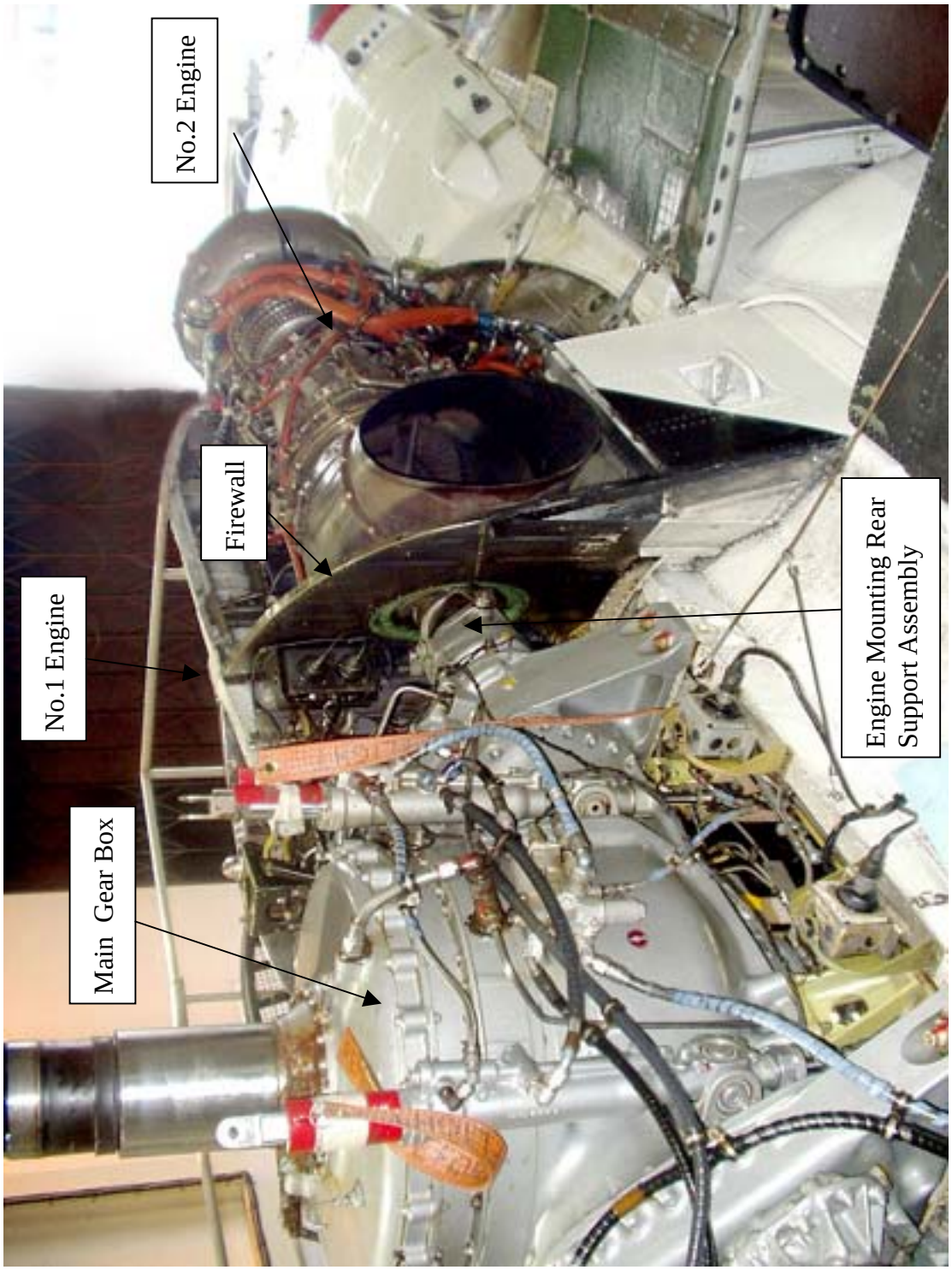
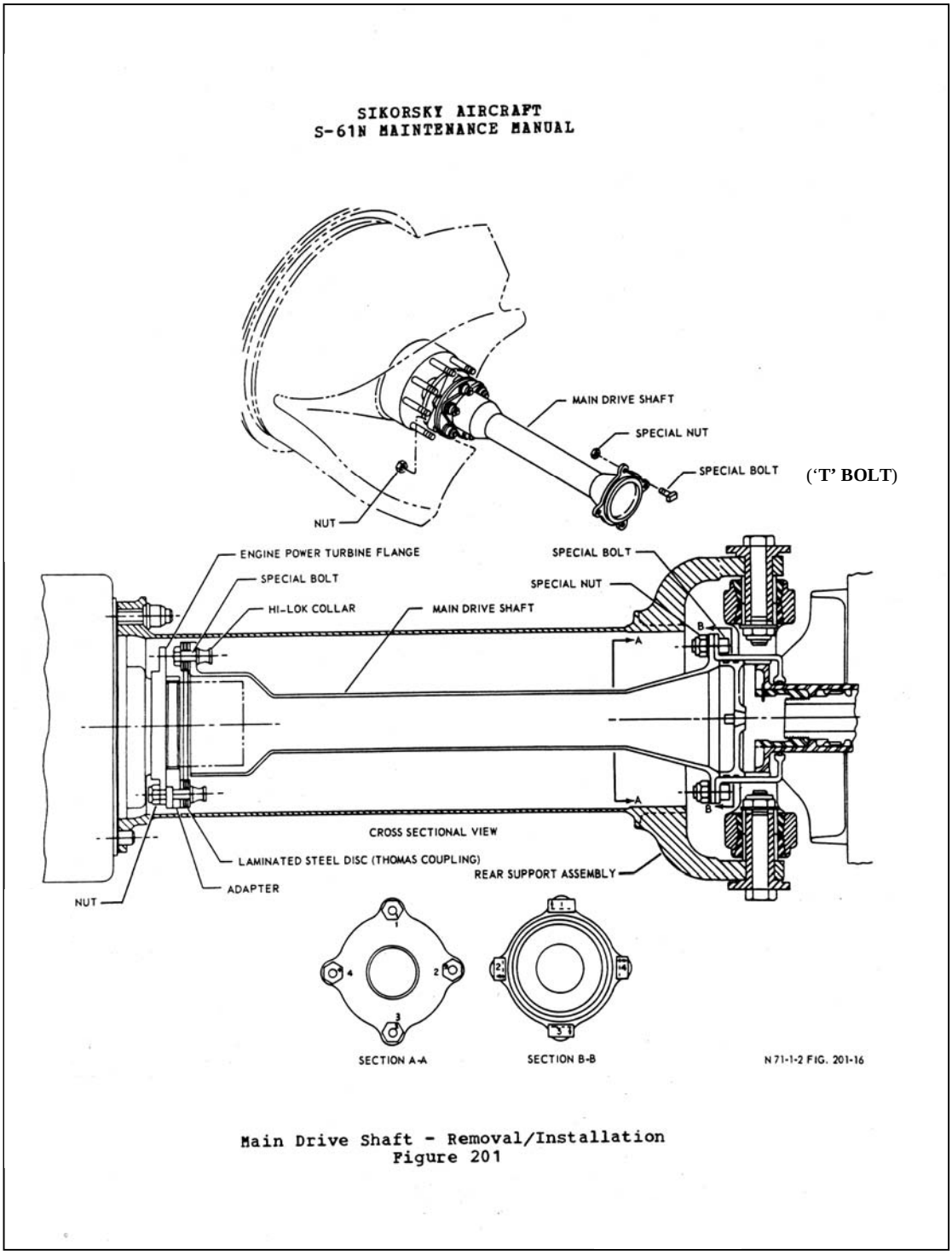


VIEW OF MAIN GEARBOX AND ENGINE BAYS WITH COVERS REMOVED



Main Drive Shaft cross-sectional view

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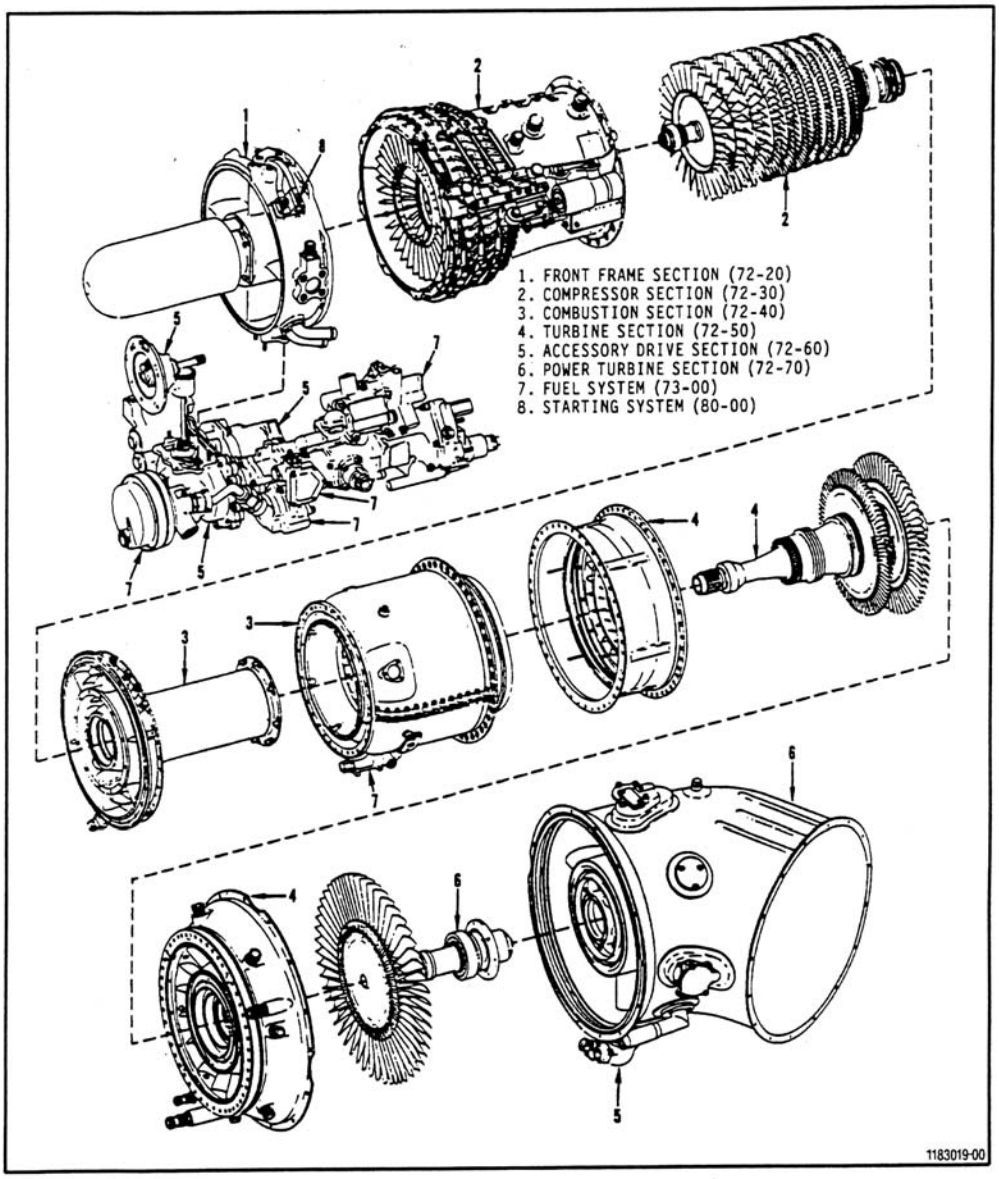
GE Aircraft Engines

