tilt to the left and forward. Both rotating scissors were in position and undamaged. Stationary scissor coupling bolt was found broken due to overload.

Red Arm - The star arm had broken due to overload in flapping (delamination at the root). The blade attach beams were destroyed. The laminated spherical thrust bearing moved into a pitch up position.

Black Arm The tip of the star arm had broken due to overload in drag. The star had moved clockwise in relation to the blade attach beams, which stopped suddenly when the blades struck water.

Blue Arm - The star arm was complete. The star had moved clockwise in relation to the blade attach beams, which stopped suddenly when the blades struck water. The frequency adapter was struck out of its fitting by the star arm.

Yellow Arm The star arm was broken due to overload in drag and flapping. The blade attachment beams moved into a pitch up position. The star had moved clockwise in relation to the blade attach beams, which stopped suddenly when the blades struck water.

G. Main Rotor Blades

Main Rotor Blades

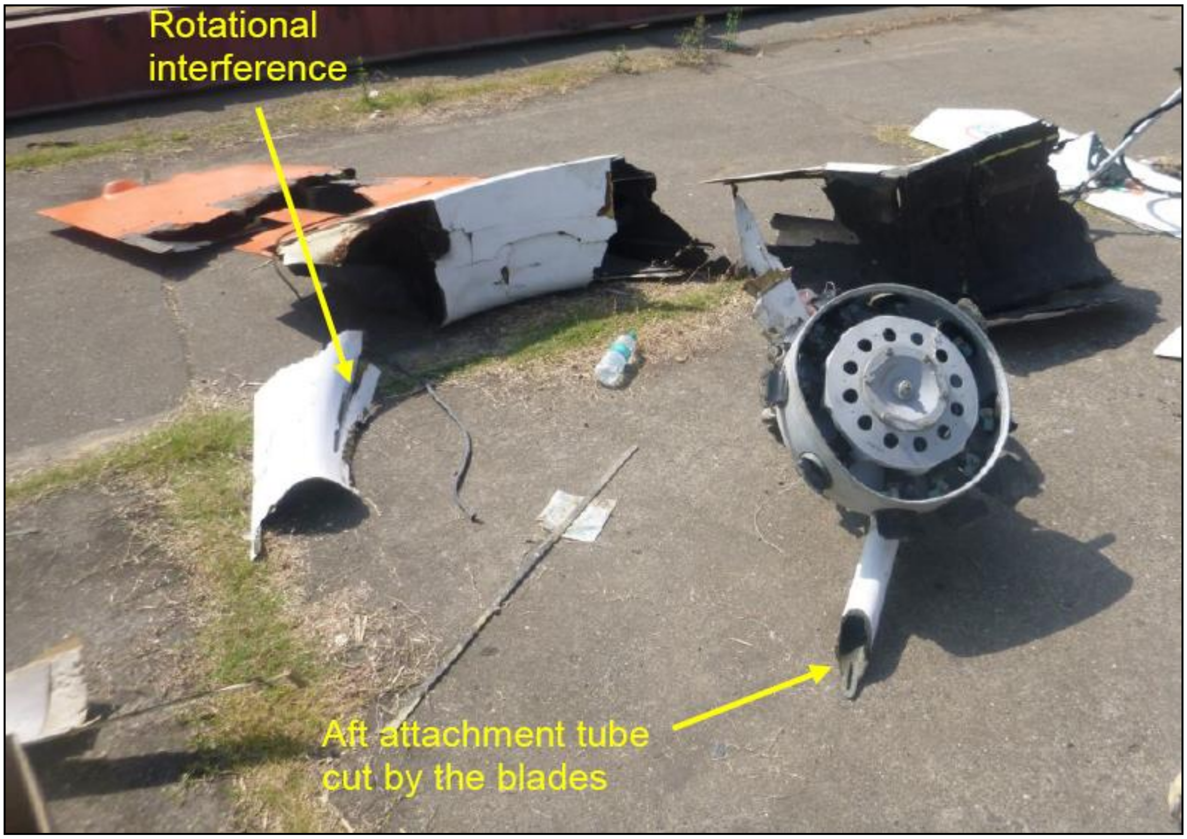
All four blades showed significant damage and had broken at about half of their respective lengths. The tip of the black blade was missing. All damages were because of the impact with a very high momentum.

H. Tail Rotor Drive System

	
Forward shaft	Aft of tail rotor drive shaft
	
Flexible coupling at MGB output	Flexible coupling at TGB input

The forward shaft was found broken by overload. No damage was observed on the two splined-end fittings and flexible couplings were in good condition. All bearings were corroded due to contact with salt water, and did not show evidence of mechanical damage prior to the accident.

I. Tail Rotor Assembly



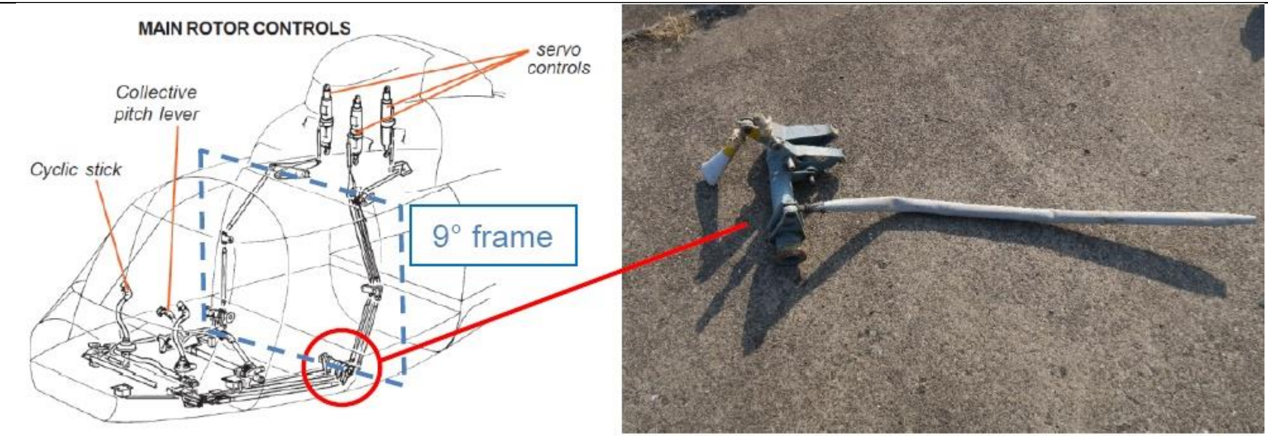
Fenestron assembly

All tail rotor blades were found broken from close to the root. Rotational interference was identified on the fenestron duct due to contact with the blade tips. The tail gearbox aft attachment tube had broken on impact at about half of its length (between the TGB attachment legs) and cut by the blades. Fenestron was rotating and had damaged and deformed the structure of tail rotor. The relative movement of the pitch change control rod and the blades' pitch was found to be in correct sense.

The tail gearbox was dismantled. Magnesium corrosion powder was found inside the casing. The pitch change control mechanism was removed from the TGB and the operation of the pitch change control bearing was found as it should be.

J. Flight Controls

Main Rotor Controls



Location of 9° frame | L/H mixing unit

L/H cyclic pitch stick and L/H roll channel bellcranks

R/H cyclic pitch stick

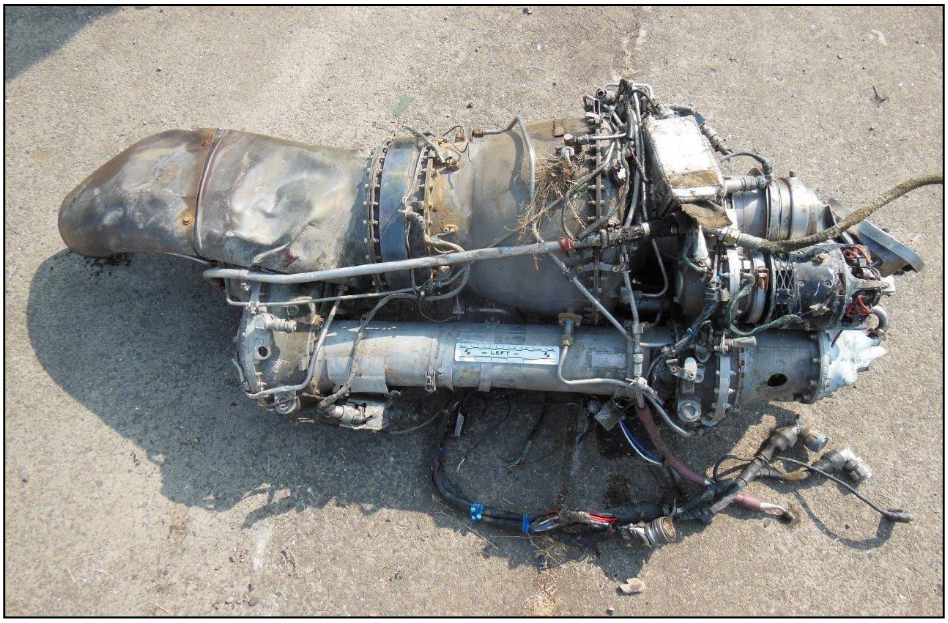
L/H collective pitch lever

R/H collective pitch lever

Some parts along the 9° frame and right side of the cockpit could not be located as these might have gone deeper into the sea bed. However from the damages observed, it could be safely concluded that ruptures were post impact and there was no pre-impact damage.

K. Engines

Both engines got separated from the engine deck. These were dusty and corroded in places due to the time spent in sea water after the accident.



All modules were together with impact damages all over.

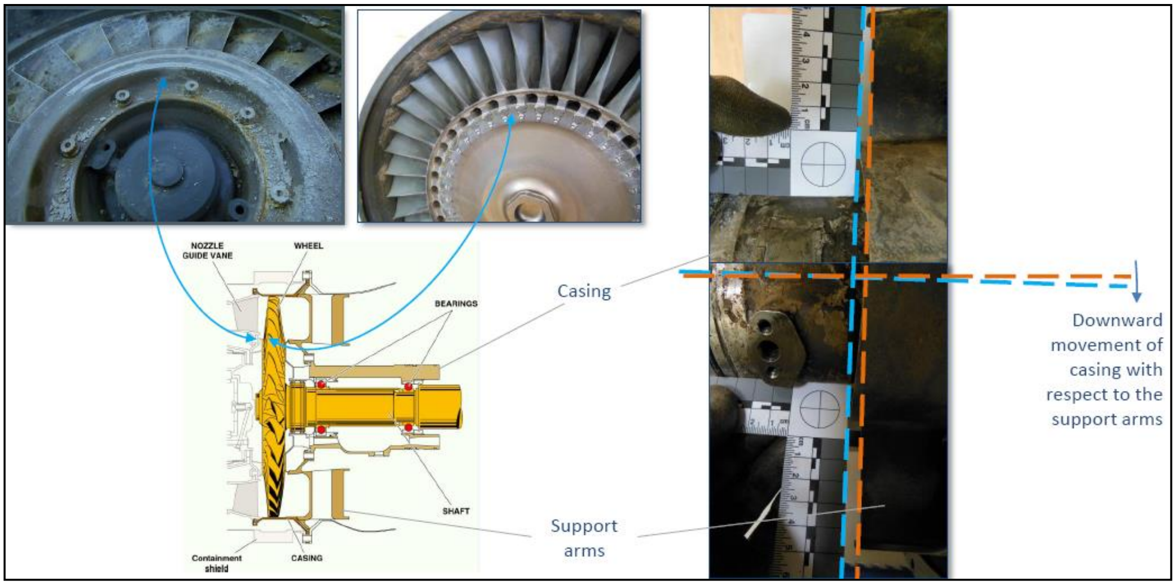
L. Engine Mounting Deformations

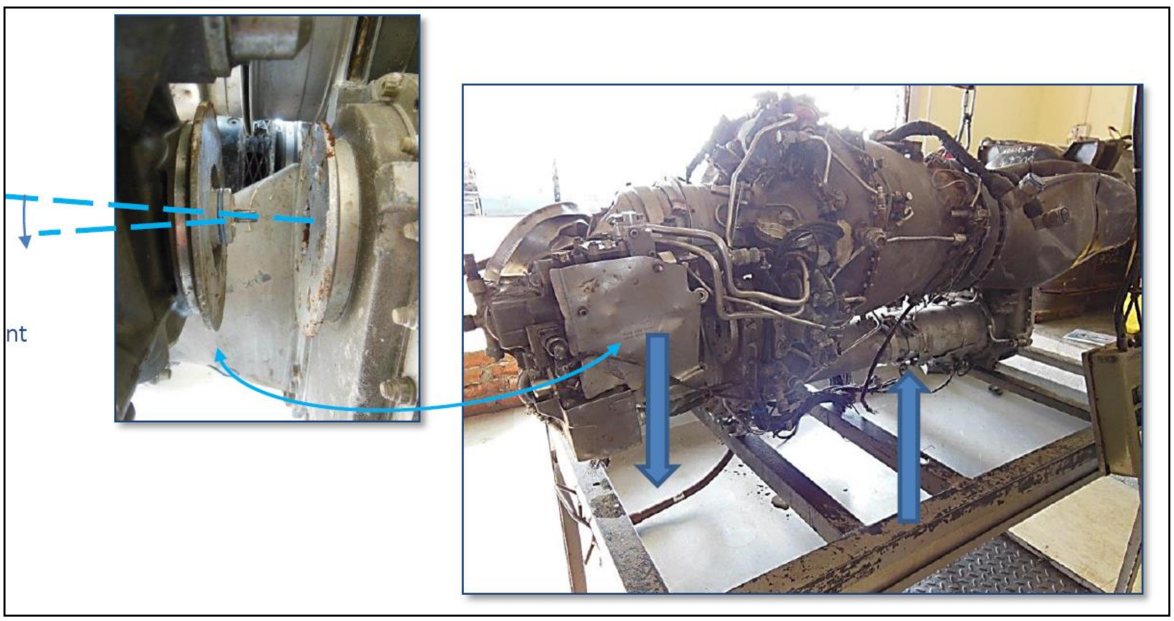
	
Left engine mount	**Right engine mount**

Both engines and their supports exhibited damages which were indicative of high vertical impact forces. Other evidences indicated that the engines moved to the right (as seen from the rear) during the accident. Most of the external damage was because of the accident or during the recovery operation. Most of the damages discussed below are to LH engine. Almost similar damages were there to RH engine.

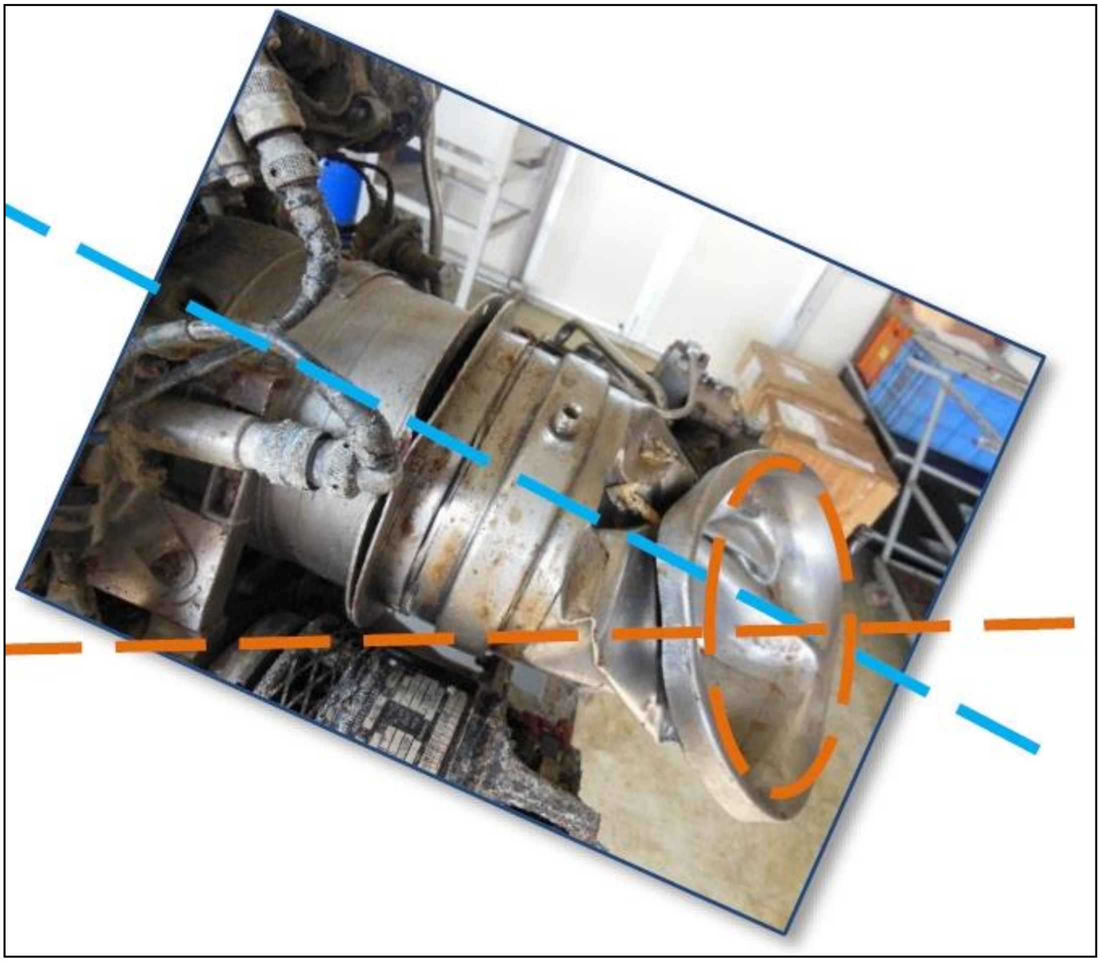
The link tube caved in at rear support level

The power turbine casing was found drifted (angular) downwards with respect to its support arms and flange, which could be caused only by strong downward vertical load. Because of that, the front face of the blades came in contact with the back of the nozzle guide vane. The circular rubbing marks show that the Power Turbine (PT) wheel was rotating at the time of impact.