CT58 TURBOSHAFT

SEI-182

MAINTENANCE MANUAL



Major Sections of Engine
Figure 1

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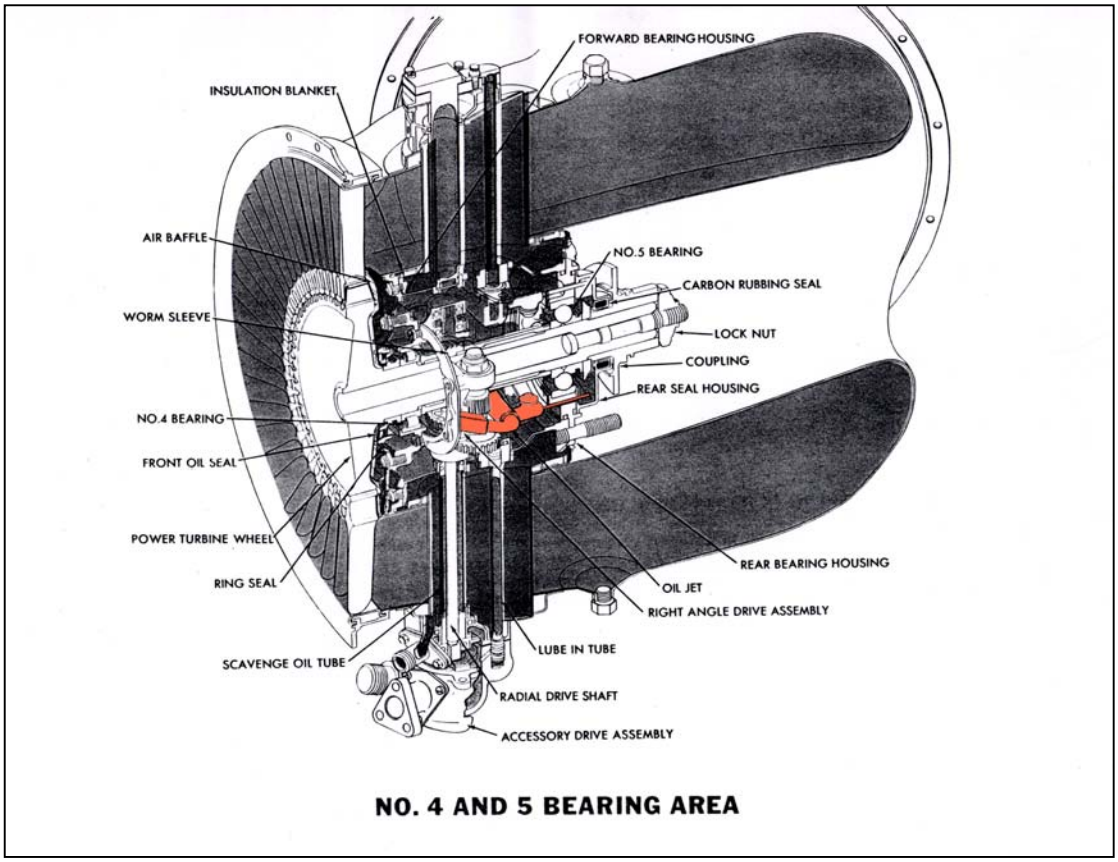
GE Aircraft Engines CT58 Maintenance Manual

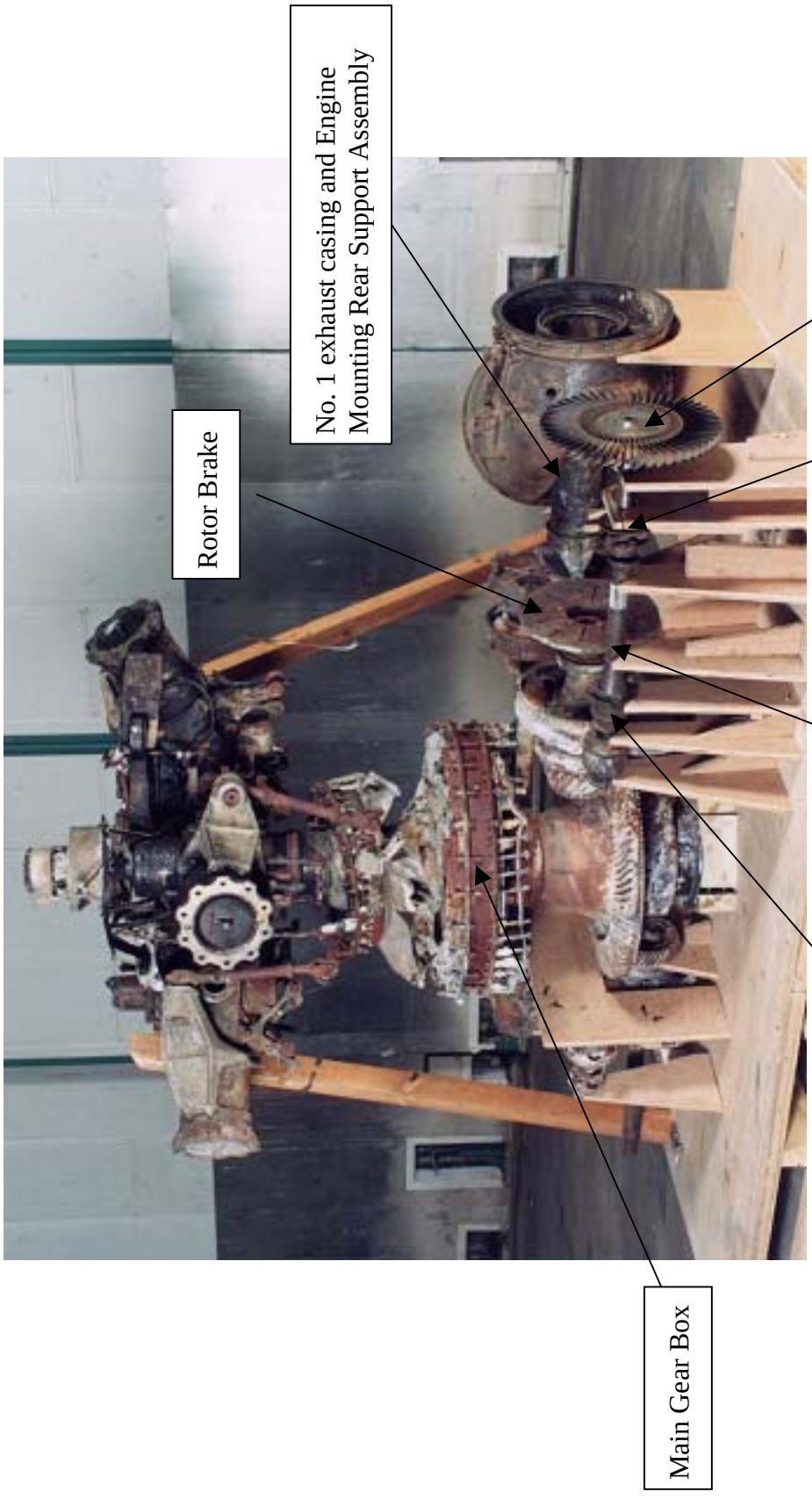
OIL JET DETAILS



ABOVE: Diagram of the Nos 4 and 5 bearing area showing the location of the oil jet

RIGHT: The broken oil jet in the bearing chamber

BELOW: a new oil jet



RECONSTRUCTION OF MAIN GEAR BOX AND TRANSMISSION

Pertinent CVFDR transducer details

Engine parameters (each engine)

Main Drive Shaft speed (N_f) – tachometer mounted on the fuel control unit (on the accessory drive) and connected through a flexible cable drive, two 'radial' shafts and a worm gear (ratio of 1:4) onto the main drive shaft. The geometry of the helix of the worm gear is such that with radial free play of the main drive shaft and worm gear, rotational speed variations may be induced in the 'radial' shaft. Speed is measured as a percentage of original design peak power turbine speed where 18,966 rpm equates to 100%.

Gas Generator speed (N_g) – tachometer mounted on the oil pump (on the accessory drive) and connected to the compressor accessory drive shaft through an axial and then radial shaft. Speed is measured as a percentage of original design peak generator speed where 26,300 rpm equates to 100%.

Torque – pressure transducer mounted on the MGB measuring the application of torque from the engine to the input shaft of the MGB prior to the free-wheel unit.

Power Turbine Inlet Temperature (T5)– Eight thermocouples connected in parallel and mounted in the second stage turbine casing.

Low Engine Oil Pressure – An on-off pressure switch measuring pressure upstream of the oil filter.

Transmission parameters

MGB low oil pressure switch – An on-off switch sensing pressure at the No 2 engine input to the gearbox. It is designed to switch at a pressure of 7.5 psig and will automatically activate emergency lubrication.

MGB oil pressure – A transducer sensing pressure at the main gearbox oil inlet. The transducer was mounted on the forward, starboard side of the MGB with cabling running aft under the MGB.

MGB oil temperature switch – An on-off switch activated when the temperature of the oil between the oil cooler and the main gearbox exceeds 121°C.

MGB oil temperature – Resistance bulb transducer mounted in the main gearbox oil sump adjacent to the oil strainer.

Other discrete parameters (on or off)

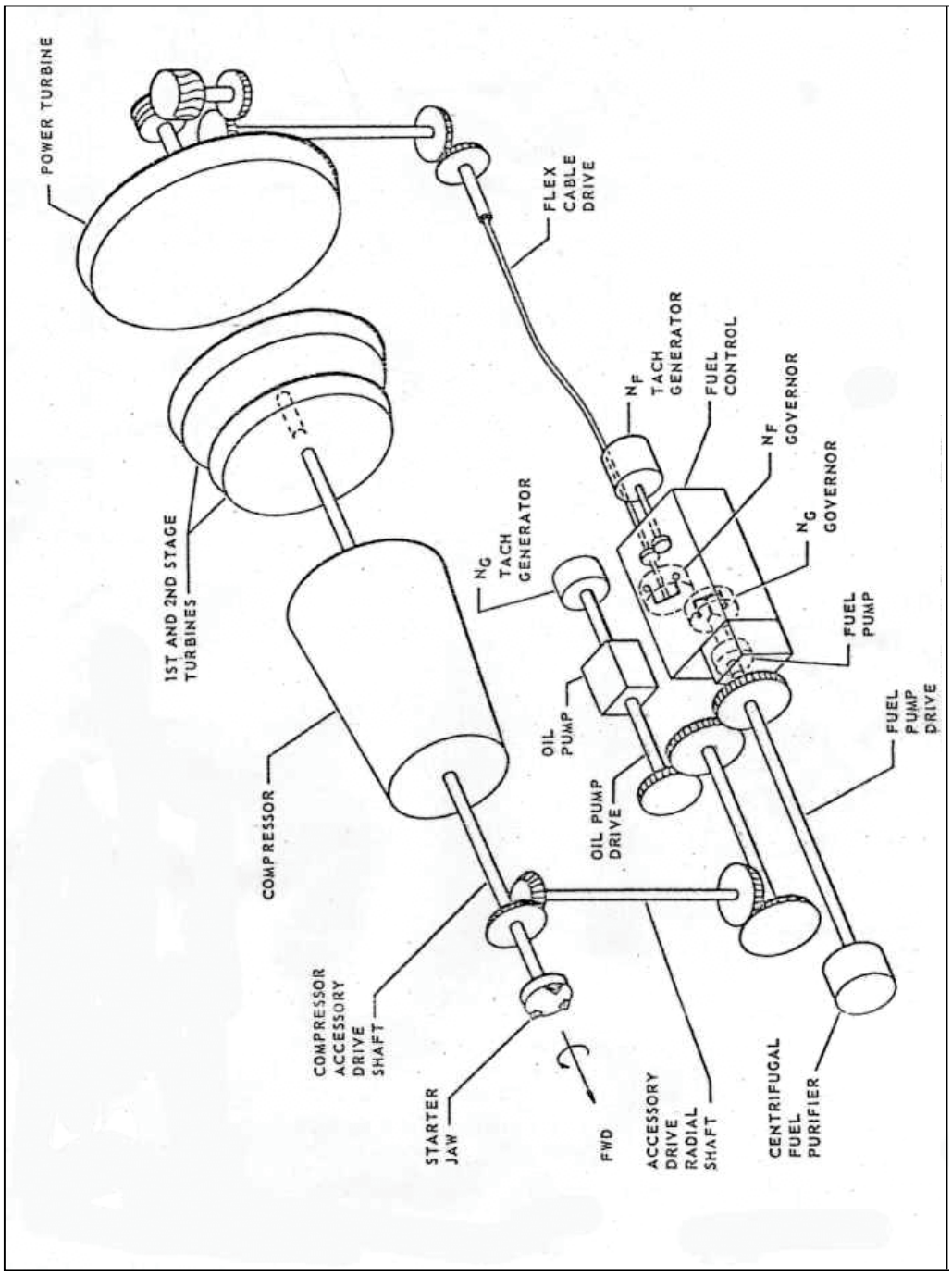
Fire Engine 1 – Thermal sensing loop running within an engine compartment designed to present a low resistance when a high temperature is sensed. The sensing circuitry also controls a synthesised warning voice to announce the source of the fire warning (eg “Fire…Engine 2”).

Primary hydraulic system low pressure – pressure switch mounted on the right hand side of the main gearbox. The switch activates whenever primary hydraulic pressure reduces from a normal 1,300-1,600 psig to below 1,000 psig.

Secondary hydraulic system low pressure – as above but sensing secondary hydraulic system pressure.

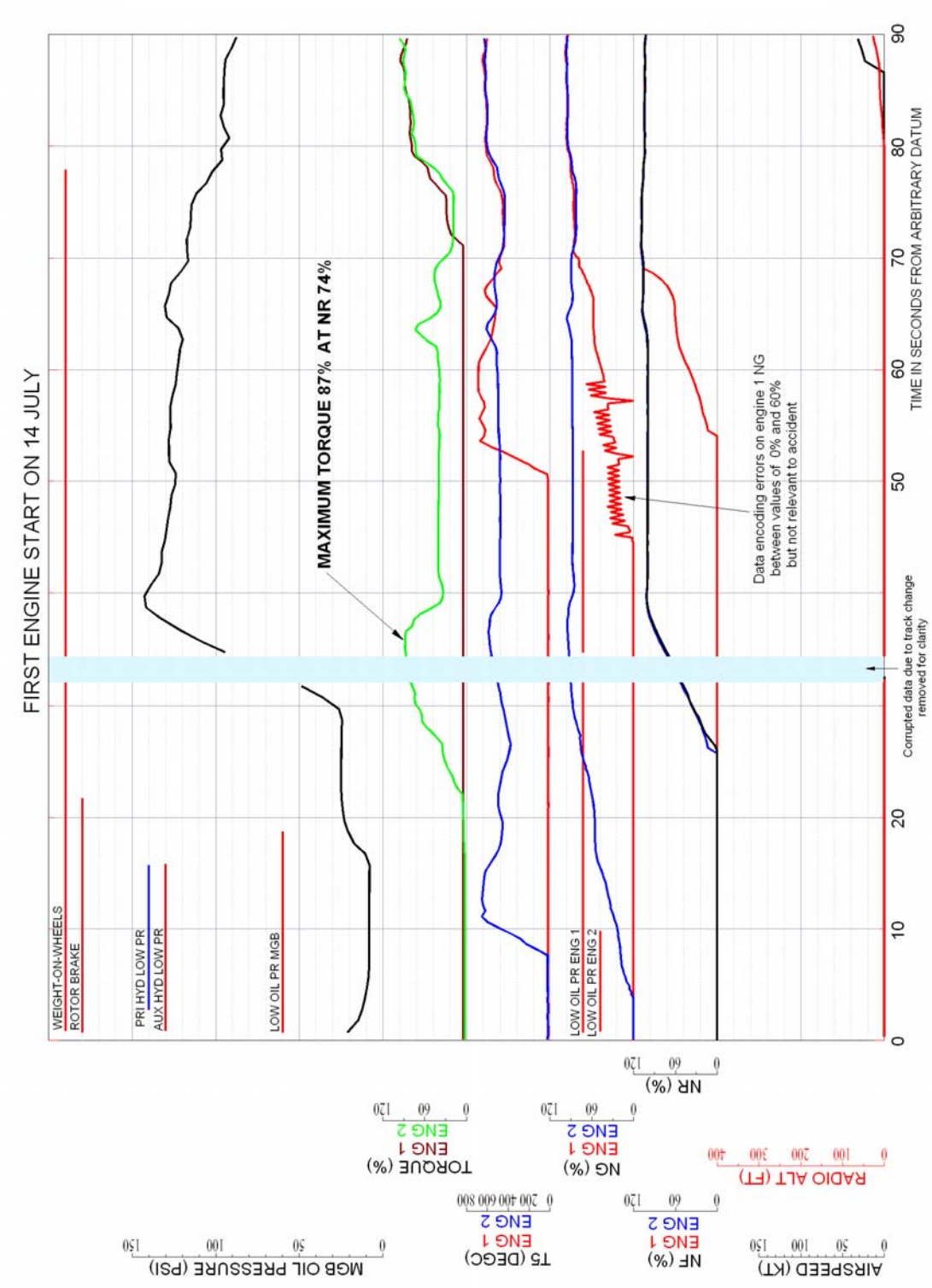
Primary / Auxiliary select – two parameters indicating whether the primary or the auxiliary hydraulic system has been selected to OFF. Interlocks are provided within the system to prevent the deselection of a pressurized system if the other has failed.

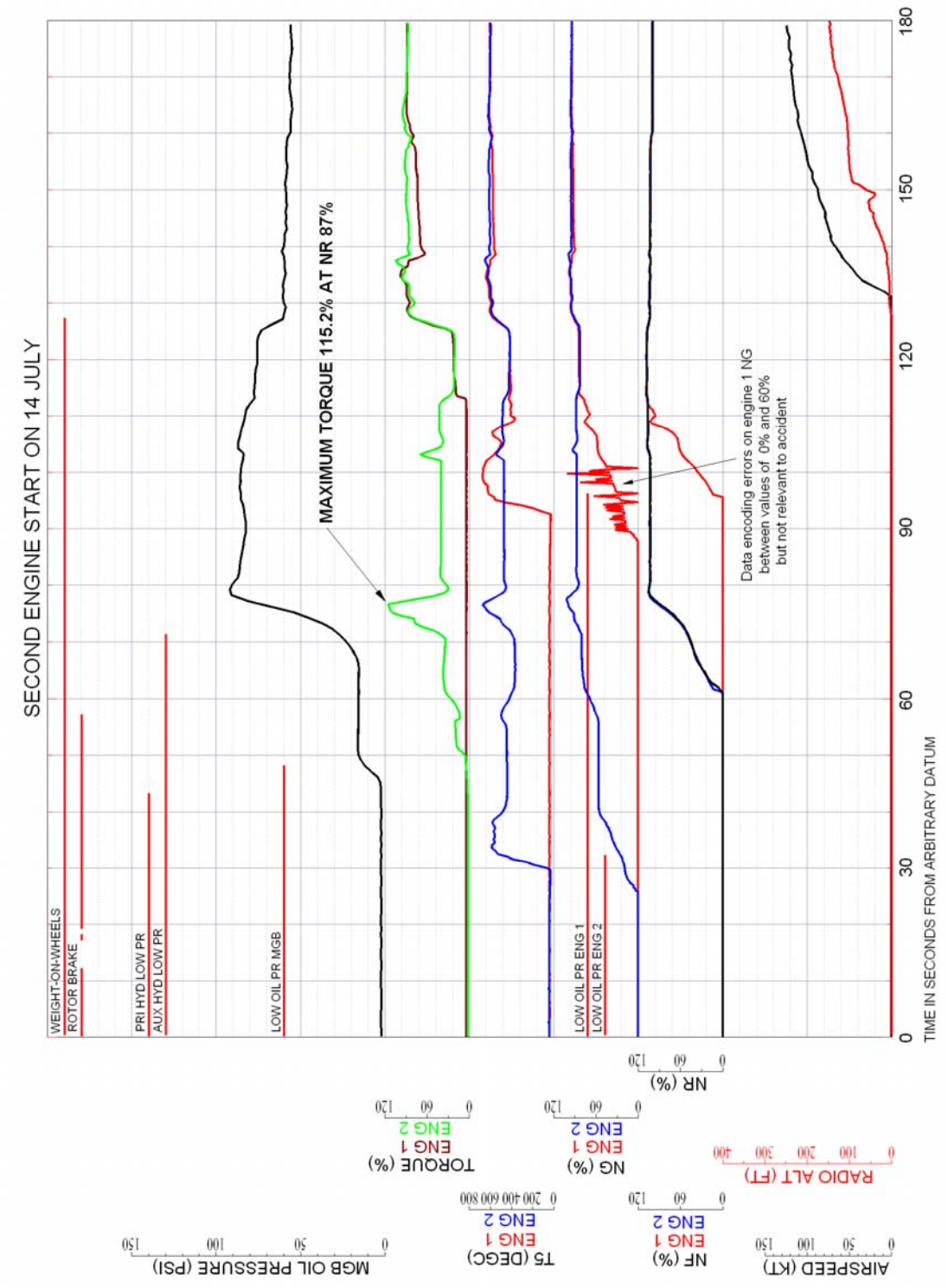
Flotation fired – parameter indicating whether the flotation has been activated. The wiring runs from behind the pilots seats to the Data Acquisition and Processing Unit in the nose of the helicopter.