As shown above, the link to caved in near rear support and the HMU got separated from the module 1's casing. The HMU's drive shaft was found bent downwards. The above shows that the engine was subjected to downward vertical force at the time of Accident.



The deformation of air intake as shown above indicated displacement of the engine towards right hand side. At the time of accident, the engine suffered damage due to impact force coming from the right-hand side.

The engine was examined and stripped. The compressors, combustion chambers, HP Turbines and Power Turbines of both engines were in good condition. The output drive shaft of both engines was found ruptured with indications of rotation at the moment of the accident. The impact led to a small displacement of the Power Turbine's casings. This displacement led to the Power Turbine wheels coming in contact with the rear of the Nozzle Guide Vanes. Circular marks left by the contact indicate that the Power Turbines were rotating and that the engines were operating at the moment of the accident.

1.13 MEDICAL AND PATHOLOGICAL INFORMATION

Pre-flight Medical examination of both the cockpit crew members alongwith the breath-analyzer test had been carried out. They were found fit to fly and the breath-analyzer test was negative.

1.14 FIRE

There was no fire.

1.15 SURVIVAL ASPECTS

The accident was not survivable.

1.16 TEST & RESEARCH

After detailed discussions with BEA France, the CVFDR recordings (FDR) and the relevant portion of CVR (for synchronisation purposes) was provided to BEA. The objectives were defined as follows:-

- decode and validate the main FDR parameters from the CVFDR
- study the behaviour of the helicopter and its systems during accident flight
- synchronise CVR and FDR data to produce a sequence of events, (for further discussions)

BEA has provided detailed reports as mentioned above along with the graphs of various flight parameters. Following excerpt are based on the discussions of the detailed reports of BEA.

<u>AFCS Behavior</u>

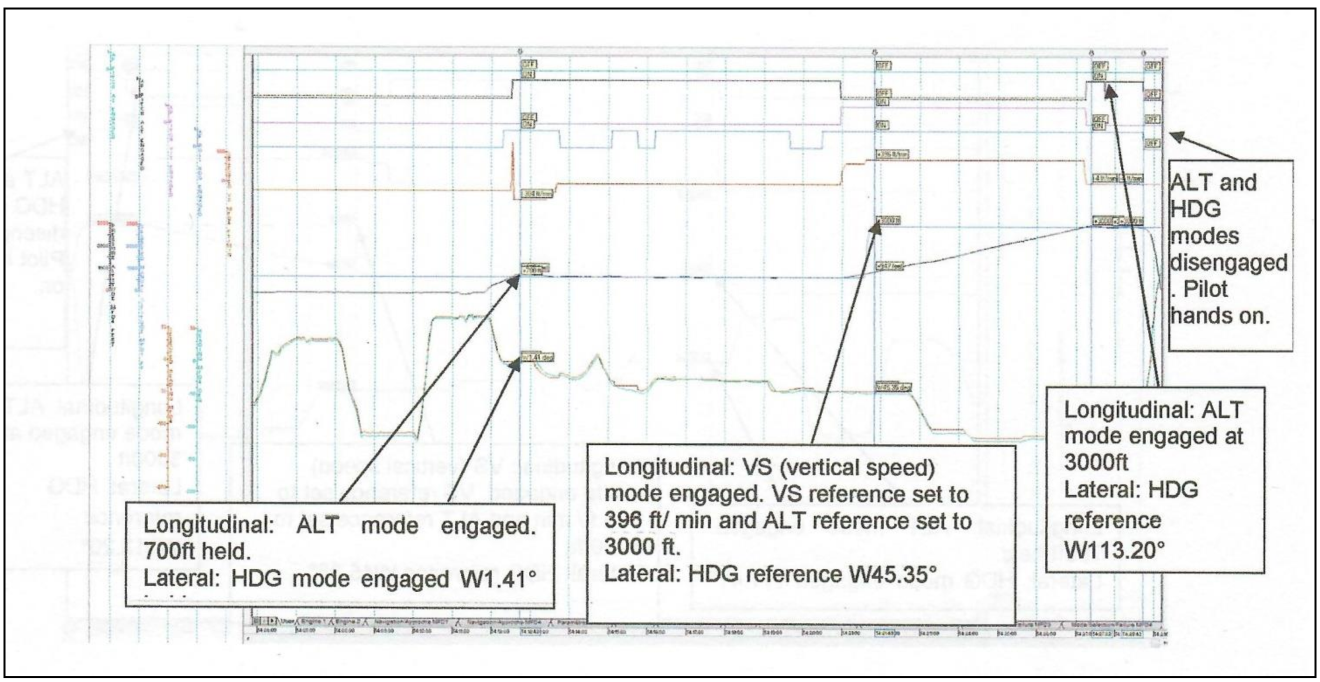
As there was drift in the heading mode (Heading was not maintaining as selected), AH helicopters were asked to provide a report on AFCS behaviour. A report containing graphical analysis of upper mode status; AFCS lateral/ yaw status (last 2 minutes); AFCS longitudinal status; AFCS warning status and Hands On/ off detection on pitch roll and yaw axis was provided by AH.

AFCS Upper Modes

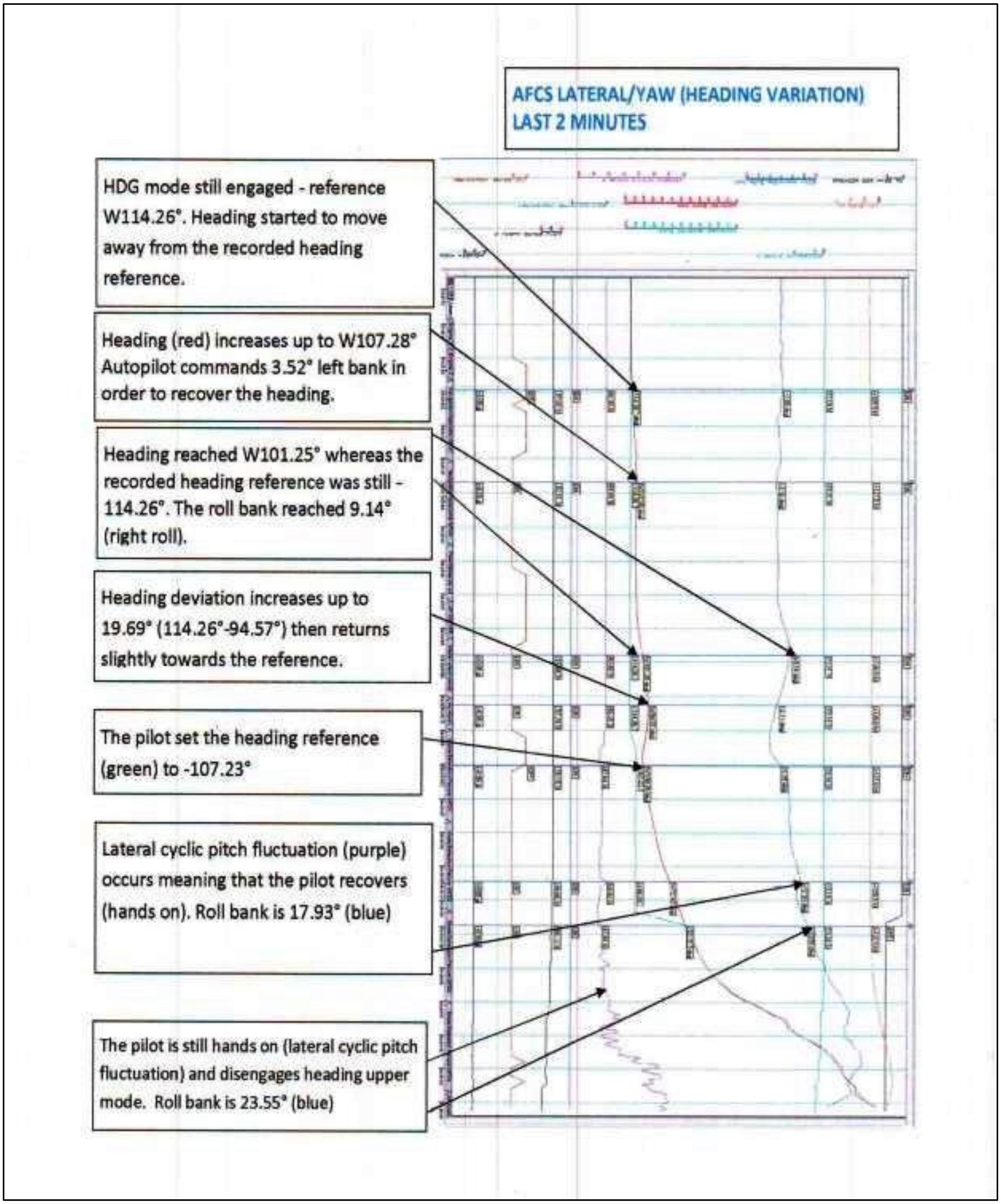
When the upper modes are disengaged, AFCS reverts to basic stabilization mode, i.e. current pitch attitude and heading are held. A specific roll attitude management is performed if a lateral mode was previously engaged (e.g. HDG). When a lateral mode is engaged, roll attitude reference is forced to 0° allowing the aircraft to return to 0° roll after a turn.

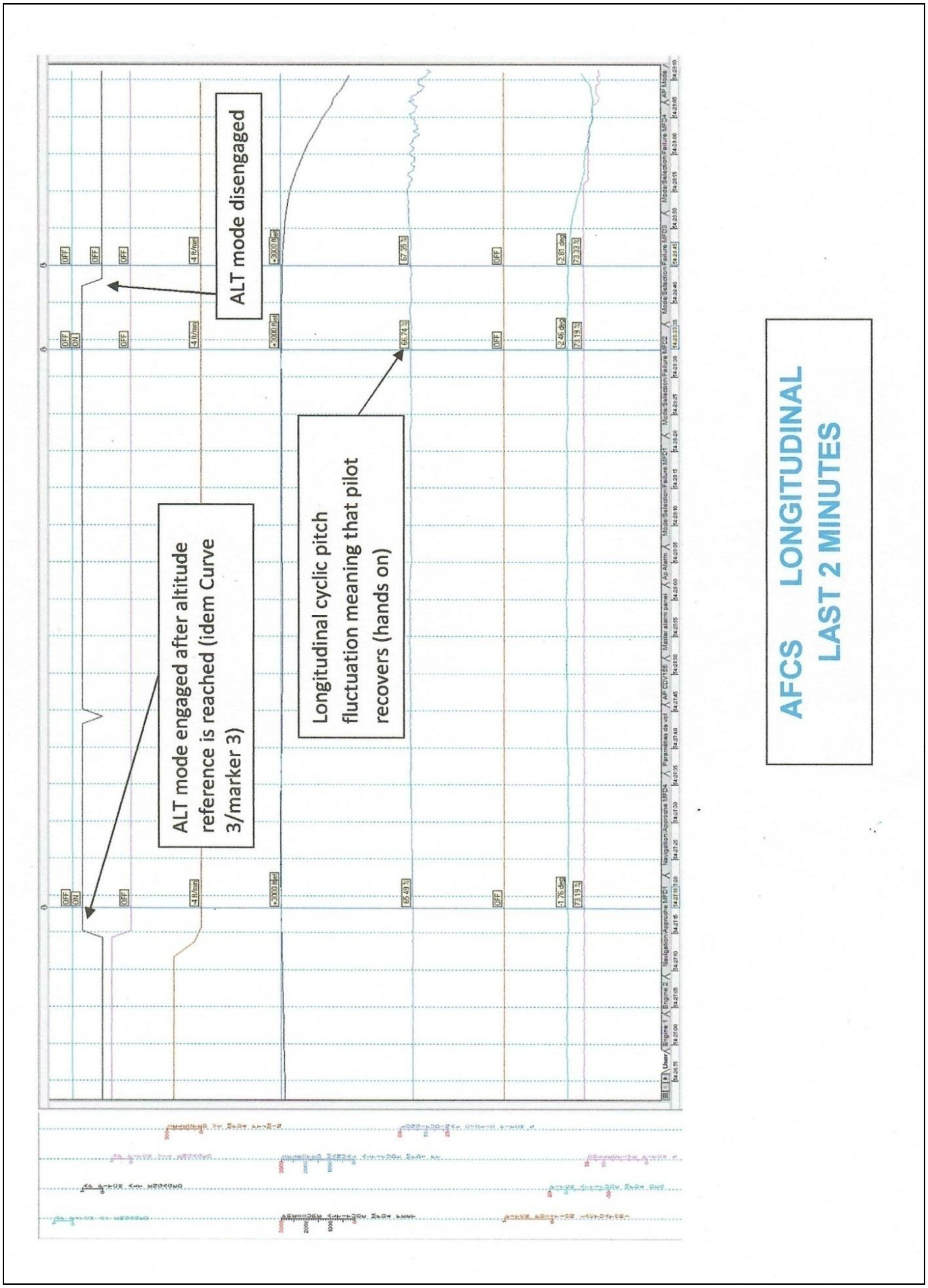
When the lateral upper mode is disengaged, 3 cases are possible:-

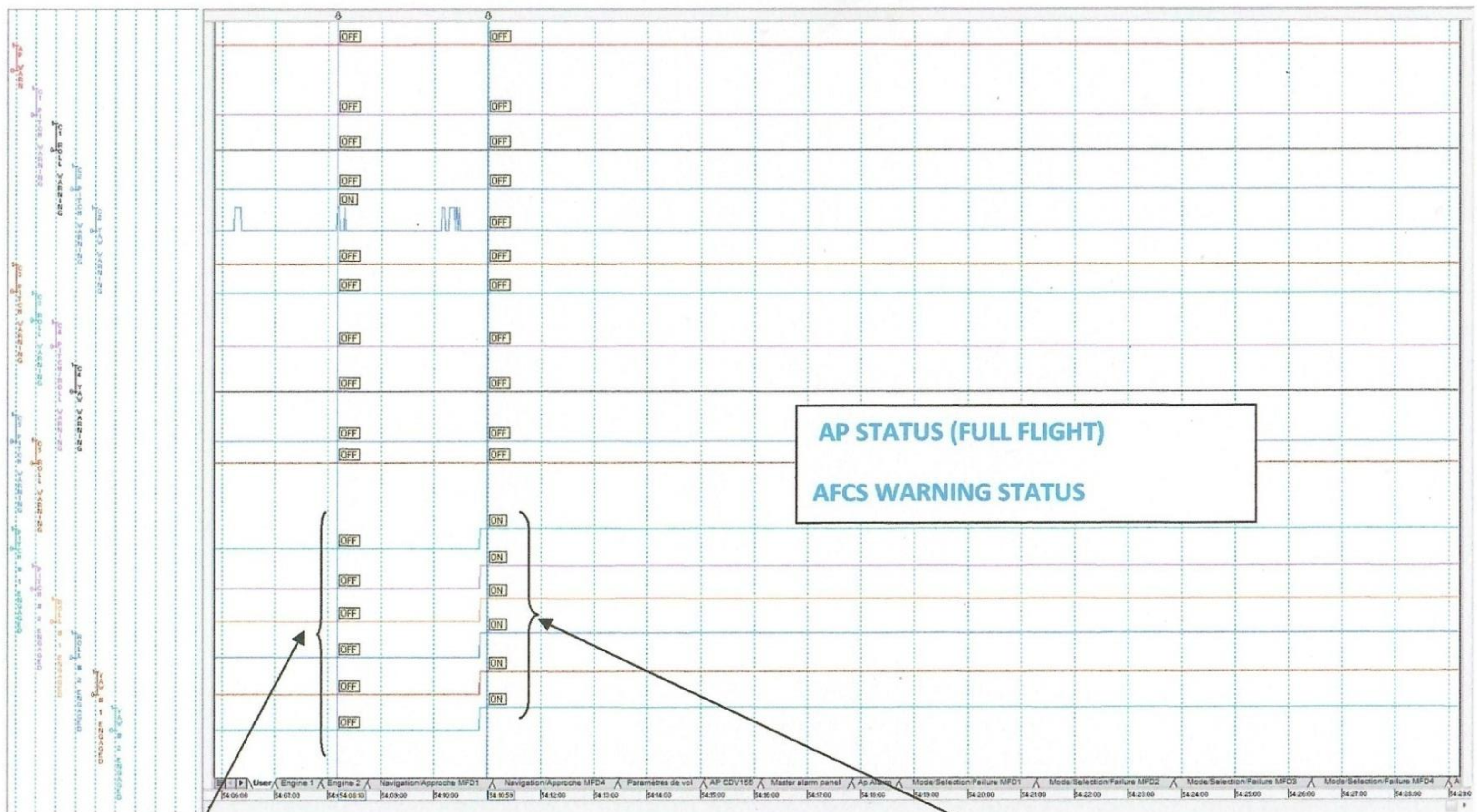
1. If the pilot doesn't take the stick, the AFCS keep the helicopter at 0° roll.
2. If the pilot performs actions on the stick without TRIM release action, the AFCS roll reference remains 0°. In this case, the aircraft returns to 0° roll attitude, when the pilot releases the stick.
3. If the pilot performs actions on the stick with TRIM release action, the AFCS synchronizes the roll attitude to the current attitude, then keeps and holds the roll attitude set by the pilot when he releases the TRIM release button.