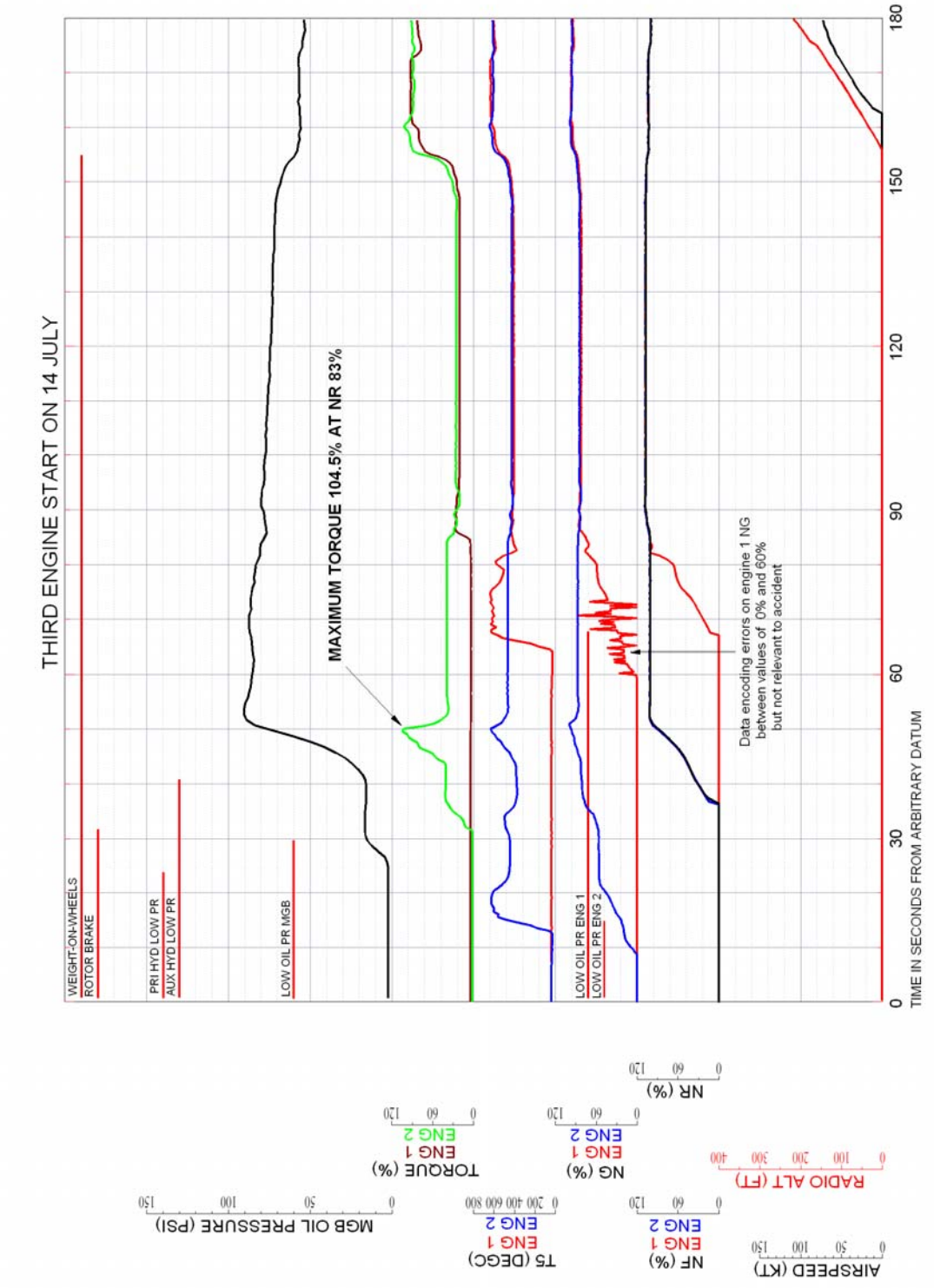


ENGINE ACCESSORY GEAR TRAIN SCHEMATIC

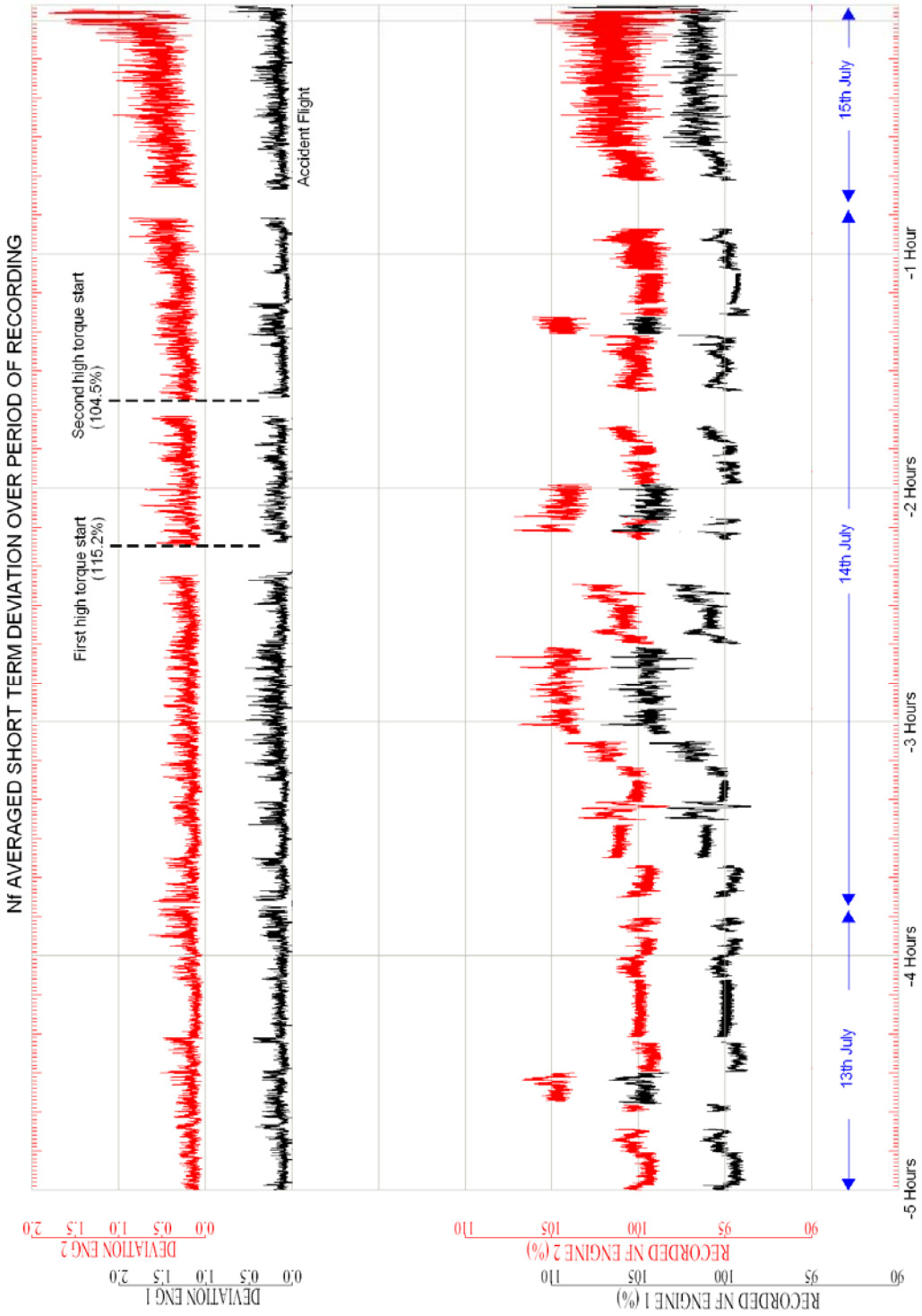
FDR plots - High torque starts



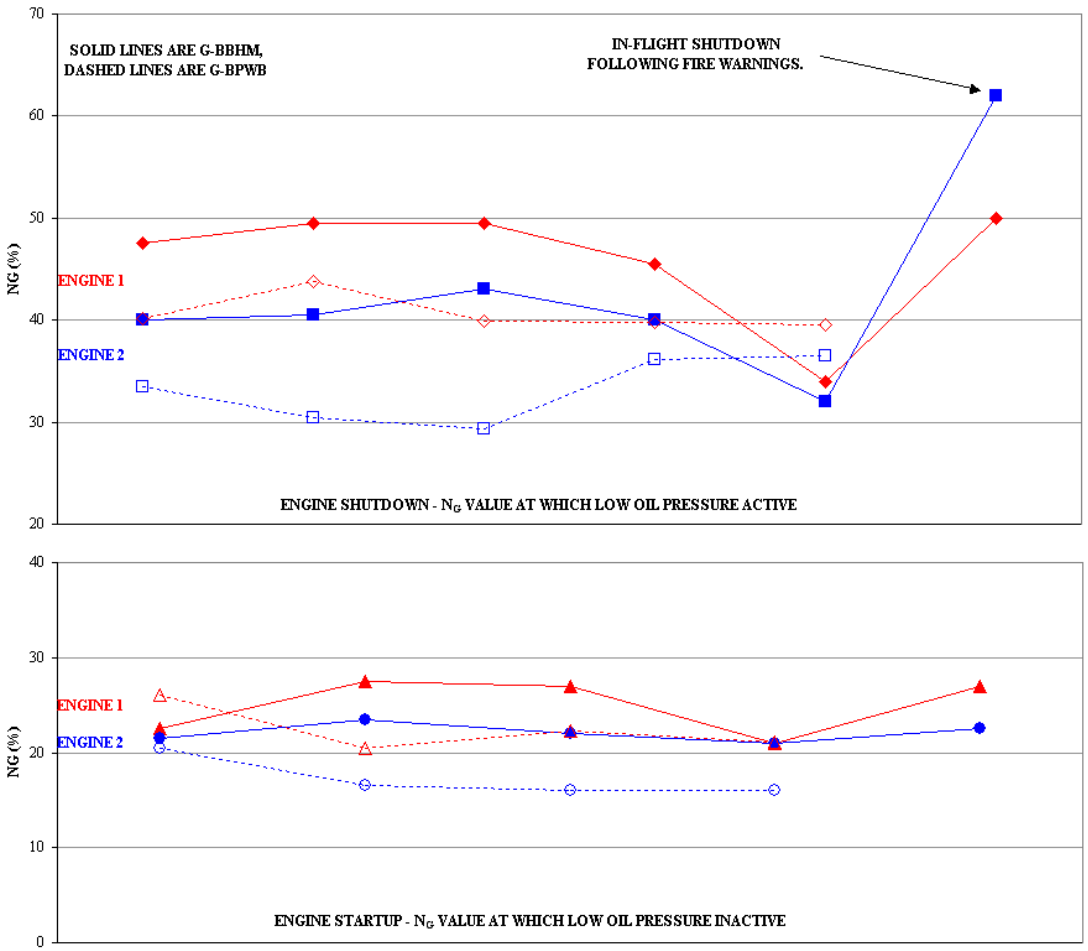

SECOND ENGINE START ON 14 JULY
MAXIMUM TORQUE 115.2% AT NR 87%
Data encoding errors on engine 1 NG
between values of 0% and 60%
but not relevant to accident
WEIGHT-ON-WHEELS
ROTOR BRAKE
PRI HYD LOW PR
AUX HYD LOW PR
LOW OIL PR MGB
LOW OIL PR ENG 1
LOW OIL PR ENG 2
TIME IN SECONDS FROM ARBITRARY DATUM
0
30
60
90
120
150
180
NR (%)
NG (%)
ENG 1
ENG 2
TORQUE (%)
ENG 1
ENG 2
RADIO ALT (FT)
NF (%)
ENG 1
ENG 2
T5 (DEGC)
ENG 1
ENG 2
AIRSPEED (KT)
MGB OIL PRESSURE (PSI)


THIRD ENGINE START ON 14 JULY
MAXIMUM TORQUE 104.5% AT NR 83%
Data encoding errors on engine 1 NG between values of 0% and 60% but not relevant to accident
WEIGHT-ON-WHEELS
ROTOR BRAKE
PRI HYD LOW PR
AUX HYD LOW PR
LOW OIL PR MGB
LOW OIL PR ENG 1
LOW OIL PR ENG 2
TIME IN SECONDS FROM ARBITRARY DATUM
0
30
60
90
120
150
180
AIRSPEED (KT)
RADIO ALT (FT)
NF (%)
NG (%)
NR (%)
T5 (DEGC)
TORQUE (%)
MGB OIL PRESSURE (PSI)
ENG 1
ENG 2

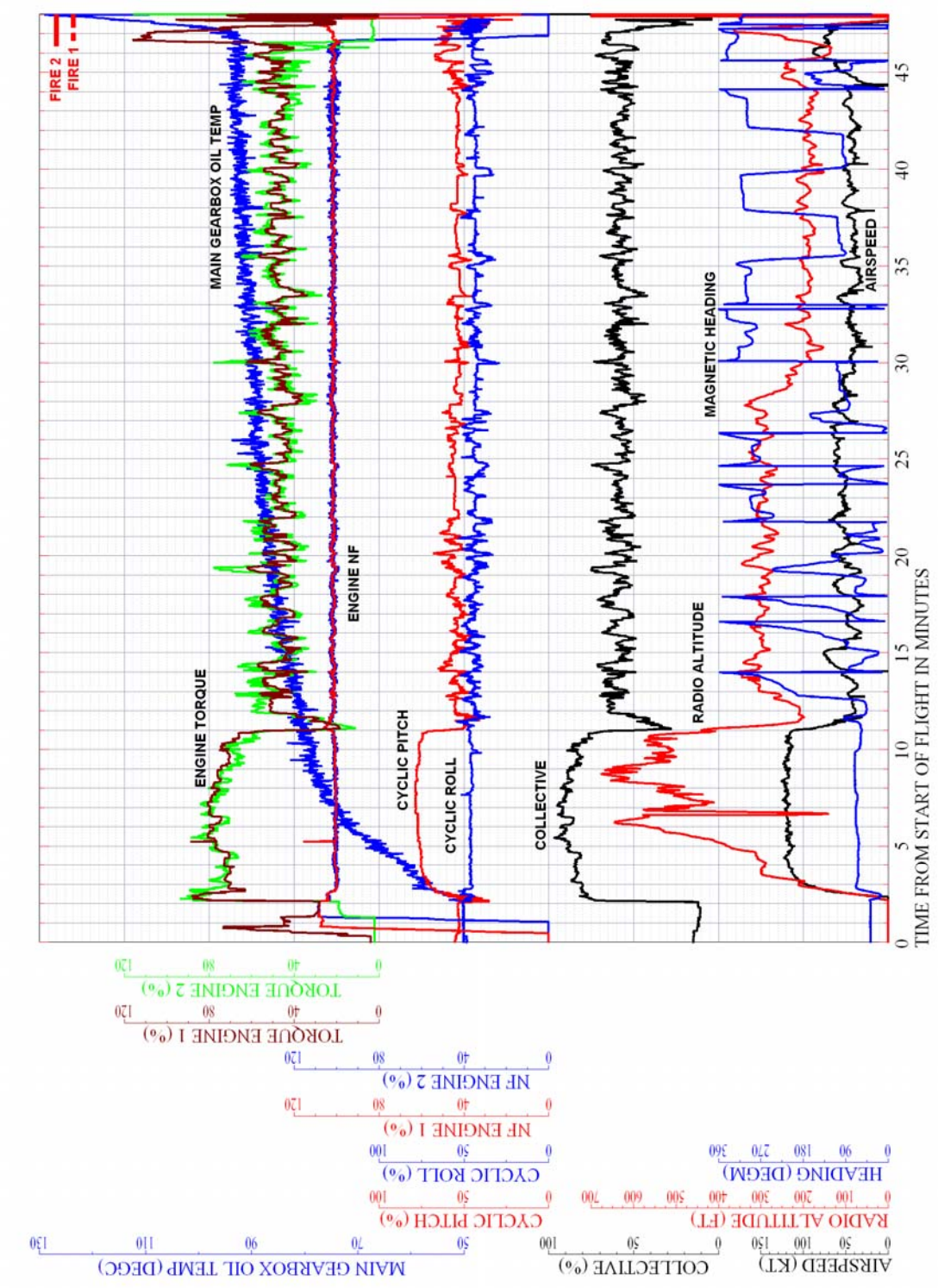
Plot of N_f 'jitter'

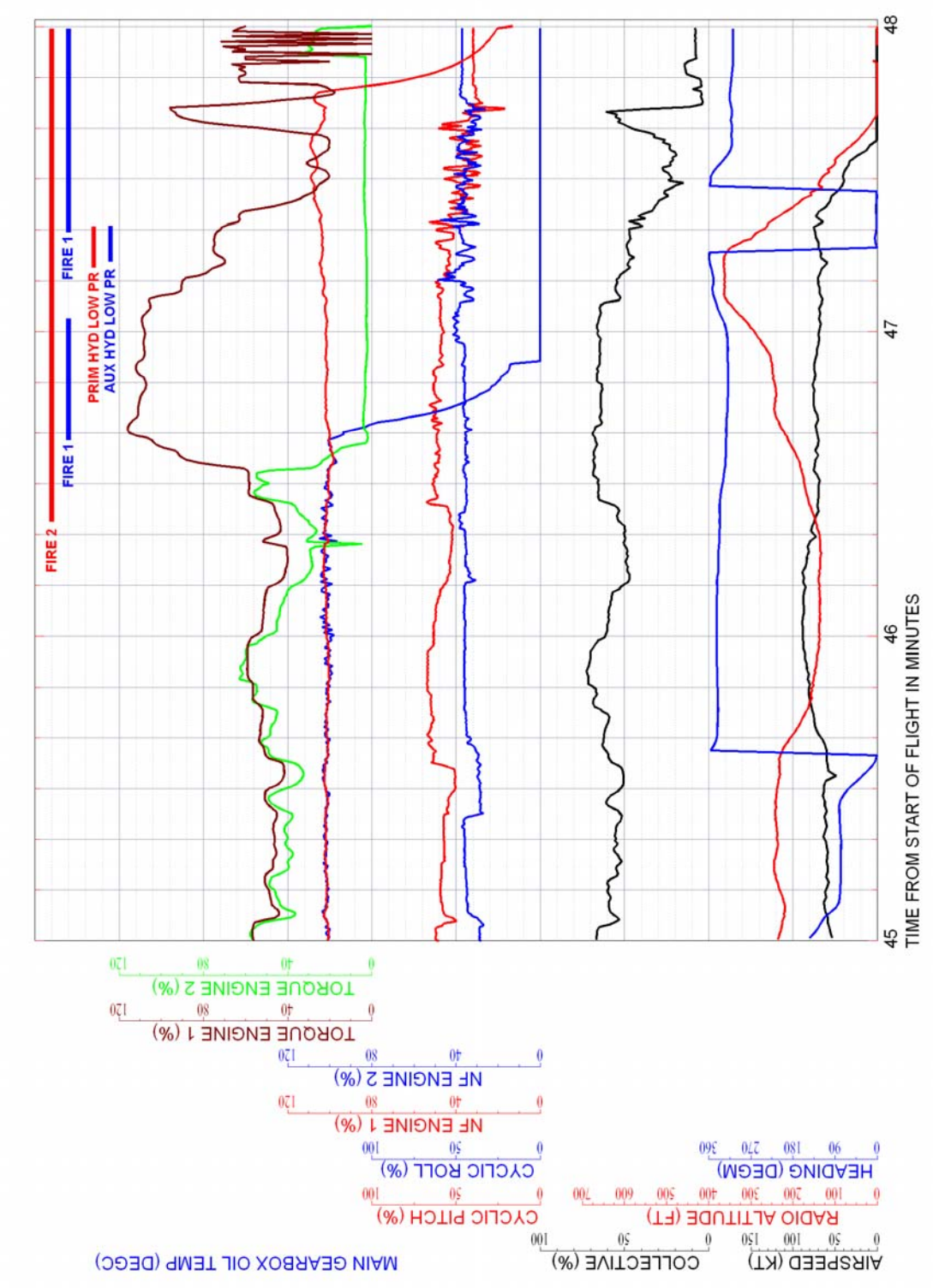


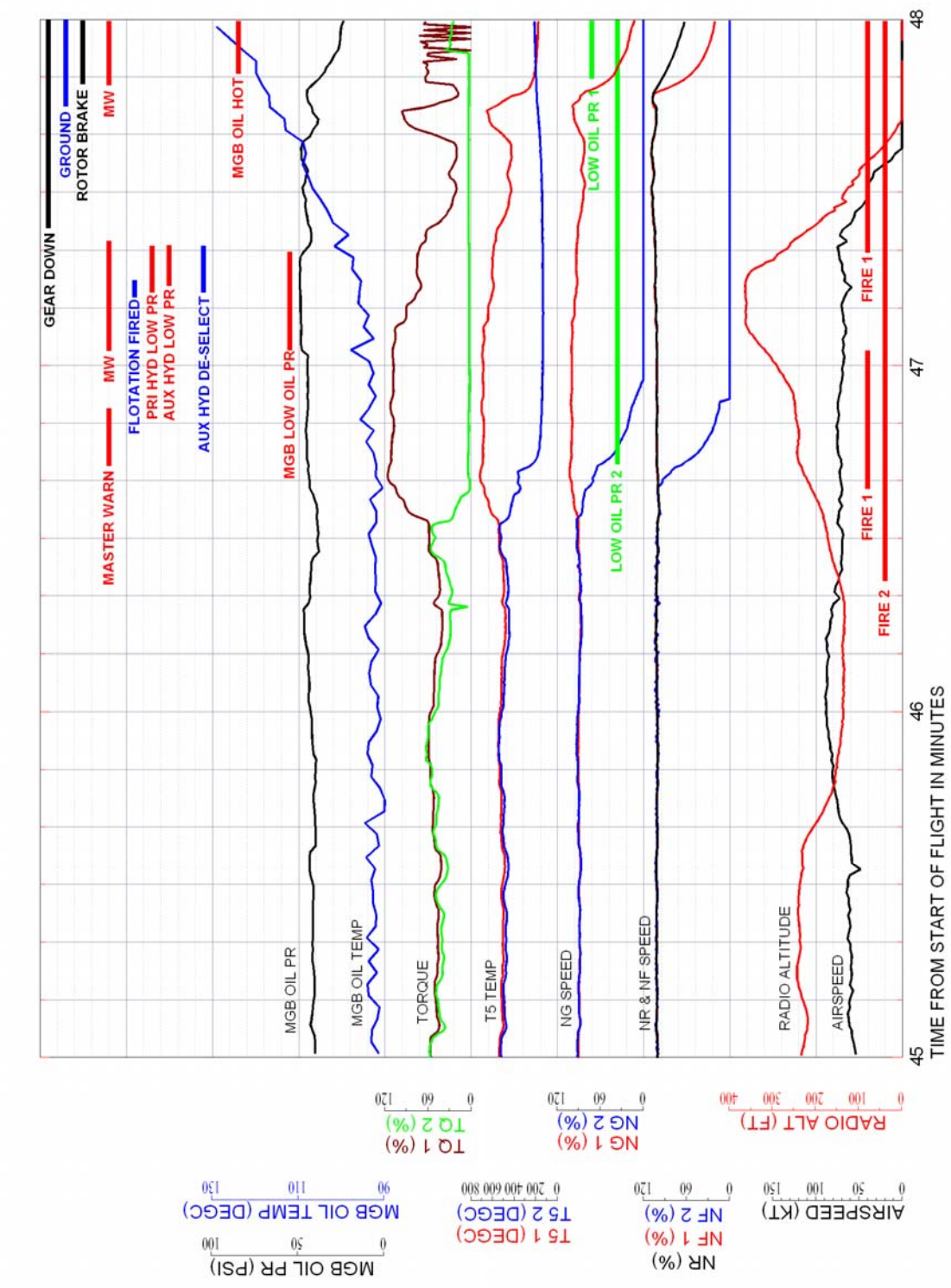
Engine shutdowns and oil pressure indications