The helicopter had climbed at the rate of 400 ft/ min to acquire an altitude of 3000 ft. Heading during this period has followed the selected reference of W45.35°. It acquired and followed the selected altitude of 3000 ft. AFCS has ensured SAS (damping) during hands on action.


AFCS LATERAL/YAW (HEADING VARIATION)
LAST 2 MINUTES
HDG mode still engaged - reference W114.26°. Heading started to move away from the recorded heading reference.
Heading (red) increases up to W107.28° Autopilot commands 3.52° left bank in order to recover the heading.
Heading reached W101.25° whereas the recorded heading reference was still -114.26°. The roll bank reached 9.14° (right roll).
Heading deviation increases up to 19.69° (114.26°-94.57°) then returns slightly towards the reference.
The pilot set the heading reference (green) to -107.23°
Lateral cyclic pitch fluctuation (purple) occurs meaning that the pilot recovers (hands on). Roll bank is 17.93° (blue)
The pilot is still hands on (lateral cyclic pitch fluctuation) and disengages heading upper mode. Roll bank is 23.55° (blue)

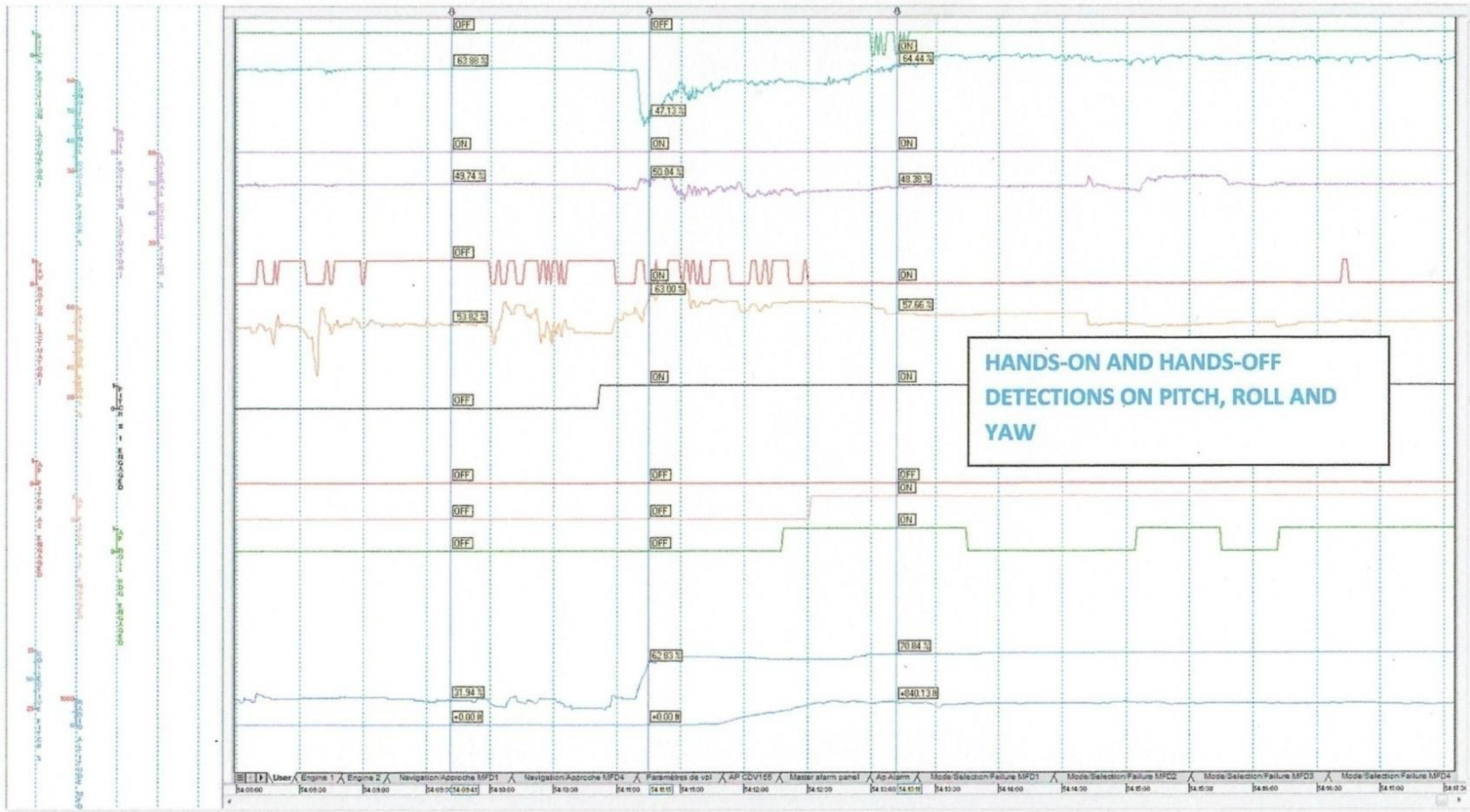

ALT mode engaged after altitude reference is reached (idem Curve 3/marker 3)
Longitudinal cyclic pitch fluctuation meaning that pilot recovers (hands on)
ALT mode disengaged
AFCS LONGITUDINAL
LAST 2 MINUTES



Pitch #1 & #2 engaged, Roll #1 & #2 engaged, Yaw #1 & #2 engaged are at OFF State i.e. AP is in disengaged state.

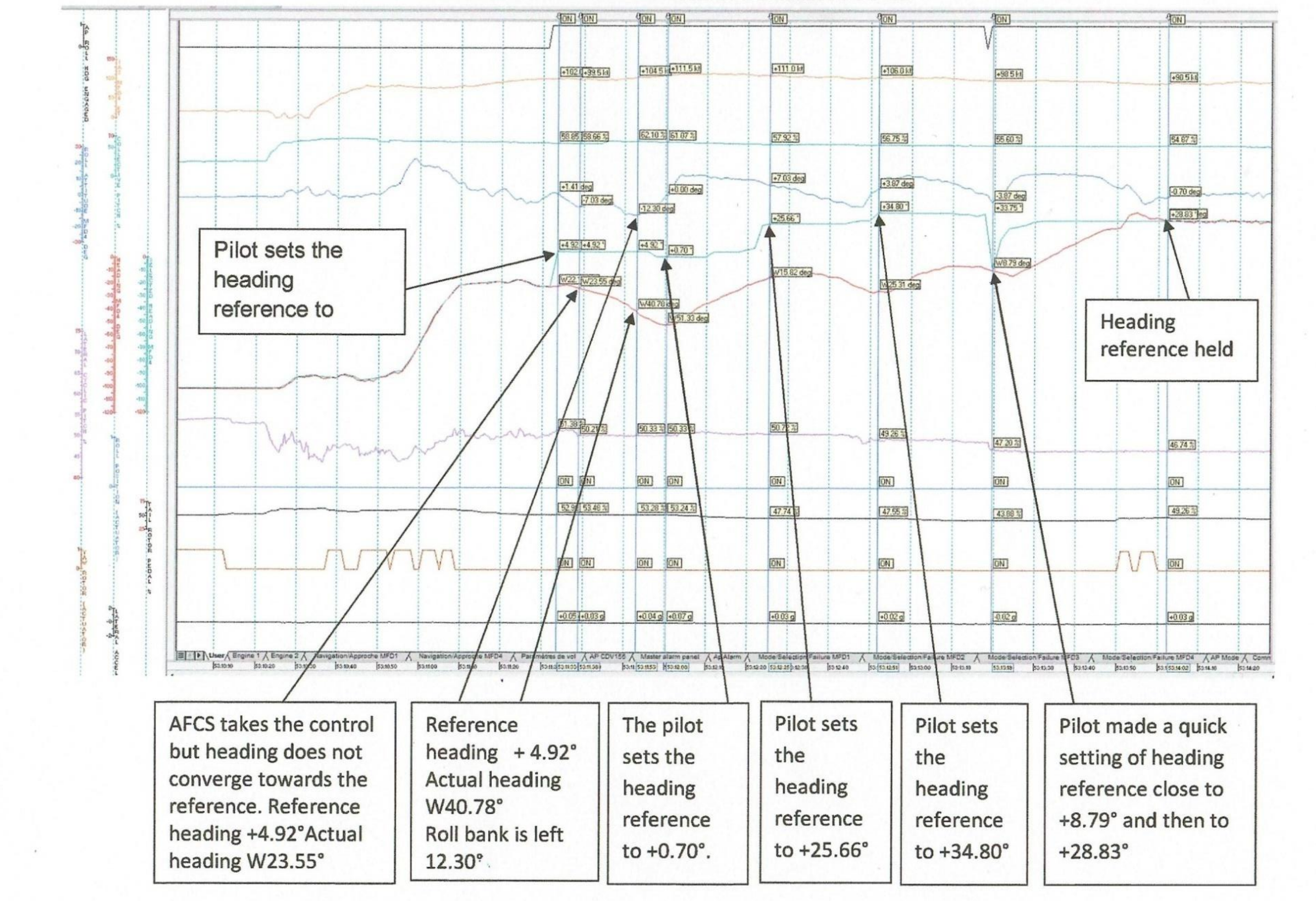
The parameter "C2 yaw" warning was a false warning because autopilot AP155 does not monitor if AP is disengaged.

Pitch #1 & #2 engaged, Roll #1 & #2 engaged, Yaw #1 & #2 engaged are at ON State i.e. AP is in engaged state. No AP warning during flight.

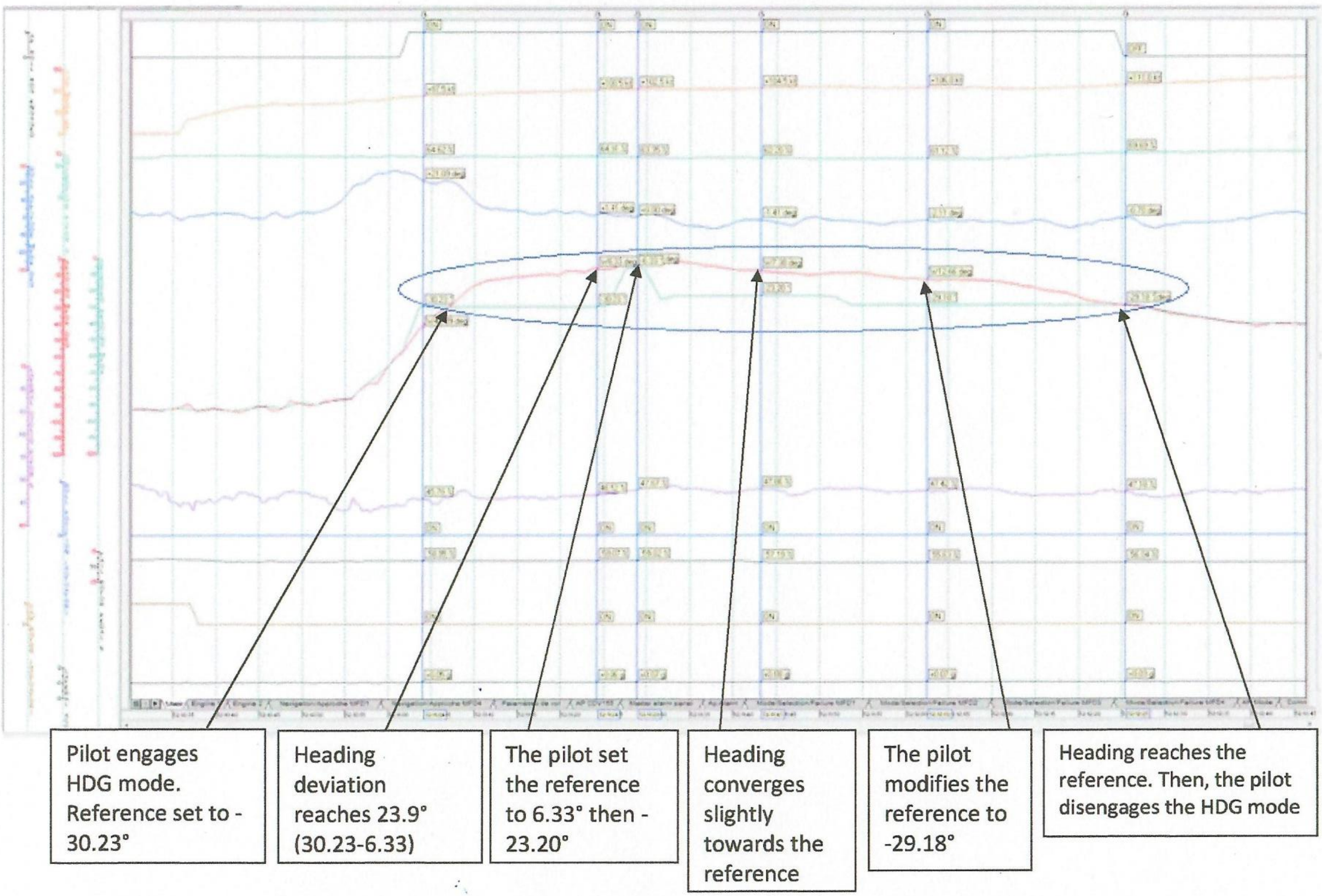


	Cyclic stick and pedal movement	State of Pitch hands-on detection ("pitch position actuator " parameter)	State of Roll hands-on detection ("roll position actuator "parameter)	State of Yaw feet-on detection ("yaw rotor actuator" parameter)
Before take-off and till AP engagement	No movement	OFF	ON	OFF
During take-off (AP engaged).	There was movement	OFF (Detector frozen to OFF position)	ON	OFF
During cruise at 700ft	Cyclic stick and pedal activities managed by AP	recovers functioning for few seconds	ON (has not changed during flight – Failure of recording of Hands ON)	OFF

HEADING DEVIATIONS DURING TEST FLIGHT



HEADING DEVIATIONS DURING FLIGHT JUST BEFORE 600 HRS. INSPECTION



HDG mode deviation as shown above (for three flights) is identified as an AFCS malfunction and the pilot has to refer to the Flight Manual to check if there is some flight limitations associated to this observation. In two pilots' flight, no upper mode is mandatory. Thus, the crew has two options:-