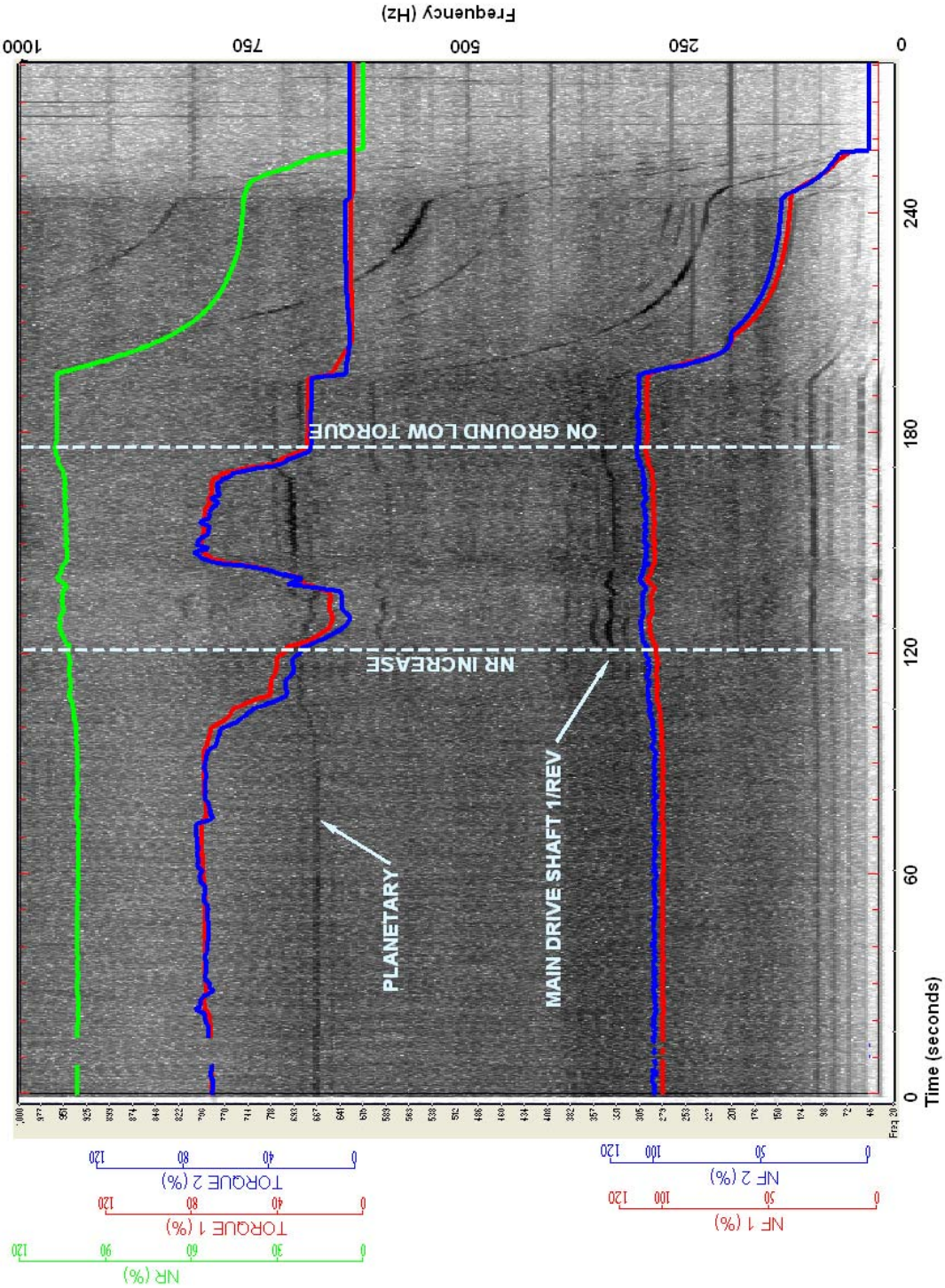
Plot of recorded data for accident flight



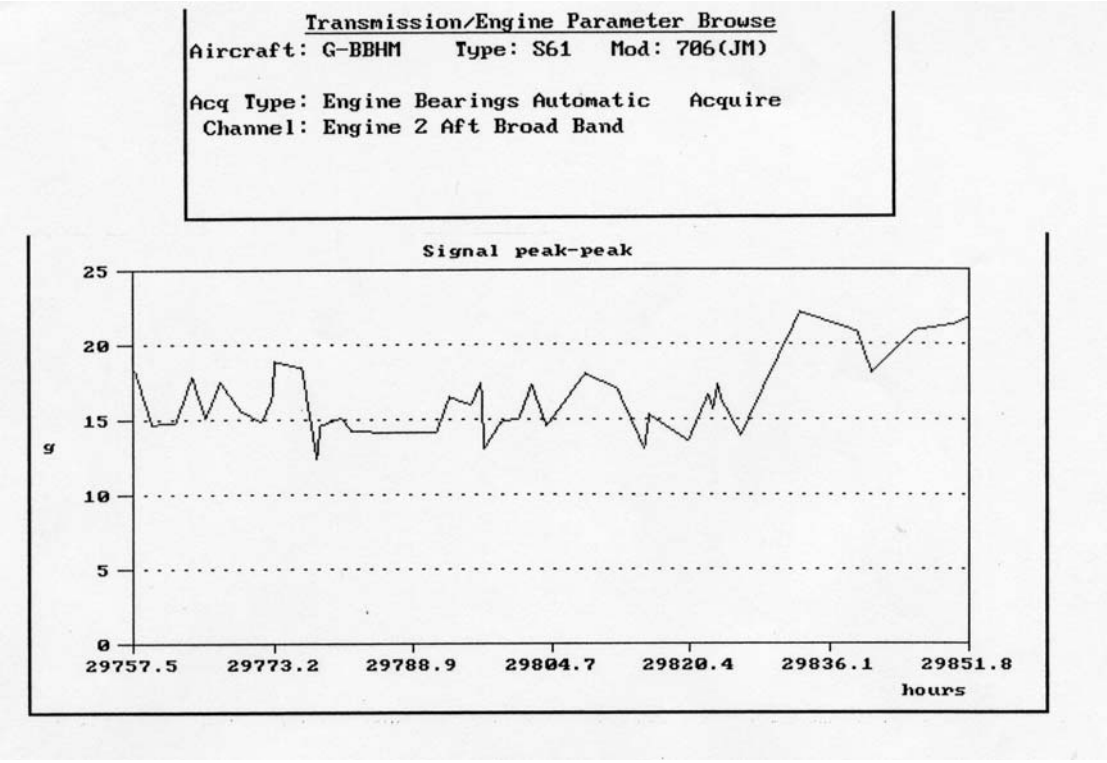

FIRE 2
FIRE 1
FIRE 1
PRIM HYD LOW PR
AUX HYD LOW PR
45
46
47
48
TIME FROM START OF FLIGHT IN MINUTES
AIRSPEED (KT)
COLLECTIVE (%)
RADIO ALTITUDE (FT)
HEADING (DEGM)
CYCLIC PITCH (%)
CYCLIC ROLL (%)
NF ENGINE 1 (%)
NF ENGINE 2 (%)
TORQUE ENGINE 1 (%)
TORQUE ENGINE 2 (%)
MAIN GEARBOX OIL TEMP (DEGC)


GEAR DOWN
GROUND
ROTOR BRAKE
MW
MASTER WARN
MW
FLOTATION FIRED
PRI HYD LOW PR
AUX HYD LOW PR
AUX HYD DE-SELECT
MGB OIL HOT
MGB LOW OIL PR
LOW OIL PR 1
LOW OIL PR 2
FIRE 1
FIRE 1
FIRE 2
MGB OIL PR
MGB OIL TEMP
TORQUE
T5 TEMP
NG SPEED
NR & NF SPEED
RADIO ALTITUDE
AIRSPEED
45
46
47
48
TIME FROM START OF FLIGHT IN MINUTES
TQ 1 (%)
TQ 2 (%)
NG 1 (%)
NG 2 (%)
RADIO ALT (FT)
AIRSPEED (KT)
NR (%)
NF 1 (%)
NF 2 (%)
T5 1 (DEGC)
T5 2 (DEGC)
MGB OIL TEMP (DEGC)
MGB OIL PR (PSI)

Voice recording spectral analysis – previous flight



Recorded HUMS data



Sikorsky S-61and similar types Engine/Transmission/MGB related occurrences of possible significance				
Registration and Type Variant	**Date**	**Report Type**	**Key features**	**Accident/Incident summary**
SH-3A	May 22, 1962	USN	Suspect MGB	Engine 2 FW, muffled explosion, eng 2 torque drop, visible fire, engine 1 FW, Nr decrease, crash
SH-3A	January 30, 1964	USN	Transmission deck fire	Transmission failure call, heavy smoke, crash
CH-3C	December 2, 1965	USAF	#2 engine fire, bearing failure	Fire attibuted to bearing failure. Water landing at Cocoa Beach. Extinguished by crew. No further details
SH-3A	August 27, 1967	USN	Brief in-flight fire High pitch hum, bang #1 engine, EMRST damaged, Thomas coupling fragmented	MGB oil hot caution light. After ditching, engine FW. Sank
	July 10, 1974	USAF		Eng 1 power loss on approach. Landed short and consumed by fire
SH-3A	April 4, 1975	USN	Spur gear shaft shear due IFWU 2 failure	Torque split and vibration. Eng 2 FW, N_f 120%
G-AZRF S-61N	September 16, 1976	CAA Occurrence No. 197604142	In-flight fire (extinguished) Loud bang EMRST severed #2 engine, #4 & 5 bearings failed Both oil jets fractured #5 oil jet tube bent	The No 2 engine oil pressure fell to 10 psi, followed by an indication of engine fire. The No 5 bearing had failed, the rear support tube had separated with fire damage to the main gearbox front casing and the wiring/hydraulic hoses damaged due to failure of the No 5 bearing oil seal. CAA Closure; Power turbine failure due to oil starvation of No's 4 and 5 bearings
SH-3D	January 30, 1978		Probably incorrect spur gear journal dimension	Squealing noise during autorotation
SH-3H	March 16, 1978		Suspect sleeve bearing failure	Metallic odour, buzz from MGB, 14 psi oil pressure drop, No 1 input shaft loose
SH-3G	April 14, 1978		Whine, chip light, Excessive play in No 2 IDS	Spur gear journals deteriorated by improper lube and plasma spray techniques

Registration and Type Variant	Date	Report Type	Key features	Accident/Incident summary
SH-3G	October 3, 1978		Loud howling, loud bang, fire	Evidence of spur gear and sleeve bearing failure caused by flange coupling/IDS
SH-3H	November 28, 1978		Suspect No 1 IFW failure	High frequency vibration. Oil analysis revealed high iron
SH-3D	February 21, 1979		Suspect No 1 input section	High pitch whine, grinding
SH-3H	March 13, 1979		Chip lights, metal flakes	
SH-3D	April 6, 1979		Flange coupling out of balance	High frequency squeal
SH-3D	April 27, 1979			High frequency vibration and whine. Steel particles. High temperature history
SH-3H	August 22, 1979		Cracked 'T' bolt	
SH-3A	June 27, 1979		Input seal worn	High porosity of spur gear plasma spray - lube problem
SH-3G	November 13, 1979		High Frequency vibration Sleeve bearing destroyed	Insufficient lube and misrigged spur gear
SH-3D	November 28, 1979		Loud howl	Lack of lube, high porosity spur gear plating
SH-3H	December 3, 1979		Loud thump, vibration, shudder	No 1 IFWU failed. Secondary failure of sleeve bearing
SH-3D	January 17, 1980			High frequency history howling from No 1 input area - not corrected by shaft change
SH-3H	February 7, 1980		Howling noise Excessive radial play in IDS	
SH-3H	May 21, 1980		Loud howl, No 2 side of MGB failed. Fire	Possible misalignment, possible spur gear
SH-3C	June 28, 1980		High pitch noise	Coupling improperly greased
SH-3H	November 9, 1980		Noise, chip lights, oil leak	High speed bearing failure suspect

Registration and Type Variant	**Date**	**Report Type**	**Key features**	**Accident/Incident summary**
SH-3H	November 14, 1980		Oil pressure fluctuation	No 2 input quill scored, carbon seal enlarged
SH-3G	April 10, 1981	USN	In-flight fire in vicinity of main rotor head	Suspect failure at No 2 engine input spur gear. A/c destroyed
SH-3G	September 15, 1982	USN	Drive failure	Transmission whine, loud bang, rotor brake caution light, engine 1 lost power, engine 1 fire warning
G-ASNL S-61N	March 11, 1983		#1 input spur gear failure	
69-5804 HH-3E	October, 1985	USAF	In-flight fire EMRST severed #2 engine, #5 bearing failed PT disc uncontained	AAIB report 3/90 describes 'almost identical damage in some areas to that seen on G-BEID's No 2 drive train
G-LINK S-61N	January 17, 1986	CAA Occurrence No. 198600154	Whine, bang #1 engine EMRST damaged Thomas cplg disintegrated	There was an uncontrolled failure of the high speed shaft engine to transmission. After normal start, a medium-high frequency whine developed, which soon increased in volume and frequency. As shut-down procedures were carried out a bang was heard, this seemed to be suggestive of high speed shaft failure. Primary failure resulted in separation of the high speed shaft from the MGB input flange, disintegration of the Thomas coupling at the forward end of the high speed shaft and separation of the input coupling from the MGB. Sikorsky reports that the shaft failure could have been due to a deviation from approved repair scheme in that the MGB input housing was secured with light alloy pins instead of steel
G-BEID S-61N	July 13, 1988	AAR 3/90	In-flight fire Unusual noises, bang EMRST severed Polygon cplg misassembled #2 engine, #5 bearing failed Both oil jets fractured	A muffled crack or 'bang' was heard by the co-pilot 43 minutes into the flight. Passengers then heard a number of abnormal noises including a grinding mechanical noise. Both crew felt a slight change in the vibratory "feel" of the aircraft, which was followed by a fire in the main gearbox bay. The PT and drive train of No 2 engine had suffered significant pre-shutdown damage. This consisted of severe damage to No 5 bearing, extensive rubbing between rotating and static parts of the PT module, and severe rubbing of the Thomas coupling against the EMRSA, which had resulted in severance of the latter. The No 5 bearing deterioration resulted from failure of the bearing cage, or by excessive imbalance forces on the bearing. The accident was caused by an uncontrollable fire in the main gearbox bay, which probably resulted from the effects of failure of the No 5 bearing in the No 2 engine. The aircraft ditched in the North Sea, 29 nm North East of Sumburgh, Shetland. The 2 crew and 19 passengers were evacuated successfully, without serious injury