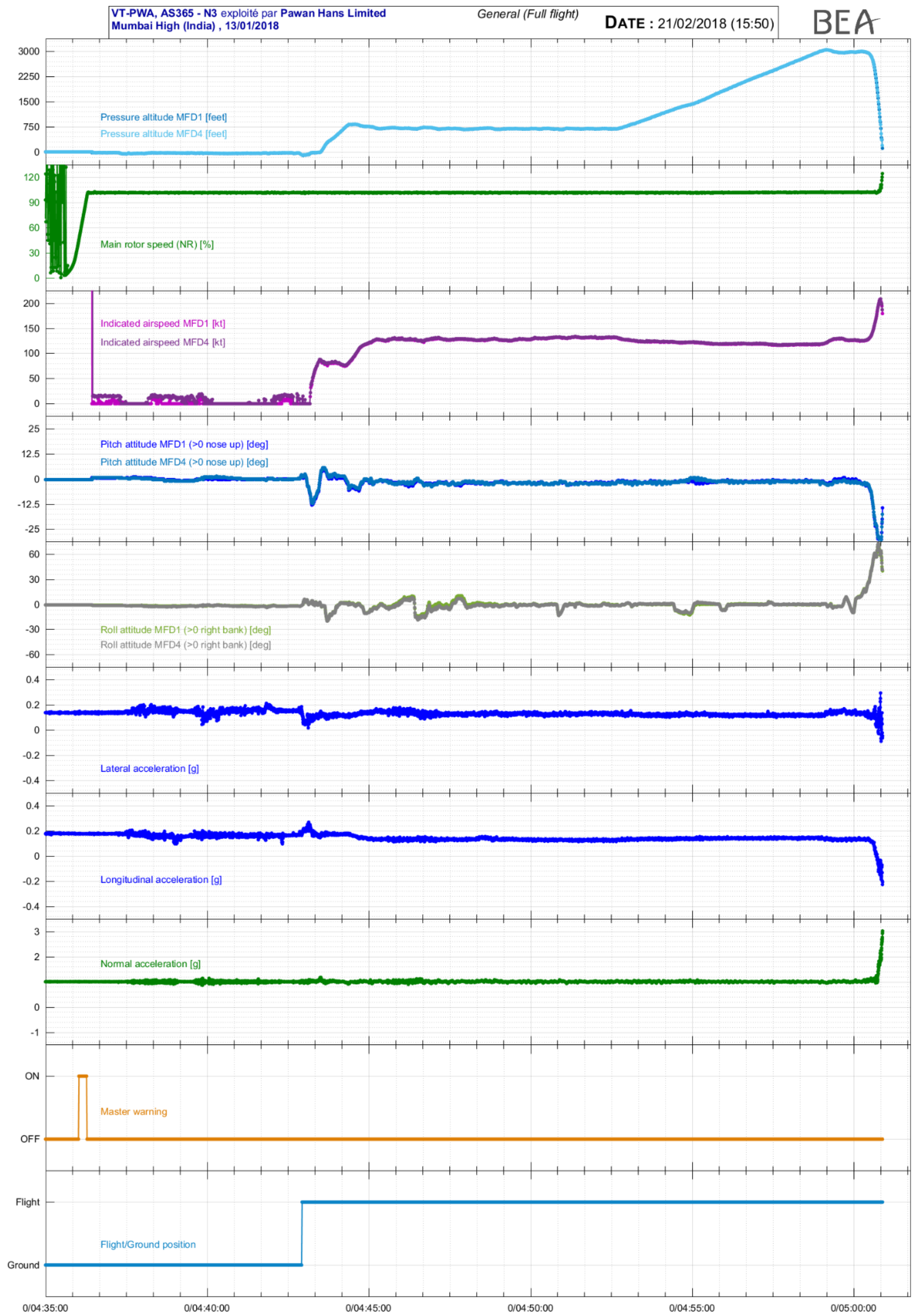
- Either to ask for a maintenance action before the next flight in order to recover heading mode proper functioning. Or
- To advise crew for the next flights, through the aircraft document follow up, that the HDG upper mode cannot be used anymore.

Records of pitch and roll hands-on detectors ("pitch position actuator" and "roll position actuator" parameters) presented some inconsistencies during the accident and previous flights but do not impact autopilot functioning (this is only a recording issue of these parameters in the Flight Data Recorders but the Automatic Flight Control System functions associated to these parameters were operated correctly).

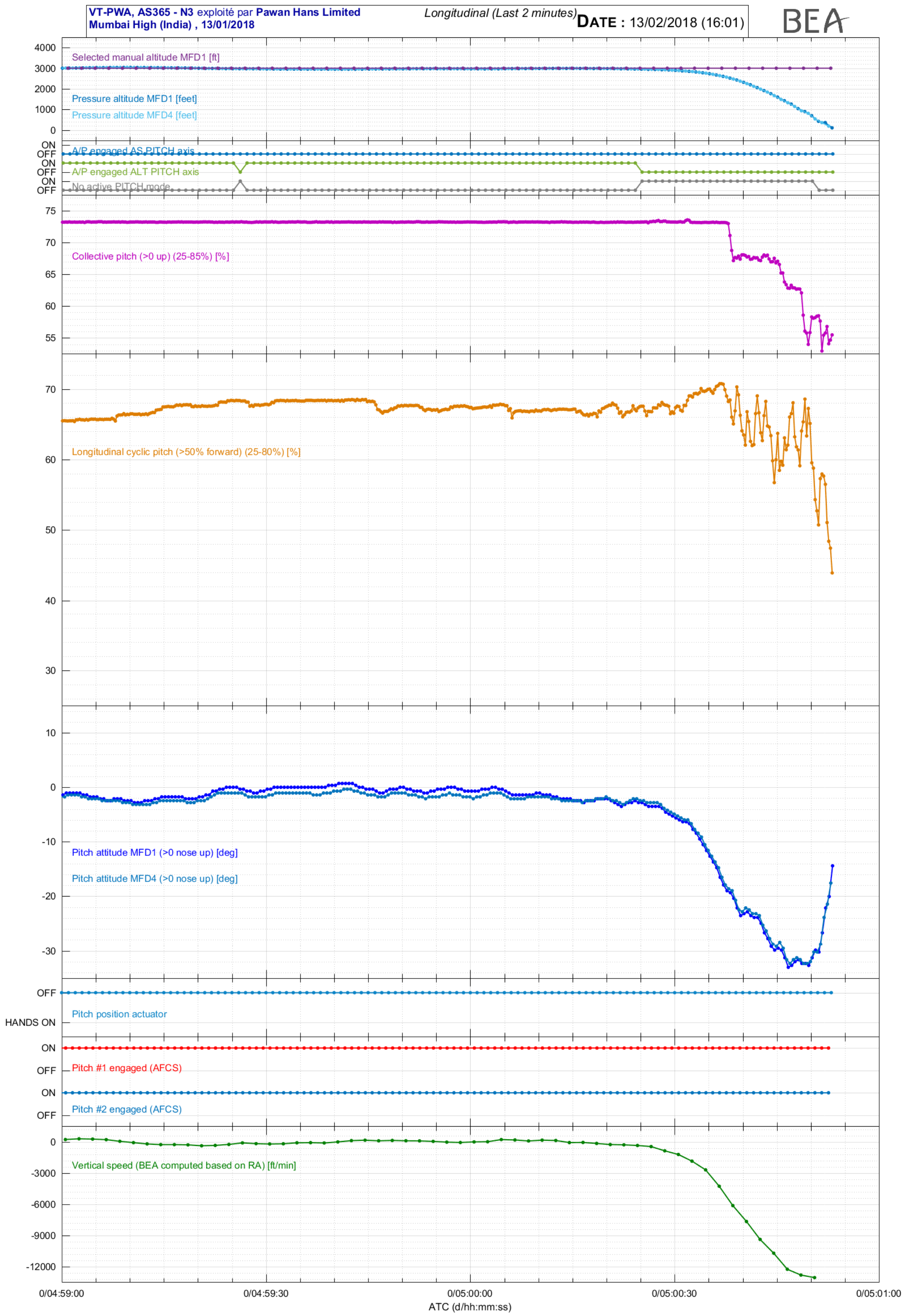
Airbus Helicopters simulation has not shown any abnormal behavior of the helicopter. It was indicated by them that this problem could come from either MFD4 output defect or CDV85 input defect.

Sequence of Events

Detailed discussions on wreckage examination, preliminary FDR observations and other evidences were held with BEA France. FDR data available for the test flight as well as some previous flights was also provided for analysis. BEA has provided detailed reports as mentioned above. As per the reports, during the DFDR parameter analysis, it was observed that the parameters analysis was not enough to have the exact scenario of the last phase of flight. Further analysis was required by synchronizing CVR and FDR data. As, in the FDR data, the values of time parameter were not consistent, therefore, ATC time as given in the file "Ship Plotter Log Extract VT-PWA.pdf" was used by BEA to establish the flight chronology of the Accident. Synchronization between ATC time and FDR time was obtained by using the respective recorded flight paths. Synchronization between CVR and FDR was obtained using "NG difference warning" which was triggered at the beginning of the flight.



VT-PWA, AS365 - N3 exploité par Pawan Hans Limited
Mumbai High (India) , 13/01/2018
General (Full flight)
DATE : 21/02/2018 (15:50)
Pressure altitude MFD1 [feet]
Pressure altitude MFD4 [feet]
Main rotor speed (NR) [%]
Indicated airspeed MFD1 [kt]
Indicated airspeed MFD4 [kt]
Pitch attitude MFD1 (>0 nose up) [deg]
Pitch attitude MFD4 (>0 nose up) [deg]
Roll attitude MFD1 (>0 right bank) [deg]
Roll attitude MFD4 (>0 right bank) [deg]
Lateral acceleration [g]
Longitudinal acceleration [g]
Normal acceleration [g]
Master warning
ON
OFF
Flight/Ground position
Flight
Ground
0/04:35:00
0/04:40:00
0/04:45:00
0/04:50:00
0/04:55:00
0/05:00:00
ATC (d/hh:mm:ss)



VT-PWA, AS365 - N3 exploité par Pawan Hans Limited
Mumbai High (India) , 13/01/2018
Longitudinal (Last 2 minutes)
DATE : 13/02/2018 (16:01)
BEA
Selected manual altitude MFD1 [ft]
Pressure altitude MFD1 [feet]
Pressure altitude MFD4 [feet]
A/P engaged AS PITCH axis
A/P engaged ALT PITCH axis
No active PITCH mode
Collective pitch (>0 up) (25-85%) [%]
Longitudinal cyclic pitch (>50% forward) (25-80%) [%]
Pitch attitude MFD1 (>0 nose up) [deg]
Pitch attitude MFD4 (>0 nose up) [deg]
Pitch position actuator
HANDS ON
Pitch #1 engaged (AFCS)
Pitch #2 engaged (AFCS)
Vertical speed (BEA computed based on RA) [ft/min]
0/04:59:00
0/04:59:30
0/05:00:00
0/05:00:30
0/05:01:00
ATC (d/hh:mm:ss)

All parameters that were plotted on the graphs were checked and found consistent by the BEA. However, some other parameters that had been checked were found to be unreliable. These were as follows:-

C2 Yaw Warning

Parameters recorded in the CVFDR described the state of the AP and the associated warnings. Among these parameters, "C2 yaw warning" activated several times from 04:37:33 until 04:42:12 (ATC time). This warning highlighted a discrepancy between the yaw attitudes acquired by the two acquisition lines. However, this discrepancy was at a computed law level, and was not considered significant as the Auto-Pilot was not activated at that time (Ground Phase).

Position Actuators

Roll and pitch position actuators parameters indicate at what point the pilot or the copilot hands were on / off on the relevant axis, whereas the yaw position actuator parameter indicates at what time the pilot or the copilot feet were on /off.

- The recording of the yaw position actuator was found valid during the accident flight and the earlier flights.
- The recording of roll position actuator was found invalid. It was recorded as "ON" state on the previous flights and on the accident flight.
- The recording of the pitch position actuator was found invalid on the accident flight. On the previous flights, the parameter seemed to have an erratic behavior.

According to analysis provided by Airbus Helicopters, however, the three position actuators seemed to have functioned as desired. The issue was only a recording issue and has not affected the behavior of the AFCS.

Heading

The heading provided by MFD1 was on the Pilot Monitoring's side (left) whereas the heading provided by MFD4 was on the Pilot Flying's side (right). A discrepancy of the heading between MFD1 and MFD4 was observed in the parameters. The heading provided by MFD4 was chosen to be the heading of reference as it was the one used by the AFCS to compute the different heading references and the one used by the Pilot Flying.

VHF keying

The VHF keying parameter recorded in the CVFDR was inconsistent with the ATC radio transmissions. This parameter has not been taken into account for the synchronization between the FDR and the ATC times.

In the following tables, the values of FDR parameters with respect to time are given. The first table gives the values of various controls, heading (actual & selected) and roll. The second table starts from the time AP was disengaged and the crew tried to control the helicopter manually.

Time	Lateral Cyclic Pitch	Tail Rotor Pedal	Selected heading	Actual heading	Roll
04:59:02 to 04:59:16	Remained steady (49.4%)		-114°	-108°	-3° to 1°
04:59:17 to 04:59:37	49.4%		-114°	-108°	-2.5°
04:59:38 to 04:59:59	49.4%		-114°	-95°	9° and then -9°
05:00:00	changed from 49.4% to 47.4%		-108°	-99°	
05:00:02		58%	-108°	Continuous deviation	
05:00:19	49.3% (Right bank order) fluctuating	57.2%	-108°	-72°	

AP HDG and ALT Mode Disengaged

05:00:24	• AP HDG and ALT mode disengaged (Manual) • Roll was between 21° and 23.5° (right bank), increasing • Pitch was -2° and started to decrease IAS was 127 kt and

	started to increase
	• Normal acceleration was stable at around 1.05 g
	• Lateral acceleration was stable
	  - Collective pitch was stable at around 73%
	  - Longitudinal cyclic pitch was stable at around 67% (>50% = forward)
	  - Lateral cyclic pitch was 47% and fluctuated between 47% and 50% (right bank order) during 10 seconds.
	  - Tail rotor pedal was 56% and started to decrease progressively (less right pedal) during 10 s.
	
	❖ The maximum heading deviation at upper mode disengagement was 57°.
	❖ Maximum roll angle commanded by the A/P is 22°.
	❖ On this helicopter, the disengagement of A/P upper modes is manual.

05:00:27	➢ PM : "Check bank" Isko thik kar lo ye, isko isko (Please correct it, this this)
	• Roll was 27° (right bank) and continued to increase
	• Pitch was -2.8, decreasing
	  - Lateral cyclic pitch was 49% (+/-1%) (right bank order)
	  - Collective pitch was stable at around 73%
	❖ Pressure altitude started to decrease
	❖ Pilot flying didn't apply left order on the lateral cyclic.

05:00:30	➢ PM : "please check bank" • Roll was 35° (right bank) and continued to increase • Pitch was -4.9°, decreasing - Lateral cyclic pitch was between 48% (right bank order) and 51% (left bank order) ❖ Pressure altitude was 2864 ft ❖ IAS was 132 kt ❖ Before A/P upper modes disengagement, aircraft was levelled at 3000 ft.
05:00:32	➢ PM : "yeah" " Bank" ➢ PF : "I am keeping the aircraft steady" • Roll was 40° (right bank) and continued to increase • Pitch = -6.0°, decreasing faster - Longitudinal cyclic pitch was stable at around 68% (>50%

	- forward) ❖ IAS = 135 kt ❖ Pilot flying continued to apply a forward order on the longitudinal cyclic pitch.
05:00:36	➢ PF : “Don’t worry” • Pitch was -13.7°, decreasing ✚ Longitudinal cyclic pitch was stable at around 70% (> 50% = forward) ❖ Pressure altitude 2705 ft ❖ Computed vertical speed was about 4000 ft/ min

05:00:38	➢ PM : “Bank bank please”
	• Roll stabilized at around 60° (right bank)
	• Pitch was -18.6°, decreasing
	• Pressure altitude was 2567 ft
	• IAS was 146 kt
	  ✚ Lateral cyclic between 48% (right bank)
	  ✚ Lateral cyclic pitch started to oscillate dynamically between 48% (right bank order) and 55% (left bank order)
	  ✚ Longitudinal cyclic pitch started to oscillate dynamically between 57 and 70% (.50 % = forward)
	  ✚ Tail rotor decreased and stabilized to 41% (left pedal)
	  ✚ Collective Pitch was 73% and stabilized to 67%

05:00:40	➢ PF : “nahi no yaar (No no)” • Pitch was -23°, stabilizing • IAS was 162 kt ✚ Collective Pitch stabilized to 68% Pressure altitude was 2372 ft
05:00:41	➢ PM : “Ok ok ok, chodo chodo (ok, ok, ok leave leave)” • Normal acceleration reached 1.2 g and continued to increase
05:00:43	➢ PF : “I got her” • Pitch was -25.3°, decreasing • IAS was 178 kts • Pressure altitude was 1984 ft ✚ Collective Pitch stabilized to 68%
05:00:44	➢ PM : “Acha ok, you got controls”

	• Gong audio warning • Pitch was -25.3°, decreasing • Pressure altitude was 1841 ft • IAS was 185 kt ✚ Collective Pitch stabilizing to 67%

05:00:45	• Roll was 72° (right bank) and started to decrease
	• Pitch was -29.2°
	• Pressure altitude was 1670 ft
	• IAS was 191 kt
	  ✚ Lateral cyclic pitch increased from 54% to 68% (left bank order) in 1 s
	  ✚ Collective Pitch went down from 67% to 63%
	Computed vertical speed was about 10 000 ft/ min

05:00:46	➢ PM : "I got her"
05:00:47	➢ PF : "hold on"
05:00:48	➢ PF : "chhodo (leave)" • IAS was 207 kt and started to decrease • NR was 103% and started to increase • Pitch was -31° and started to increase ✚ Collective Pitch went down from 63% to 54%; then to 58%
05:00:49	• NR increased • Lateral acceleration reached a maximum of 0.22 g • one second later a minimum of -0.14 g • Normal acceleration reached 2.1 g and continued to increase
05:00:50	• High NR warning • The warning sounded until the end of the CVR recording
05:00:51	• Decision height warning • The warning sounded for 1.2 s
Last Recorded Parameters	
05:00:51	✚ Go Around pitch A/P mode engaged
05:00:52	• NR= 124%
05:00:53	End of recordings • Pressure altitude = 107 ft • Radio altitude = 423 ft

	• IAS = 179 kt • Pitch = -17.6° • Roll = 40.1° (right bank) • Collective pitch = 55.5$ • Lateral cyclic pitch = 43.9% (backward order) • Tail rotor pedal = 30.8% (left pedal) • Normal acceleration= 3.01 g • Lateral acceleration = -0.10 g • Longitudinal acceleration = -0.21 g • Latitude = 72.44953 • Longitude = 19.41658 The last recorded position was at about 15 NM from the land.