Registration and Type Variant	Date	Report Type	Key features	Accident/Incident summary
G-BDES S-61N	November 10, 1988	AAR 1/90		In a low hover, after takeoff, a buzzing noise was heard, followed by a thump in the passenger cabin and an increase in vibration. There was then a loss of the main transmission oil pressure. The accident resulted from progressive failure in the main transmission, initiated by a fatigue fracture of a single tooth on the main combiner gear wheel. The helicopter suffered a catastrophic failure of the helical combiner gear within it's main transmission input gear train, which occured after 3.875 hours of operation. The fatigue cracking that originated in a gear tooth, was in a tooth zone containing non-metallic inclusions. The aircraft ditched in the North sea, 90nm North East of Aberdeen. The 2 crew and 11 passengers evacuated the aircraft and were rescued without injury
G-BCEA S-61N	February 23, 1989	CAA Occurrence No. 198900539		A hammering vibration was felt from the main rotor at a maximum speed of 98kts and 65% torque. The hammering vibration was repeated every 30 seconds in moderate turbulance. A heavy accumulation of salt was confirmed as the cause
61786 S-61N	February 28, 1989		Brief in-flight fire High pitch hum, bang #1 engine, EMRST damaged, Thomas coupling fragmented	Far east MHS S-61N Thomas coupling fragmented. IDS splined coupling separated. IP journal eccentric damage and fractured. Plain bearing grossly damaged and rotated. AAIB thought this was due to a 'T' bolt coming loose. At the time self locking nuts were being re-used without checking the run-on torque
G-BFFJ S-61N	May 11, 1989	Bulletin 7/90 Jul-90	Whine, then bang #1 IDS aft flange damage	Five minutes after engine start an abnormal whining noise was heard, which soon culminated in a loud bang. The crew on an adjacent S-61 noticed a quantity of oil running down the left side of G-BFFJ's fuselage. The aircraft's passengers later reported hearing the noise for some time before the bang. Examination of the aircraft revealed that the No 1 input pinion and IDS had fractured. The Thomas coupling had fragmented, the IDS had separated from the splined coupling, the EMRSA had been damaged, the gimbal ring had fractured and the No.1 input pinion forward journal had fractured. There had been reports of oil leaks from the No 1 input area on two other occasions before the incident. It was possible that damage had resulted from a temporary seating failure of the No 1 input pinion oil seal some time before the incident, although no positive evidence was present. The aircraft had not departed from Sumburgh Airport, Shetland Islands. All persons on board were evacuated and no injuries were sustained
G-BEDI S-61N	May 1, 1990	Unobtainable		No report was found. The report on S-61, G-BCLD uses this aircraft as one of the 'other cases' found with similar/relevant problems: In this case the MGB was bought by a UK operator as part of a used S-61N that was transferred from the USA. On arrival in the UK abnormal debris was found in the MGB scavenge filter, including white metal. Strip examination reportedly showed that the aft bearing for the No 1 input pinion was severely distressed. Part of the journal had flaked off; the sleeve bearing was loose in its sleeve and had turned; the sleeve was loose in the housing bore; and the sleeve location pin was loose. During test-running on a rig following repair the No 1 input pinion failed

Registration and Type Variant	Date	Report Type	Key features	Accident/Incident summary
G-BCLD S-61N	October 9, 1990	Bulletin 12/91 Dec-91	No fire Whine, then bang #1 IDS 3 'T' bolts torn off minor damage to engine live oil jet cracked dead oil jet fractured	Five minutes into the flight, as transmission torque was increased, the crew heard a whine. This was identified as coming from the left side of the transmission. Around one minute after the whine was heard initially, there was a loud bang. Power was lost and the No 1 engine shutdown. After landing, oil was seen pouring down the left side of the aircraft. Prior to the oil leak, the crew noted a slight rise in MGB oil temperature and a slight fall in the oil pressure but both parameters remained within limits. This tendency continued during subsequent flights and immediately prior to the accident. The No 1 drive train input pinion and the IDS/splined flange connection had fractured. This forward journal exhibited gross rotational wear, deformation and overheat. The engine exhibited considerable damage consistent with the effects of excessive vibration. The crew established the aircraft in autorotation and achieved a gentle landing 5 nm East of Mount Pleasant Airport, Falkland Islands. The 3 crew and 14 passengers evacuated the aircraft without difficulty
G-AYOY S-61N	November 5, 1990	CAA Occurrence No. 199002052		The right-hand aft transmission support STA 290 was found to be cracked during maintenance. This seemed to have been caused by internal stresses induced into the structure by incorrect maintenance practice
?	?		Gearbox 943 IP fractured during ground rig run after repair	Reported due to external oil line kink - see G-BEDI above (same gearbox)
G-BDDA S-61N	November 6, 1990	CAA Occurrence No. 199004924		During a mid-point inspection, unauthorised repairs were found to have been carried out on the main gearbox. On No's 1 and 2 input spur gears unauthorised blending repairs were found in the gear teeth crowns. The helical input gear had been repaired beyond authority on 4 gear teeth, both sides of the crown. No 1 input gear white metal bearing was damaged and worn to copper base lining together with surface cracks on the rear bearing journal. Repairs to both white metal bearing housing bosses were not re-protected. It was confirmed that when these repairs were carried out an incorrect sized No 1 aft bearing had been fitted, which resulted in damage to other parts
C-FFHD S-61N	December 16, 2002	TSB under investigation	#1 input pinion fractured, IDS bent 4 degrees	Test flight to adjust topping of #2 engine. Logging operation. During climbout, whine and vibration noted. Smoke in cabin. Flames seen, bang and shudder. A/c autorotated to safe landing on road, but struck power lines. Severe damage to a/c. #1 input pinion journal and carbon seal disintegrated, pinion fractured, severe gimbal rub. All four 'T' bolts in place
N81664 S-61A	March 23, 2003		Lloyds List 26-3-03	Hovering at 200ft, load bang and smoke reported. A/c dropped to the ground and was destroyed

EMRSA	Engine Mounting Rear Support Assembly
IDS	Input Drive Shaft
IFWU	Input Free Wheel Unit
IP	Input Pinion
MGB	Main Gear Box
SC	Splined Coupling

Appendix I

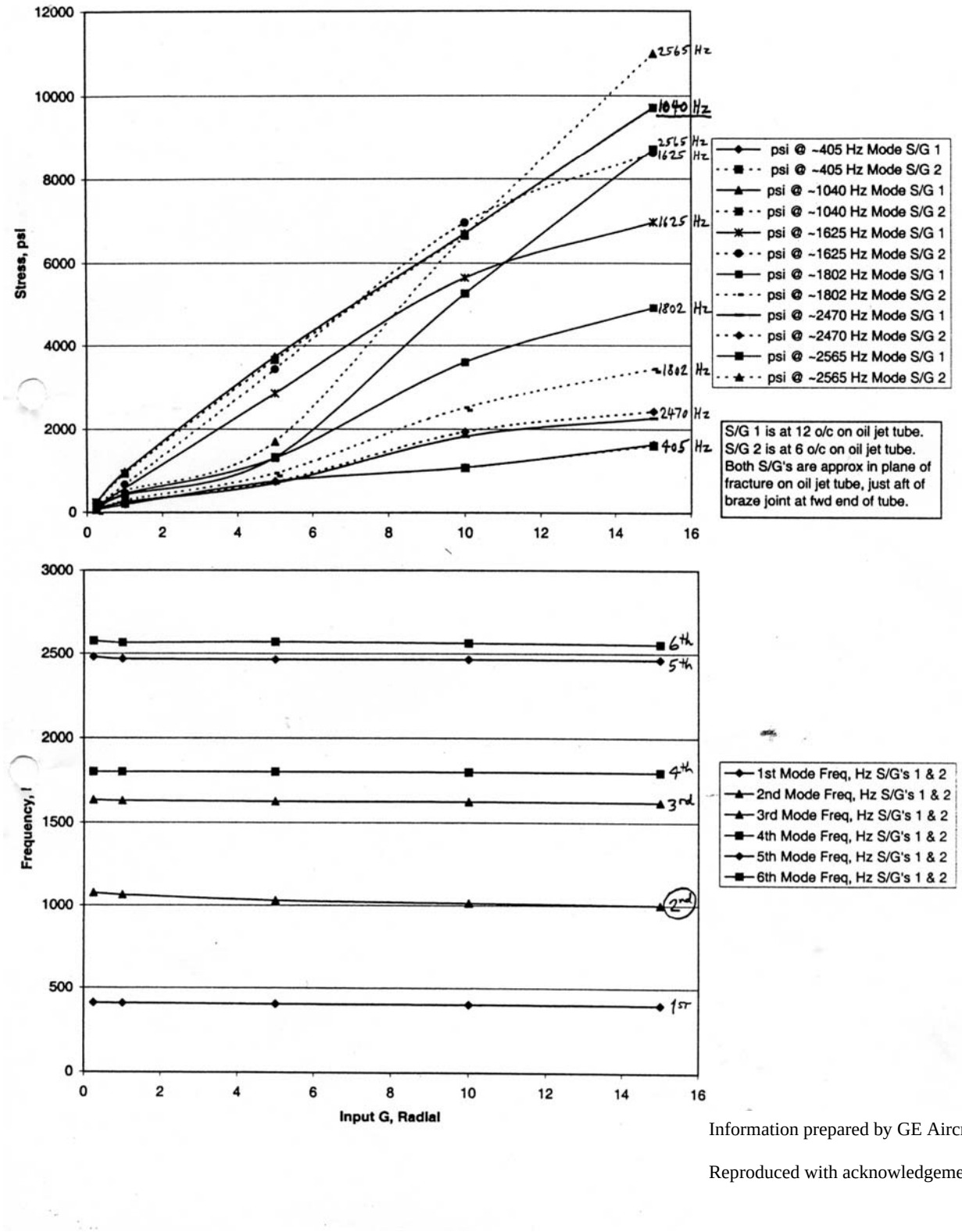
BRISTOW S-61N ACCIDENT, G-BBHM; 7/15/02
CAUSE OF CT58-140 #5 BEARING DISTRESS

GE LAB: Advanced distress precludes definitve root cause determination.
Metallurgical condition of bearing is atypical of "less than normal" lubrication:
- lack of corroborating evidence on ALL bearing components.
- significant metallurgical differences between inner and outer races.
- generalized operating conditions do not produce localized damage.