1.17 ORGANIZATIONAL AND MANAGEMENT INFORMATION

1.17.1 PAWAN HANS LIMITED

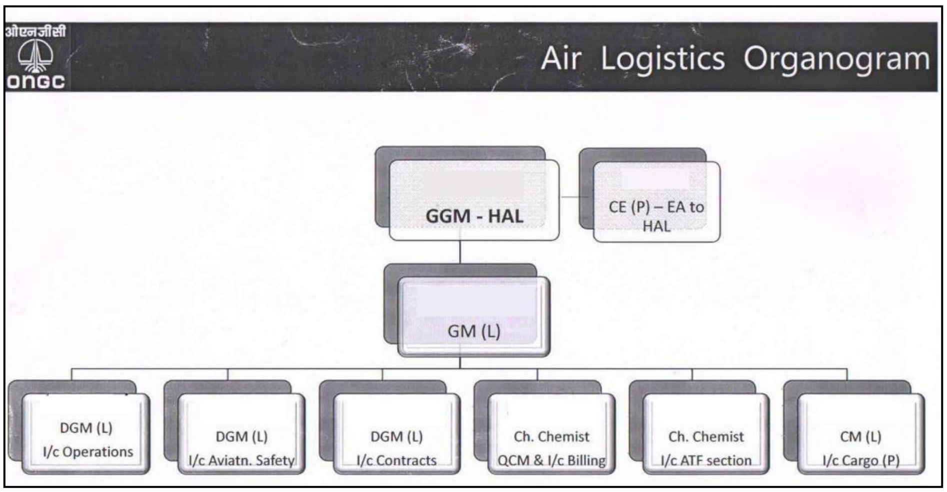
The operator was incorporated as a company in October, 1985. It is a non-scheduled air transport operator with valid NSOP and is engaged in helicopter charter operations. It gives support to petroleum sector mainly ONGC; connecting areas in the North and North East; travel tourism and intra city transportation. The company carries out operations and maintenance contract of helicopters across the country. The Board of Directors is the apex body and its normal operations are overseen by a CMD. The helicopters based at Juhu, Mumbai undertake crew change (providing transport facility of ONGC offshore employees) service and production sorties in Mumbai off-shore. In addition, PHL also provides helicopter for medical causality evacuation.

As per the PHL Operations Manual, functioning of GM (Regions) includes supervision of all operations on all types of helicopters operated by the company in his region, coordination of the maintenances activities and engineering support services and supervision of training program for pilots, examiner/ instructor/ check pilot/ check air crew in consultation with DGM (Ops) and DGM (Training). At the time of accident, the Mumbai base was headed by a GM level officer with marketing background.

1.17.2 OIL & NATURAL GAS COMMISSION (ONGC)

ONGC is the largest producer of crude oil and natural gas in India. It has an in-house service capability in all areas of Exploration and Production of oil & gas and related oil-field services.

The Group General Manger (Head Air logistic) ONGC work as Installation Manager for Air Logistics providing support of helicopter services for offshore operations and he is assisted by a officers(Non-aviation background) for carrying out duties. It was intimated that there is no document wherein the roles and responsibilities of the various designation is defined. An Air Logistic Organogram was provided as below.



The following information was collected which is based on the procedures followed by the helibase officials and is not documented. GM Logistics looks after interaction with helicopter operations and regulatory authorities regarding operation in addition to other administrative and financial duties. DGM Logistics is responsible for daily scheduling of helicopters including interaction with user sections for prioritization and optimal utilization of helicopter available.

Coming to helicopter operations and aviation safety, ONGC had appointed DGM (Air Safety) to look after Aviation Safety. Besides, Aviation Safety, he is also responsible as HSE incharge at helibase. As per the organogram, he reports to the Head (Air Logistics), helibase through GM (Logistics). He is not involved with day to day Operations and ONGC has a DGM (operations) who controls helicopter operation and interacts with operations (including pilot) of operator. His duties include:-

- Ensuring that pilots/ helicopters deployed by operators are as per ONGC AS 4 standards. Monitoring helicopter performance standards.
- Inspecting and auditing document of helicopter and carrying out physical check when helicopters are offered to ONGC for operation.
- Carrying out investigations whenever any incident takes place.
- Ensuring continuous airworthiness of helicopters whenever helicopters are offered to ONGC after snags.
- To ensure compliance of instructions of DGCA India.
- To audit the documents of pilots and verify the suitability of pilots for adherence to ONGC Aviation policy and DGCA.
- To monitor and liaise with various Assets & Services and operators for implementations of observations received through Hazard Alert Cards. Inspect helidecks for its condition and safe operation of helicopters.

Procedure for Requisition and Execution – Offshore Sortie

- As per weekly helicopter schedule programme, the user sections (i.e. production and drilling services) prepare the Request for Manifest (RFM) in SAP system on previous day of schedule. Concerned officers in each user section are authorized for creating RFM in SAP system.
- Upon its creation, RFM flows in the system and is accessed next day at Juhu Helibase Reporting Counter, which adopts the RFMs and creates passenger manifests as per available payloads.
- Generally, RFM is created by the user section, as per the priority and same is adhered to. However, in case of variations due to operational requirements of the user, the same is communicated to the helibase telephonically/ through IP messenger, as per instructions normally at the level of General Manger of end-user section.
- To cater any offshore emergency / pressing urgent requirements such as visit of VIPs, urgent onsite requirements of any oil-field specialist etc, Juhu helibase

has been given special permission to create RFM. However, this authorization is used only in exceptional situations of such requirements.

Aforesaid SAP process had been designed jointly by ONGC Core Team (New Delhi) along with SAP professionals in early 2004. The end users are given hands on training for familiarization from time to time. There is no separate documentation of the above.

Manual Manifest Creation

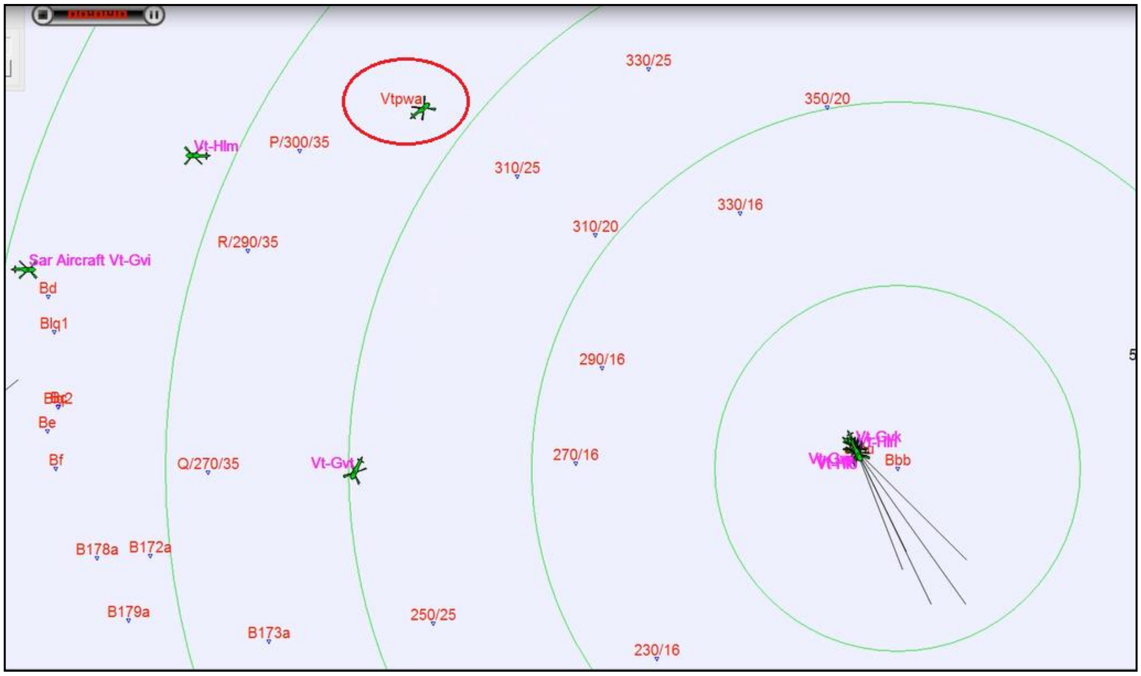
In case of a network / system failure, ONGC prepare manual manifests for continuity of offshore helicopter operations, since operational requirements are continuous in nature. However, the same is regularized as soon as system is restored. However, RFM from user sections are always prepared in system only.

1.18 ADDITIONAL INFORMATION

1.18.1 AIS (AUTOMATIC IDENTIFICATION SYSTEM) – TRACKING

Automatic Identification System (AIS) is used by ONGC for tracking of ships in real time. ONGC has made it mandatory to have such equipment on helicopters serving offshore oilfield. It was originally used as a collision avoidance tool as it enables commercial ships to see each other more clearly in any conditions (visibility) and to improve the helmsman‘s information about the surrounding environment. Combined with a shore station, this system also offers authorities and maritime safety bodies with the ability to manage maritime traffic and reduce the hazards of marine navigation. Communications integrity is maintained even in overload situations.

By using suitable AIS receiver and plotting software, it is possible to monitor & track all ships and helicopter equipped with AIS system in real time. Presently, ONGC is using software ―Ship Plotter. A screenshot showing the pictorial output of ships and helicopters (including VT-PWA) is shown below:-



1.18.2 600 HRS / 02 YEARS MAINTENANCE SCHEDULE

The helicopter was maintained as per the DGCA approved maintenance program. The last 600 hrs / 02-year inspection was carried out from 01.12.2017 to 06.01.2018 including the test flights of 54 minutes. Accident flight was the first flight after 600 hrs inspection. The helicopter had done 5966 Air frame hours till that date.

In addition to the normal 600 hrs schedule, following maintenance work order were issued by the CAM (WR), PHL.

- Carry out self-test of ELT KANNAD
- Replace rowing bar
- Replace one main rotor servo
- Replace tail rotor servo
- Carry out Service Bulletin (SB) i.e. check of the emersion probe of CVFDR and flotation gear system
- Carry out SB i.e. Check for corrosion of the connection between the main landing gear legs and the upper part of the torque link.

- Carry out SB (DGCA MANDATORY MOD) i.e. maintaining the charge of COBHAM or air precision emergency lighting battery.
- Carry out SB i.e. check the main rotor blades tip for security and if required change the rivets.
- Check of the main rotor mast / hub attachment / screws (bolts) as per the requirement of the manufacturer in view of the failure of main rotor hub /mast attachment screws.
- Carry out to check torque confirmation box resistance values as per the EASA AD for both engines.

During this 600 hrs inspection, a ground run was carried out on 28.12.2017 for carrying out oil / fuel leak check and no fuel / oil leak was found. During this ground run, all parameters except main rotor and tail rotor vibrations were found within limits. Adjustments were carried out on main rotor and tail rotor. Helicopter was offered for ground run to check the main rotor and tail rotor vibrations on ground.

On 03.01.2018, another ground run was carried out and main rotor/ tail rotor vibrations were found within acceptable limits. Subsequently, Helicopter was offered for flight to check the vibration.

Main rotor vibrations were found above specified limits during forward flight. Adjustments were carried out as per Maintenance Manual. Main rotor vibrations were to be further checked during the next flight.

On 04.01.2018, as per Performa power margin of both engine was checked and found satisfactory on ground. Aircraft was offered for temperature margin check for No. 1 Engine during forward flight. On 05.01.2018, as main rotor vibrations were found above specified limits, adjustments were carried out. Aircraft was offered for forward flight to check the main rotor vibrations.

During forward flight, vibrations in all phases of flight were found to be within acceptable limits. Aircraft was offered for test flight as per test flight Performa.

Range and performance check of radio equipments, com, Nav &radar to be carried out during test flight.

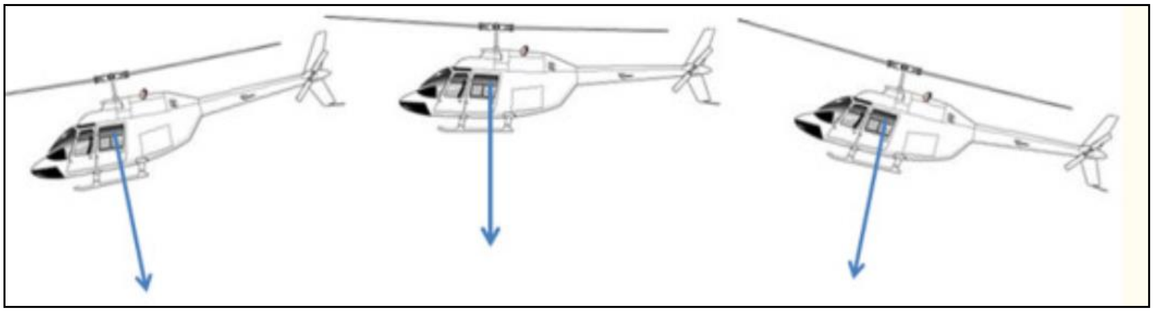
As per filled in Performa, after the flight on 06.01.2018, parameters were found to be within acceptable limit.

1.18.3 SPATIAL DISORIENTATION

Spatial disorientation or spatial unawareness is the inability of a person to correctly determine his/her body position in space. The three-dimensional environment of flight is unfamiliar to the human body. This creates sensory conflicts and illusions which cause spatial disorientation. These illusions occur because of complex motions coupled with certain visual scenes which are encountered under combination of adverse situation. The pilot is, therefore, unable to determine accurately the attitude or motion of the aircraft in relation to the surface below.

The hazardous illusions that lead to spatial disorientation are created by information received from motion sensing systems, which are in each inner ear. The sensory organs in these systems detect angular acceleration in the pitch, yaw, and roll axes. Sensory organs also detect gravity and linear acceleration. In flight, the motion sensing system may be stimulated by motion of the aircraft alone or in combination with head and body movement.

In a helicopter, there is no longitudinal force as in fixed wing aircraft. The force that both lifts the helicopter off the ground and drives it forward (or backward or sideways) is generated by the main rotor, and this force is always vertically upward relative to the fuselage of the helicopter, whatever the attitude may be with respect to the surface of the earth



ACCELRATION   CONSTANT VELOCITY   DECELRATION

The arrows indicate the magnitude and direction of the resultant force vector generated. The lift of the main rotor is the only source of force for both lift and forward acceleration or deceleration. Forward acceleration can only be achieved by putting the helicopter into a nose-down attitude. However, the force from the rotor remains predominantly vertical. In consequence, a helicopter feels to be in a level attitude whether it is accelerating, at constant velocity or decelerating.

One of the major illusions leading to spatial disorientation is "The leans”. A banked attitude which is entered too slowly may set in motion the fluid in the 'roll' semicircular tubes. An abrupt correction of this attitude can then set the fluid in motion and so create the illusion of a banked attitude to the opposite direction. The disoriented pilot may make the error of rolling the aircraft back into the original attitude or, if level flight is maintained, will feel compelled to lean to the original direction of bank, until this illusion subsides. In other words, if one doesn't roll quickly enough into a turn, the fluid in ears won't start moving, and brain thinks one is still straight-and-level.

This illusion or false impression occurs when information provided by sensory organs is misinterpreted or is inadequate. Possibility of non availability of horizon exists for flight over the deep sea particularly in case of a reduced slant visibility. In such a case, the disoriented pilot will feel that he is flying straight and level.

In flight, there are two principal sources of orientation information which are as follows:-

- the visual environment and
- the force environment.

Under certain circumstances, while flying, a pilot may be inadequately informed by the external visual environment and deceived by the force environment. Disorientation in flight is result of an unconscious misapplication by the pilot of the normal terrestrial rules of engagement. A pilot deprived of visual information cannot maintain his intended flight path by the feel of the aircraft alone.

1.19 USEFUL OR EFFECTIVE INVESTIGATION TECHNIQUES

Nil

2.0 ANALYSIS

2.1 FACTUAL ANALYSIS

Before analysis, of the various evidences which were collected by investigation and various reports provided by BEA, France is carried out, let us recall in brief what exactly happened.

The helicopter was operating flight a from Juhu to NQO platform. The helicopter was flown by the PF from the right seat and the PM occupying the left seat. It took off from Juhu and routed via K017 routeing for destination. The flight was cleared under Special VFR. During the initial out bound leg, the helicopter had drifted from the selected heading which was corrected by the crew. After reaching 25NM from Juhu at 700 feet altitude, as per the SOP, the helicopter turned towards point ‘P’ and initiated climb to 3000 feet. The ETA for ‘P’ was given as 0504 UTC. The helicopter was flown using “heading” mode of auto pilot. Short of ‘P’, the helicopter had levelled off on reaching 3000 feet.

After about 18 minutes of flight (approx 0501 UTC) and approaching ‘P’, the PM observed that the helicopter was drifting from its selected heading and apprised the PF of the same. This was acknowledged by the PF and he initiated corrective action. After about 10 seconds, the PM cautioned the PF again to check and correct the bank of the helicopter. However, the bank angle further increased. The PF at that moment told the PM not to worry as he is keeping the helicopter steady. However, the PM yet again cautioned the PF about the excessive bank and tried to over ride the controls. This was resisted by the PF and for the next 6 to 7, seconds there were dual inputs from both pilots.

2.1.1 HELICOPTER & ITS MAINTENANCE

The Operator is a CAR-145 approved Organization and the major maintenance work is carried out at Mumbai. At the time of accident, the Mumbai base was headed by a GM level officer with marketing background. The engineering staff (particularly avionics) travels to other stations for carrying out routine maintenance

/ checks and attend to the snags, if required. Even at times the person, though a part of the major maintenance team, was also being utilized for normal snag rectification or daily / weekly schedule maintenance. Although, the documentation for major maintenance carried out prior to the accident flight was complete but as brought out in the factual information, the engineering person could not devote quality time for the major maintenance. The deeper analysis of the information available would have resulted in rectification of the defects, though not reported or documented.

Frequent cannibalization (removal) of components/ equipment was carried out from one aircraft to another as a matter of routine. After test flight on 6/1/2018, the helicopter was in the hangar with some of the components removed. It is on record that the accident helicopter was provided on 12/1/2018 to ONGC after making the helicopter serviceable by installing certain components which were removed from another helicopter (grounded because of snag). Though it is not inferred that malfunction of any component has resulted into the accident but it is appreciated that frequent removal and reinstallation of the components induces unsafe probabilities.

2.1.2 CREW QUALIFICATIONS

Both pilots held valid licenses and were qualified on type. Their ratings were current. The PIC had a total flying experience of 13420 hrs and the co-pilot had a total flying experience of around 6850 hrs. Both had valid class I medical and had undergone proficiency checks as per the requirements. The crew had undergone pre flight medical including breath-analyser test before taking off for the first flight of the day and they were not under influence of alcohol.

2.1.3 WEATHER – OBTAINING & TRANSMISSION PROCEDURE / DOCUMENTATION

Up-to-date, accurate meteorological information is critical for offshore helicopters for flight planning purposes. Enroute meteorological information is also equally essential. The weather at Juhu including visibility was “Special VFR” but the weather en-route was hazy with poor slant visibility. As informed by the crew of another helicopter flying in that area and around the same time, horizon was not visible once climb was initiated from 700 ft upwards. However, vertical visibility was fine.

The crew was provided with the Juhu weather including visibility which was fine for special VFR operations. The enroute weather particularly beyond 25 NM from Juhu is normally not available with the crew and assessment is made by them during flight only. As mentioned above, on the day of accident, the weather enroute was hazy and the forward slant visibility downward was resultantly very less. This sufficed as one of the condition for the pilot to lose horizon while flying around 3000 feet over the sea.

2.1.4 WRECKAGE EXAMINATION

Evidences on the damaged parts of the wreckage retrieved from sea indicated that the aircraft was complete when it impacted water. The attitude at the time of impact was pitch down, a bank to right. The impact was high energy impact. Main and tail rotor were rotating at high RPM at the time of impact.

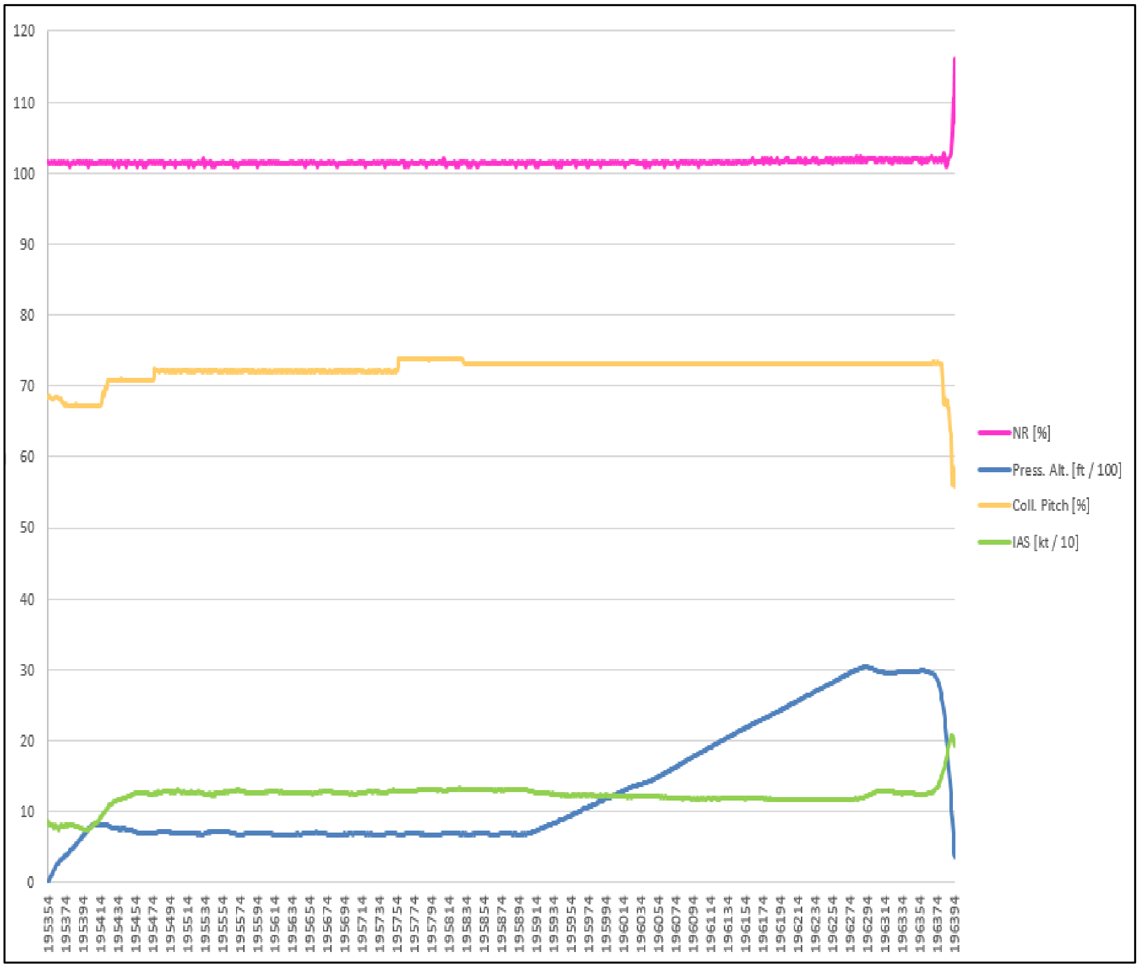
All observed damages, ruptures and deformations on the recovered parts of the wreckage (including the dynamic components, main and tail rotor flight controls, airframe, engines, etc…) are the consequence of overload resulting from the accident sequence and no pre-impact damage or disintegration was observed.

The condition of the star arms and blade attach beams showed that the main rotors were rotating under power when the blades impacted the sea. The damage was as a consequence of rotating blades impacting with water.

The examination of engines showed that the compressors and gas generators of both engines were in good condition. Evidences of rotation of Power Turbine and Output Shaft locations (Relative Circular Motions) showed that both engines were operating at the time of the accident.

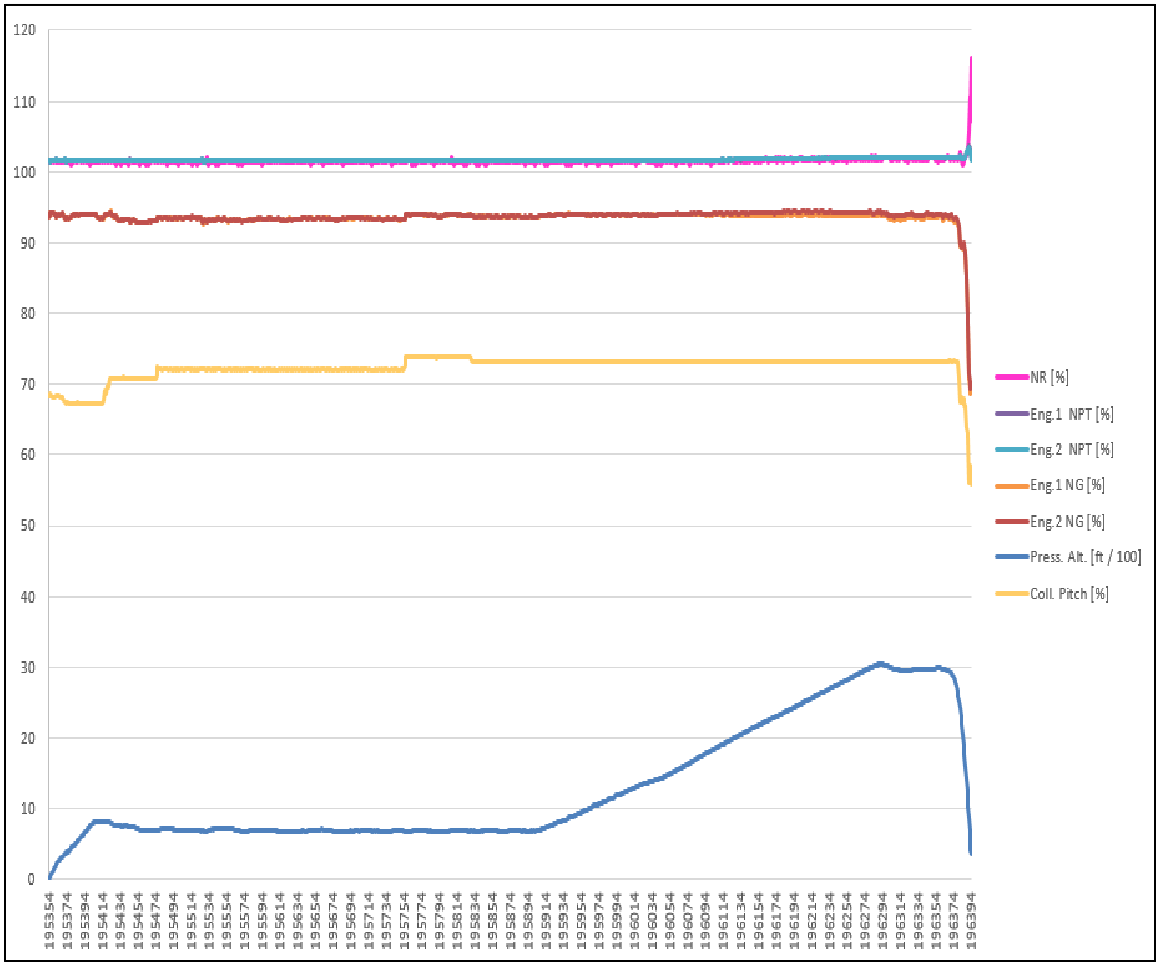
2.1.5 FDR ANALYSIS FOR ENGINES BEHAVIOR

Spectrum analysis of CVR audio recording and FDR analysis was provided by BEA for engine behavior. As per the FDR, the percentage of collective pitch, N_R, IAS and pressure altitude varied as given in the following graph.



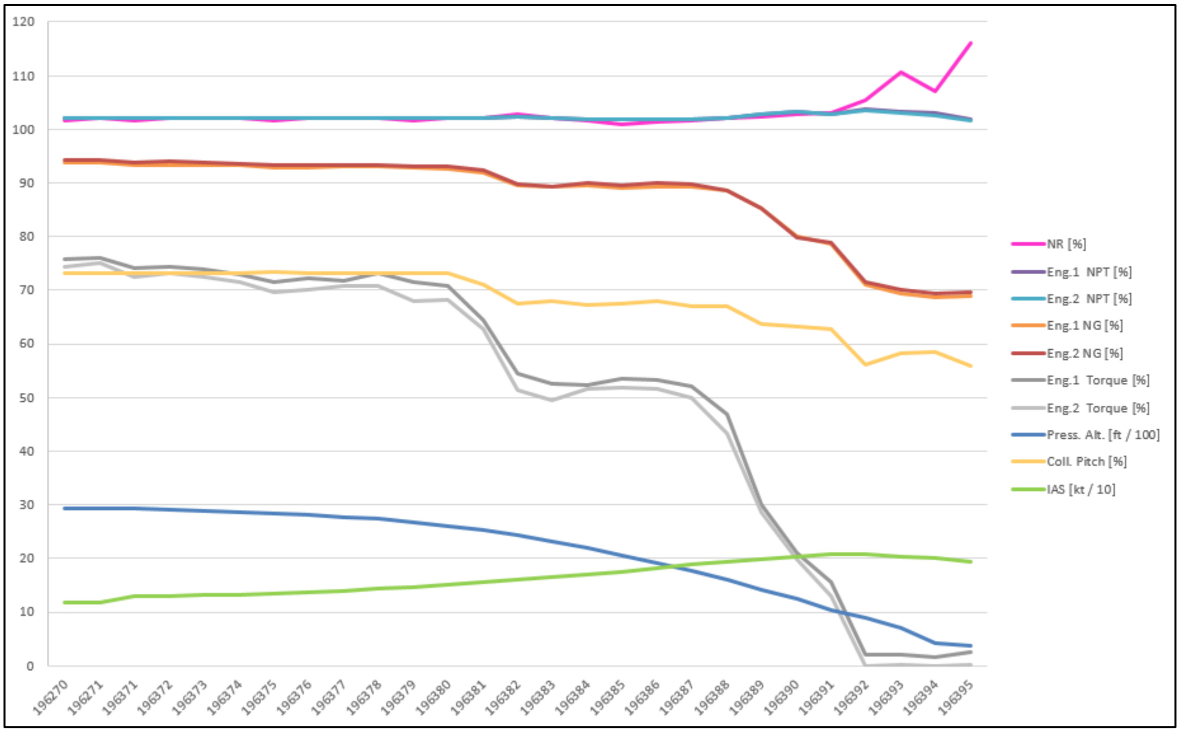
N_R was maintained at normal value for most of the flight which began to rise after the aircraft had started to lose altitude and gain speed. N_R increased sharply when the collective pitch went down.

N_{G1} & N_{G2} were stable and well synchronized till the aircraft started to lose altitude and gain speed. When the collective pitch went down, both N_{G1} & N_{G2} decreased sharply though in unison



The following graph is of the last 25 seconds of the flight for N_R, N_{PT}, N_G, Torque, IAS, Collective pitch and IAS. It can be seen that during the last 25 seconds of the flight, the helicopter started to lose altitude and gain speed. Power demand was decreasing. Both NG_1 & NG_2 and Torque of engine 1 & 2 started to decrease.

N_R remained normal though there was higher rate of descent coupled with decreasing collective pitch input. Power demand continued to drop. Thereafter, engines slowed down and NG_1 & NG_2 and Torque of engine 1 & 2 decreased significantly. During this time, collective pitch reduced further and N_R went into over speed. With Free wheels disengaged, the engines slowed down to idle and torques decreased to zero.



It was, therefore, concluded that both engines remained well synchronised for the whole flight. Approx. 25 sec before the end of recordings, the aircraft started to descend and gain speed. N_R was maintained at normal value. Consequently, the engines' control systems adapted to the reduced power demand by gradually slowing down the engines. Approx. 10 sec later, the collective pitch input started to decrease thus decreasing the power demand further. Consequently, the engines' control systems adapted again by slowing these down further.

Approx. 10 sec later, N_R exceeded the normal value and went into overspeed mode. This over speed was not generated by the engines because their control systems slowed these down to idle in order to maintain the Power Turbine speeds (N_2) at normal value. The rising gap between N_R and N_2 indicated that the free wheels on the main gearbox's (MGB) input shafts were disengaged. So

- **During the whole flight, the engines remained under automatic control and delivered the power required of them**
- **The engines' control systems reacted normally to the external conditions**

2.1.6 AFCS BEHAVIOR DURING FLIGHT

During the flights immediately prior to the major maintenance, heading deviations drift had occurred when HDG upper mode was selected. During the last flight before the major maintenance, when the pilot engaged HDG mode, the heading deviation increased until he modified heading reference twice (-6.33° then -23. 20°). Afterwards, the mode recovered slightly and was functioning until pilot disengaged HDG mode. The analysis of these flights phases showed that the pilot had changed heading reference settings several times before the heading mode was captured as expected.

The heading deviations drift which was though observed and known before the 600 hrs maintenance could not be attended to during maintenance. Heading deviations drift occurred during test flight after the major maintenance but was not reported.

During the test flight performed after major maintenance, heading deviations again occurred between HDG mode engagement and HDG mode held. The maximum heading deviation noted was 52.03° and the maximum roll bank was up to 12.30°. During this period, the pilot had reset the heading reference 5 times until the deviation was eliminated and the heading mode worked properly. The pilot did not report the defect after the test flight.

During accident flight, when the first deviation occurred, the pilot adjusted the reference but the deviation increased up to 62.14°. The pilot had taken over the controls and disengaged the HDG mode which was indicated by the stick lateral advancement rate, which was above the maximum speed of parallel actuator (TRIM). At that time, the roll attitude was between +19.69° and +22.5°. The maximum roll angle allowed by the autopilot is 22°.

The pilot carried out a slight heading reference modification before he disengaged the upper modes. This action was similar to those performed during the previous flights. One scenario could be that the pilot tried to recover the operation of HDG mode by using the same method as the one used during the previous flights.

From take-off and until heading deviation drift, the AFCS functioning and behavior was normal. No AFCS warning was observed during the flight until the end of the recording available. As soon as the pilot took over the control, AFCS had ensured normal SAS function (i.e. turbulence damping) and operated as expected. During this phase, there was no AFCS warning.

So it can be seen that to solve the heading deviations in flight (selected v/s actual), similar actions (small changes of heading reference) were taken by different pilots who flew the helicopter prior to the accident flight. Though for the accident flight also the crew tried to make changes in the heading reference, it is not known if pilots of the accident flight were aware of the issue before embarking on the flight.

Considering the AFCS architecture, the heading deviation could have been due to an erratic behavior of the heading reference signal provided by MFD4 to the CDV85 computer.

It can be concluded from the analysis of the AFCS data recording in the FDR that the system was operational, although some erratic heading deviations were observed when the heading mode (HDG) was engaged.

2.1.7 INCONSISTENCIES OF ROLL POSITION ACTUATOR AND PITCH POSITION ACTUATOR

Roll and Pitch position actuators parameters provide the hands-on / hands-off status of the relevant axis. The inconsistencies observed in parameters recorded in FDR for roll position actuator and pitch position actuator were a recording issue as the analysis of these parameters show that the roll position & pitch position actuators operated in correct sense as commanded by AFCS system. Roll position actuator parameter was no more alive during terminal phase of flight and remained at ‘ON’ status. Acquisition of pitch position indicator parameters also had erratic behavior. During the accident flight, it was at “OFF” state throughout except for a few seconds when it switched several times between OFF and ON state.

2.1.8 TEST FLIGHT

The test flight was the previous flight to the accident flight and was carried out as per the test schedule provided by the engineering. It was a part of the 600 hours maintenance. As already discussed, the crew composition for the test flight could have been better. While handing over the blank test flight schedule to the flight crew, there was no briefing by engineering to flight crew. Nor the flight crew asked for anything. They went through the columns to be filled as a routine. The flight crew was not sure if there was any SOP or regulation for carrying out such flight. The PF was aware that the PM has just joined the organization and got type endorsement recently. At times during the test flight, he had to explain to the PM about procedure or about monitoring of the parameters. The entries made in the schedule reflected were not from perspective as to that of a test flight. As an example, blank sheet of the test flight schedule was signed without any entry. On the other hand entries were made and signed for the checks which were not carried out during that test flight. To conclude, the test flight could have been carried out with more seriousness giving an opportunity to arrest the precursor (heading not holding) to the accident.

2.1.9 OCCURRENCE REPORTING CULTURE

In any organization, the backbone of safety is the data on the hazards, defects, incidents etc. From the analysis of FDR of the test flight, accident flight and general discussions with the engineering and operational personnel; it could be inferred that the system of verbal reporting was prevalent in the organization. Number of technical defects reported and documented was not in proportion with the sorties and flight hours, flown. This undocumented sharing of the information with technical staff hampered the snag rectification. Had the information regarding problem with heading mode during accident flight been available with engineer and/ or flight crew (which appeared repeatedly during flights earlier to the accident flight), the precursor i.e. non holding of the heading mode would not have been there.

2.1.10 MONITORING OF FDR DATA

The FDR data of the accident flight and a few flights prior to that revealed that the deviation of parameter was though recorded and available but was not taken note of for rectification. Investigation in order to analyze the flight went through the FDR readout system and analysis procedure (FOQA). The readout and analysis was carried out only for a very few parameters. This analysis was confined only to the exceedences values which prohibited detailed analysis of the readout of all parameters. The monitoring, therefore, was devoid of capturing any hazard or unsafe condition.

2.1.11 CONTRACT BETWEEN ONGC AND THE OPERATOR

The helicopters are flown for ONGC by the operator. Both organizations have signed a contract for this purpose. The contract has a liquidated damages clause (on hour basis) for non-provisioning of helicopter. As mentioned earlier, the helicopters for all sub bases were maintained and provisioned from Mumbai. In case of any snag requiring grounding of the helicopter, the serviceable components were frequently removed from the helicopter under maintenance. This was regular practice with the organization as there was always pressure because of liquidity damages clause which is neither safe nor desirable. There is preponderance of unsafe situations due to this clause.

2.1.12 IRREGULAR FLYING BY THE PIC

The scrutiny of records of PIC of helicopter revealed that he was off flying during 2015 and 2016 on 03 different occasions due to medical or unknown reasons. In 2016, he has flown only for 3 months. In 2017, he was again off flying for long periods. This fact was not appropriately handled and no document was provided to the investigation indicating that due diligence from safety perspective was carried out, for long absence of the PF from flying duties.

2.1.13 ONGC RADIO OFFICERS

Automatic Identification System (AIS) is used by ONGC for tracking of ships in real time. ONGC has made it mandatory to have such equipment on helicopters serving offshore oilfields. The system provides for automatic content resolution between system and other stations. The communications integrity is maintained even in overload situations. Using suitable AIS receiver and plotting software, it is possible to monitor and track all ships and helicopter equipped with AIS system in real time. Presently, ONGC is using software —Ship Plotter. It displays Ships & helicopters operating in the oil fields on a 2-dimensional map on the screen of computer. The Marine Radio officers thus can provide information of position of helicopters and transmit wind direction/ velocity to the flight crew. They are neither authorized nor competent to provide any guidance to the helicopters. This aspect was brought out in the investigation of the previous fatal offshore helicopter accident also.

2.1.14 AVIATION ELEMENT (PERSONNEL) IN ONGC

ONGC had appointed DGM (AS) to look after Aviation Safety. He is a retired Air Force (engineering) officer. Besides, Aviation Safety, he is also responsible as HSE incharge of helibase. As per the Organogram he reports to the Head (Air Logistics), helibase through GM (Logistics). He is not involved with day to day helicopter Operations. DGM (operations) controls helicopter operation and interacts with operations (including pilot) of operator. DGM (AS) is entrusted with

- monitoring helicopter performance standards;
- inspecting and auditing document of helicopter and carrying out physical check when helicopters are offered to ONGC for operation;
- ensuring continuous airworthiness of helicopters whenever helicopters are offered to ONGC after snags;
- to audit the documents of pilots and verify the suitability of pilots for adherence to ONGC Aviation policy and DGCA.

The above monitoring even if carried out religiously could not capture any latent hazard or contribute towards safe operation as viewed from the SMS point of view.

2.1.15 INTERIM SAFETY RECOMMENDATION

Preliminary analysis of the occurrence was carried out after taking into account the available evidence and holding series of meetings with BEA teams/ PHL/ ONGC. The interim observations were then forwarded to the operator after two months of the accident for taking follow up action in order to remove the situations which in combination with other deviations may cause an incident in future. Action taken report received from the operator indicated that the organization went into denial mode instead of taking these observations in a positive sense.

2.1.16 SUPERVISION OF MAINTENANCE AND OPERATIONAL ACTIVITIES

The helicopter had undergone 600 hours inspection which is one of the major inspections. One of the B1 engineers of the operator was told verbally to carry out the 600 hrs maintenance of the aircraft. There was no briefing by Continuous Airworthiness Manager (CAM). No evidences were available that CAM had carried out regular or random supervision. So, there was lack of due diligence on ground in the maintenance process especially to identify defects.

Similarly, there was no supervision of the operational activities on day to day basis as no senior person having adequate authority was available. The supervisory functions were being carried out as formality. The reason might have been shortage of manpower. So much so that there was no record provided to the investigation indicating that any meetings were held between contractor and charter personnel to discuss and consider safety aspects relating to provision of the services.

2.1.17 DOCUMENTED PROCEDURES TO MONITOR SAFETY OF OPERATIONS

The crew who carried out the test flight was not aware of any SOP (of operator) or DGCA CAR on carrying out test flight. Throughout the organization, there were many operation and monitoring aspects for which the procedures were not adequate or documented such as crew scheduling, CVFDR monitoring, random checks, supervision etc. Similarly, in the aviation wing of ONGC there was absence of effective documented procedures to monitor safety of operations.

2.1.18 REGULATORY AUDIT REPORTS

Full regulatory audit of the operator as per the CAR was carried out by DGCA team in Oct 2017. The audit report was not provided to the operator by DGCA till the date of accident i.e. almost 3 months after carrying out the audit. The operator could not carry out any corrective actions (till the date of accident) as there was no debrief given by the audit team of DGCA.

2.1.19 PIB REPORTS

Investigation reports of the earlier incidents for the accident aircraft were scrutinized. These investigations are carried out by Permanent Investigation Board (PIB) of the operator wherein DGCA representatives also associate. It was observed that the investigation was carried out in a shallow manner without any root cause analysis. On the accident aircraft there was an occurrence, where all lights went off with total loss of communication at an altitude of 700 feet. The cause given in the investigation report was unintentional operation of "**emergency cut off**" switch resulting in total electrical power failure. Though it was very serious issue, the report did not cover any aspect of human factors investigation because of which the emergency cut off switch was inadvertently operated. Incidentally the PF of the accident flight was one of the crew members on that sortie.

2.1.20 SMS

Previous issues covered under this section indicate that hazards were existing across the organization. Safety management seeks to proactively mitigate safety risks before these result in aviation accidents and incidents. Through the implementation of safety management, one can manage their safety activities in a more disciplined, integrative and focused manner. Possessing a clear understanding of its role and contribution to safe operations enables an organization to prioritize safety risks. Though the organization fulfilled all requirements (had the paper work) as laid down in various Rules and Regulations. but there was general reluctance to go beyond that.

2.1.21 CRM

The primary aim of CRM is to enhance situational awareness, leadership, assertiveness, decision making, adaptability and communication. PM had repeatedly cautioned the PF of the increasing bank but the PF who was disoriented did not hand over controls to PM to correct the bank. There was dual inputs during the last few seconds of the flight.

Secondly, the CVR read out brought out lack of adherence to challenge and response in checks and communication protocol between the crew members.

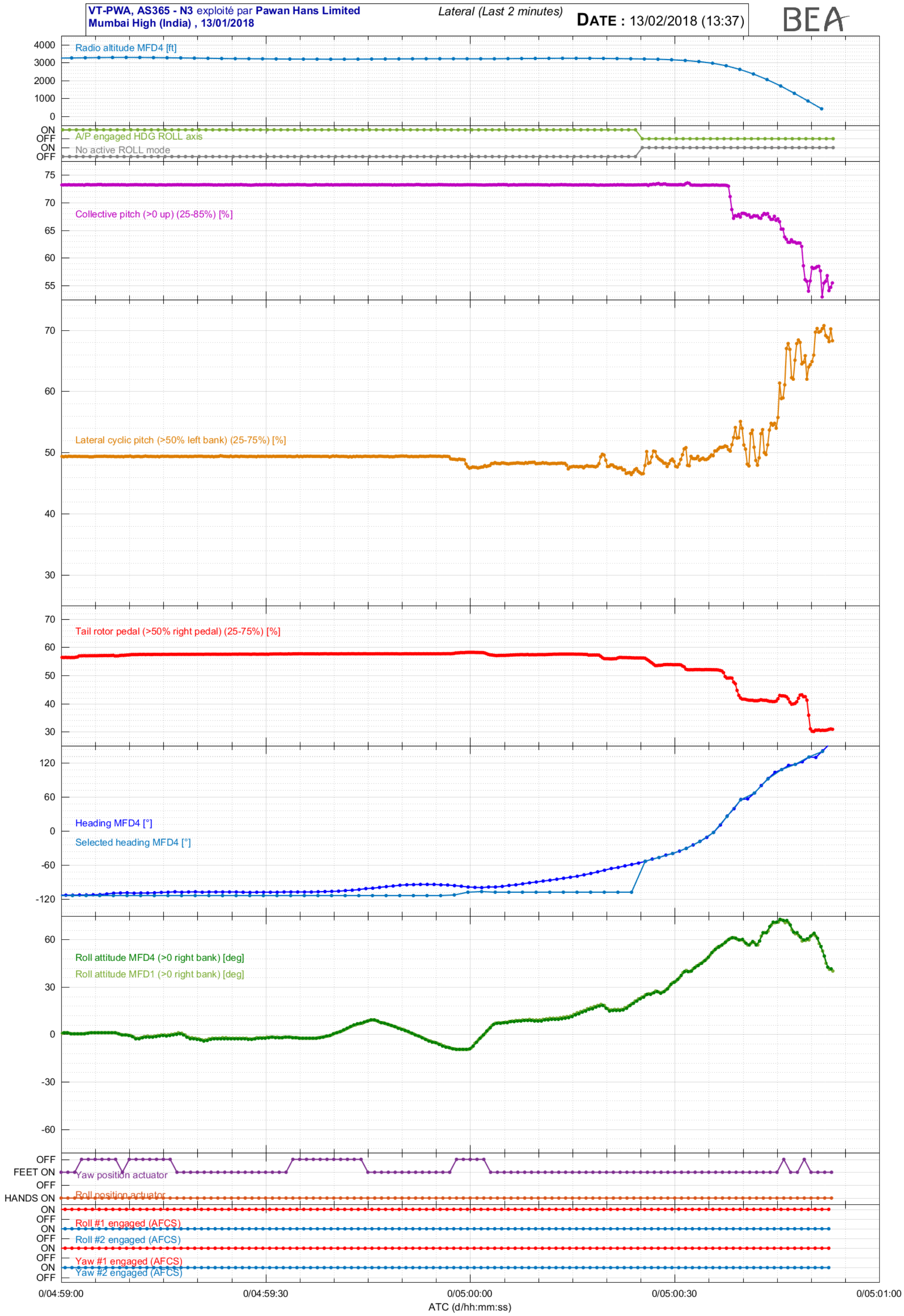
2.2 CIRCUMSTANCES LEADING TO THE ACCIDENT

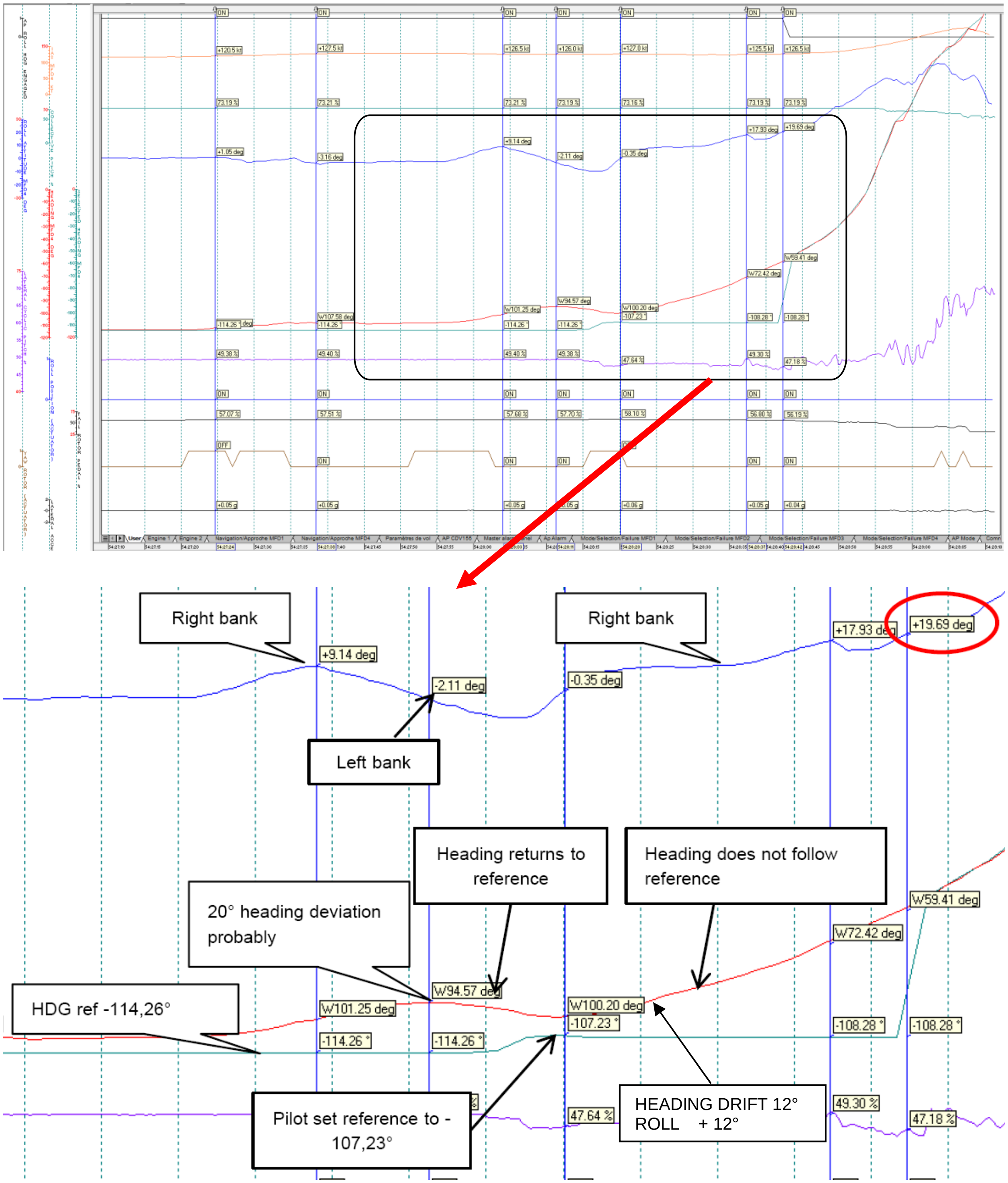
The helicopter was positioned at ONGC helibase for the planned take-off. The flight was cleared under special VFR with revised take-off time. After take-off, the helicopter transmitted its flight details to the helibase.

After reaching 25 NM from Juhu airport, the crew switched over to offshore frequency 118.2. At time 55 seconds, prior to the accident, there was a slight movement of lateral cyclic pitch, indicating that the PF had manually moved the lateral control and that position of lateral cyclic pitch was held for about 20 seconds. At that time bank angle was -8°. As per the CVR recording, 45 seconds prior to the accident, the PF had observed that the heading was drifting on its own. The same was acknowledged by the PM. As per the FDR, the heading drift at that point of time was 24º and roll was 12°. This heading deviation drift might have been induced by a right roll (bank).

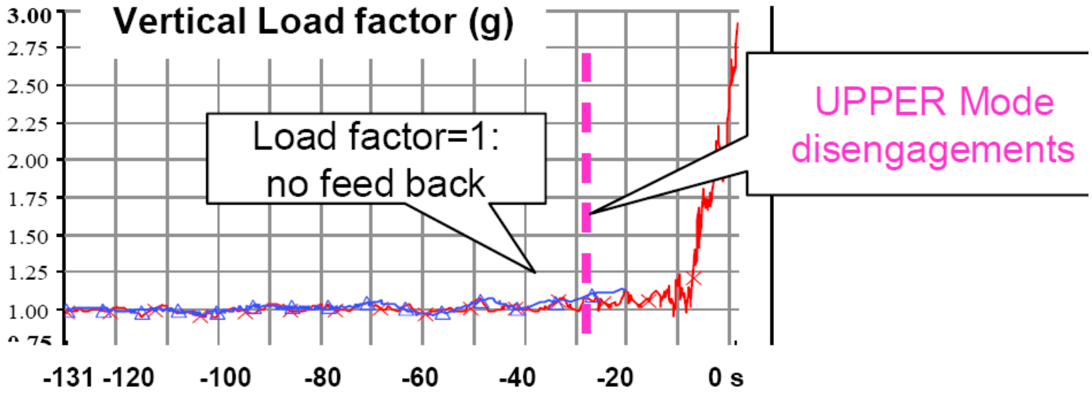
There was no AFCS warning. From the stick lateral movement rate, which was above the maximum speed of actuator (with autopilot engaged), it was inferred that the pilot disengaged the heading mode and took over controls about 22 seconds prior to the accident. At that moment, the roll attitude was between + 19.69° and 22.5°.

As soon as the pilot took over the controls, the AFCS functioned in SAS mode. After the disengagement of auto pilot upper mode, the bank angle continued to increase. Normally under such situation, the pilot should immediately try to restore the attitude by appropriate control inputs. In the present case, however, this did not happen. The PM has shouted “bank”, still there was no corrective action either on the lateral or on the longitudinal controls.


VT-PWA, AS365 - N3 exploité par Pawan Hans Limited
Mumbai High (India) , 13/01/2018
Lateral (Last 2 minutes)
DATE : 13/02/2018 (13:37)
BEA
Radio altitude MFD4 [ft]
A/P engaged HDG ROLL axis
No active ROLL mode
Collective pitch (>0 up) (25-85%) [%]
Lateral cyclic pitch (>50% left bank) (25-75%) [%]
Tail rotor pedal (>50% right pedal) (25-75%) [%]
Heading MFD4 [°]
Selected heading MFD4 [°]
Roll attitude MFD4 (>0 right bank) [deg]
Roll attitude MFD1 (>0 right bank) [deg]
Yaw position actuator
Roll position actuator
Roll #1 engaged (AFCS)
Roll #2 engaged (AFCS)
Yaw #1 engaged (AFCS)
Yaw #2 engaged (AFCS)
0/04:59:00
0/04:59:30
0/05:00:00
0/05:00:30
0/05:01:00
ATC (d/hh:mm:ss)



As soon as the controls were taken over, the helicopter started losing height with increasing vertical acceleration.



Coupled with poor slant visibility and no horizon, the PF got disoriented resulting in control freeze. The PM who was not disoriented tried to take over controls which was resisted by the PF. At an altitude of about 1700 ft, 20 seconds after heading mode disengagement, left bank order was commanded, that led to reduction in the bank angle.

2 seconds prior to the last recording, "Go Around" pitch mode was engaged. This dual control inputs (for almost last 20 seconds) worsened the situation and the helicopter crashed into the sea at very high velocity.

3.0 CONCLUSIONS

3.1 FINDINGS

3.1.1 GENERAL - FACTUAL

As per the documents available with the operator,

- The operator was carrying out operation of helicopter under NSOP and the maintenance of helicopter under CAR 145.
- The Certificate of Airworthiness, Certificate of Registration and Certificate of Release to Service of the helicopter was valid on the date of the accident.
- The defect records were scrutinized and there was no documented defect pending on the helicopter prior to the flight which could have contributed to the accident.
- All major modifications and Service Bulletins were complied with.
- There was no abnormality reported on the navigational or communication equipment prior to the accident.
- The PIC & the co-pilot were holding valid license on the type of helicopter.

- Both crew members held valid medical certificates as per the requirement.
- The crew had undergone pre-flight medical examination and nothing abnormal was observed. The BA test was negative.
- The training as required by the relevant regulations on the subject was imparted to the flight crew members.
- Special VFR conditions existed around Juhu airport at the time of takeoff.
- The Roll position and Pitch position actuators operated in correct sense as commanded by AFCS.
- The helicopter impacted the water surface at a high velocity with nose down, right bank attitude and got disintegrated.
- AFCS not maintaining the heading mode could be because of either MFD4 output defect or CDV85 input defect.

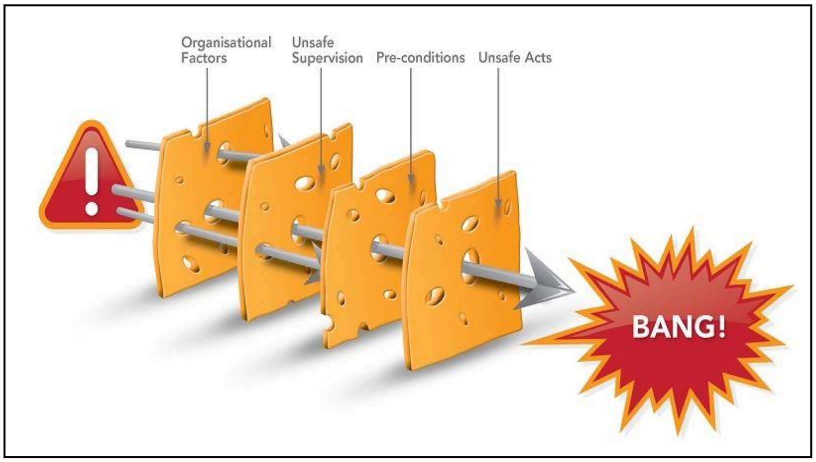
3.1.2 GENERAL – OBSERVATIONS (NON-CAUSATIVE)

- Recommendations of earlier investigations having serious operational/ safety implications are yet to be implemented by PHL in true spirit. The minimal actions taken on some of the recommendations have withered away due to complacency.
- The liquidated damages clause (hourly) for non-provisioning of helicopter is unsafe.
- The marine radio officers are only providing the offshore traffic information. They are neither authorised to monitor nor control the offshore helicopter traffic.

3.1.3 CAUSAL FACTORS ANALYSIS

Accidents occur through the concatenation of multiple factors, where each may be necessary and at the same time are sufficient enough to produce the accident. Any complex system contain potentially multi-causal factors (vulnerabilities), but rarely these create a possible trajectory for an accident. Often these vulnerabilities are “latent”, i.e. present in the organisation long before specific conditions are triggered. Most of these are a product of the organization itself as a result of staffing, system & procedures, training policy, communication patterns, culture, hierarchical relationship, managerial decisions etc.

A root cause analysis of the last unsafe act unearthing the vulnerabilities along with their interlinking is a must for proper investigation for suggesting preventive measures to avoid the recurrence. Vulnerabilities were observed during the present investigation and it is felt that had the systems been in place, there was an opportunity at various stages to stop the progression of unsafe situation which ultimately culminated into accident.



Following is the gist of the vulnerabilities observed during the investigation which have been discussed in detail in the preceding sections.

- **Actions or inactions**
  - ➢ Nonadherence to the “challenge and response” procedure of checklist and callouts during various phases of flight and inadequate management of cockpit resources.
  - ➢ The test flight was carried out and test Performa was filled in casual manner.
  - ➢ Though the heading mode was not capturing during the test flight, the flight crew has not reported or documented the same after the test flight.
- **Precursors**
  - ➢ The existing and forecast weather including visibility and cloud base beyond 25NM was not available with the flight crew at the time of takeoff from Juhu.
  - ➢ Misbehavior of heading mode of the AFCS.
  - ➢ Delayed identification of excessive bank (situational awareness) by PF.

- **Supervision**
  - ➢ Lack of effective supervision on operational and maintenance activities.
  - ➢ Non-systematic post flight FDR analysis (FOQA) in general and particularly for the flights prior to 600 hours maintenance inspection and test flight systemic analysis could have captured the anomaly in the operation of AFCS.
- **Organizational Influences**
  - ➢ The crew composition for the purpose of carrying out test flight after 600 hours maintenance was not appropriate.
  - ➢ There was cannibalization of critical components from and to the helicopter prior to and after the test flight, which is unsafe practice.
  - ➢ The PF could not make himself available for flying for extended periods on regular basis due organizations typical terms of pilot's employment without assuring safety. There was no due diligence of these aspects at supervisory level from safety perspective.
  - ➢ The malfunction of "heading" mode of AFCS system though known among the flight crew members, yet it was neither reported nor documented resulting in its non-rectification.
  - ➢ The existing latent hazards contributing towards the present accident were neither identified, nor any mitigation action was taken as there is no effective practical safety management system.
  - ➢ Even though major utilization of the helicopters offshore is by ONGC, it does not have any effective safety management system for the aviation activities.

3.1.4 THE ACCIDENT

1. The weather enroute was hazy with poor slant visibility. The horizon was not visible once climb was initiated from 700 feet upwards.
2. The flight was uneventful till levelling off at 3000 feet altitude.
3. Short of point 'P' during level flight at little above 3000 feet altitude, the helicopter was found not holding the selected heading and was in right bank attitude. The PF disengaged the heading mode.

4. After disengagement of heading mode, the PF felt he was able to fly the helicopter steady, which was not the case at that point of time. In view of poor visibility, disorientation had set in for him.
5. The heading could not be restored and the helicopter continued its banking to the right. The pitch angle started to decrease. There was no significant increase in acceleration.
6. The PM who was aware of the excessive bank and was not disoriented tried to override the controls. This was resisted by PF.
7. This resulted in dual control inputs, which caused excessive deviation in attitude of the helicopter about the three axes.
8. The unusual attitude resulted in rapid loss of height and the helicopter plunged into the sea.

3.2 PROBABLE CAUSE OF THE ACCIDENT

The helicopter plunged into the sea at high velocity as the PF was induced into spatial disorientation while operating in poor visibility conditions as a result of malfunction (known and existing) of AFCS coupled with not handing over of controls to PM despite repeated caution of excessive bank by PM.

4.0 SAFETY RECOMMENDATIONS

1. The existing SMS of PHL should
   a. Have sincere implementation of components of SMS.
   b. Be able to identify hazards with clear proactive risk mitigation process.
   c. Develop safety culture throughout the organization which encourages documentation of reporting of snags/ hazards/ incidents.

2. Mumbai, one of the major operational and engineering bases of PHL should be headed by a person with engineering or flying background.
3. PHL should plan and ensure that adequate spare parts are available for carrying out scheduled maintenance and snag rectification, thereby avoiding unnecessary cannibalization.

4. The liquidated damages clause in the present production helicopter contract agreement between PHL and ONGC should be reviewed and if possible avoided.
5. ONGC should develop an effective SMS for its aviation activities.
6. PHL needs to ensure that the flight crew is sensitized and indoctrinated regarding CRM, with particular emphasis on merits of adherence to SOPs, good aviation practices, communications and assertiveness.
7. The procedure of obtaining and transmitting accurate weather information including visibility, cloud base and ceiling to the flight crew should be put in place.
8. PHL should ensure that planning and conduct of the test flight after major maintenance is with due deliberation and serious intent.
9. In view of the typical terms of flying crew employment, PHL should streamline the system of flight crew rostering to ensure availability of flight crew as planned.

(R S Passi)
Investigator-in-Charge

(Shilpy Satiya)
Investigator

(Capt. Satish Koikal)
Investigator

Date: **11th July 2019**

Place: **NEW DELHI**