	#5 BEARING EVIDENCE	EVIDENCE CONSISTENT WITH: *(THIS IS GE'S OPINION)*	
		INADEQUATE LUBRICATION	**DYNAMIC RADIAL IMBALANCE**
STATIC	Material condition unaltered from its production condition, except for a localized area at the 12 o/c location	NO	YES
OUTER RACE	No significant surface distress; only adhered material at 4-8 o/c	NO	YES
	No evidence of surface wear, plastic flow or microspalling	NO	YES
ROTATING INNER RACES	Severe asymmetric, eccentric wear on both inner races	MAYBE	YES
	Significant general surface distress and wear	YES	YES
	Altered microstructure and plastic flow (microspalling absent due to the advanced damage to races?)	YES	YES
	Uniform wear track 360° around forward and aft rails	MAYBE	MAYBE
CAGE	Silver plating shows no evidence of tarnishing, melting or discoloration	NO	YES
	Excessive cage wear on both sides of all 11 ball pockets	MAYBE	MAYBE
	Uniform 360° wear track thru silver plate on both fwd and aft cage rails	MAYBE	MAYBE
BALLS	Significant general surface distress and heavy wear: ~10% dia reduction	YES	YES
	Altered microstructure and plastic flow (microspalling absent due to the advanced damage to balls?)	YES	YES

GE Aircraft Engines - **Proprietary Information**

Oil Tube Stress Levels



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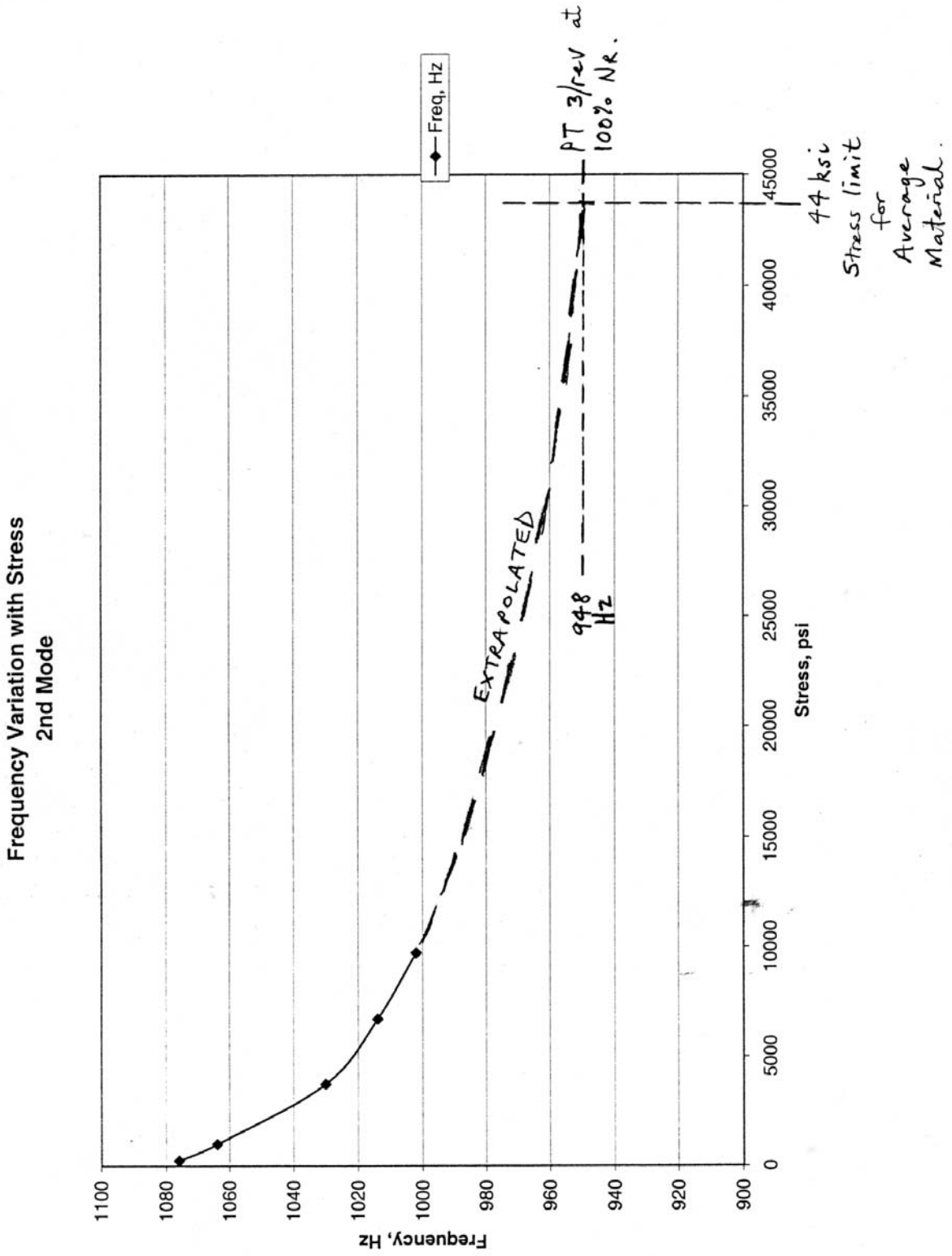

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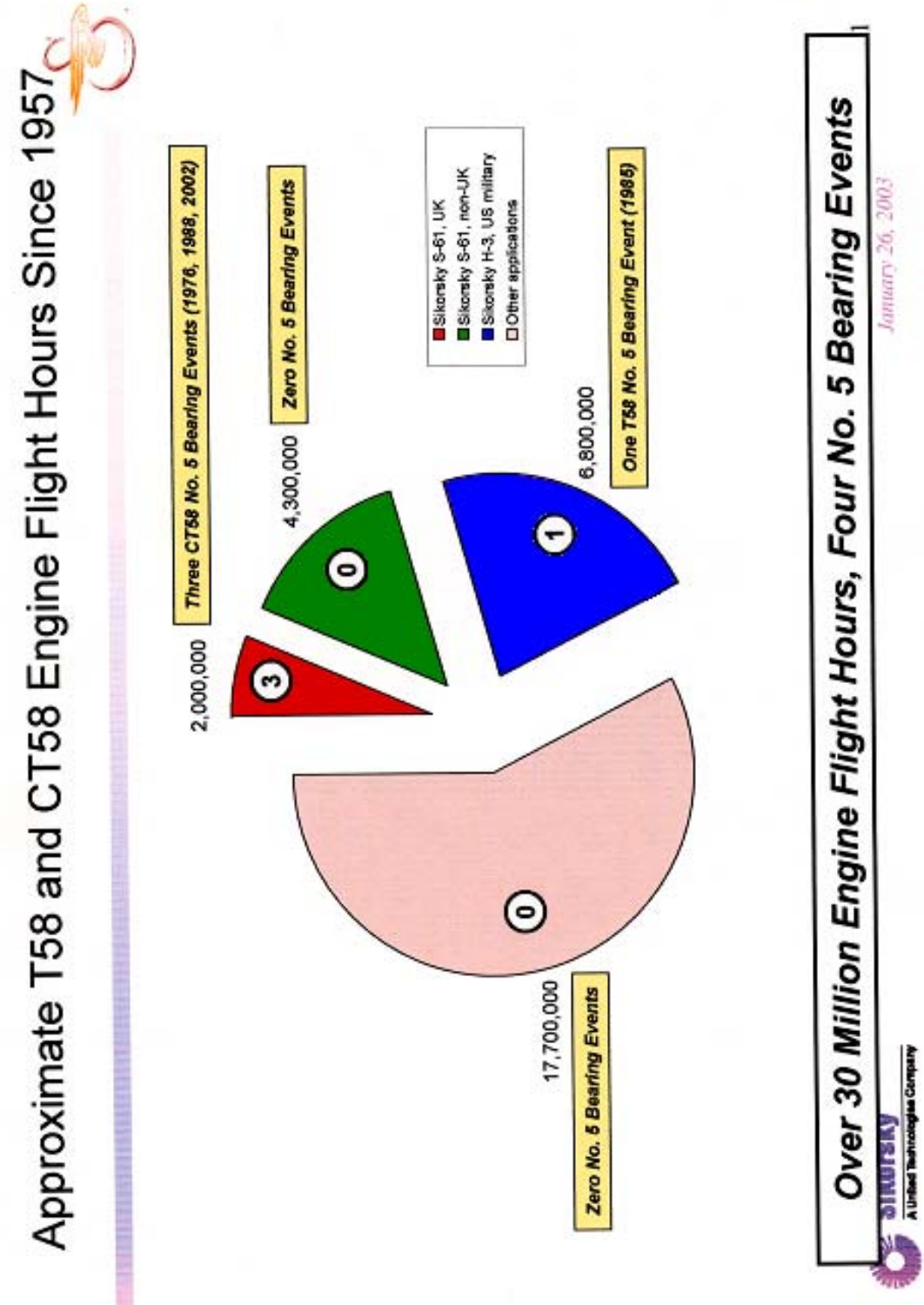
Distribution of Bearing Related Events



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Department for Transport

AAIB Bulletin S2/2002 *SPECIAL*

AAIB Bulletin No: S2/2002	**Ref: EW/C2002/07/03**	**Category: 2.1**

Aircraft Type and Registration:	Sikorsky S-61N, G-BBHM
Serial Number:	61713
Year of Manufacture:	1973
Date & Time (UTC):	15 July 2002 at 1515 hrs
Location:	Poole Harbour, Dorset
Type of Flight:	Public Transport (SAR)
Persons on Board:	Crew - 4 Passengers - Nil
Injuries:	Crew - Nil Passengers – N/A
Nature of Damage:	Helicopter destroyed
Commander's Licence:	Airline Transport Pilot's Licence (Helicopters)
Commander's Flying Experience:	4,600 hours (of which 2,750 hours were on type)
Information Source:	AAIB Field Investigation

ISSN 0309-4278

History of the flight

The helicopter, which was based at Portland, was being operated in the Search and Rescue role by a commercial company on behalf of HM Coastguard. The crew came on duty at 0800 hrs on 15 July and completed serviceability checks on their respective equipment. This included the commander checking the aircraft and setting it up for a scramble start. No unserviceabilities were noted.

The crew received their first alert at 1425 hrs and were airborne, after uneventful engines start within five minutes. Their task was to look for a possible 'person in the water' in Poole harbour. During the subsequent search, the commander was handling the aircraft and maintained approximately 200 feet amsl with an airspeed of between 30 kt and 80 kt. The cabin sliding door was open and the winchman was seated in the open aperture with a safety harness. After about 40 minutes, the crew were requested to investigate reports of a vessel emitting a lot of smoke to the north of their position. From his location to the west of Brownsea Island, the commander headed 350° at 80 kt and at 200 feet amsl.

Shortly afterwards, the two rear crew members noticed an unusual noise and commented on this on their intercom. Almost immediately, the 'NO 2 ENG FIRE WARN' light illuminated accompanied by the audio alert. As the crew were completing the appropriate checks, smoke was seen to be coming out, under pressure, from the area of No 2 engine exhaust; smoke was also seen in the cabin. The crew continued with the fire drill as the commander initiated a climb and a turn towards Bournemouth Airport, some 7 nm away. The sliding door was closed and an emergency was declared on the coastguard radio frequency. Following discharge of the extinguisher system, the fire light remained illuminated. Shortly after, the 'TRANS OIL PRESS' light illuminated on the caution panel accompanied by the 'MASTER CAUTION' light. By now the co-pilot had identified a suitable landing field to the left of the helicopter and called this to the commander's attention. The commander called "Immediate Landing" and this decision was transmitted on the coastguard frequency. As the commander established his approach to the selected sports field to the west of Poole, the 'PRI SERVO PRESS' light illuminated followed by the 'AUX SERVO PRESS' light. He was also aware of an uncommanded lateral movement on the cyclic control. On final approach, the co-pilot lowered the landing gear and also noted that the 'NO 1 ENG FIRE WARN' light had illuminated. Within the cabin, the smoke was becoming more dense as the commander made a successful landing on the sports field. After touchdown, the crew shut down No 1 engine and quickly vacated the helicopter. G-BBMH was destroyed by fire shortly after the crew were clear.

The crew of this helicopter were suddenly faced with a serious emergency followed shortly after by further indications of additional problems. However, all members of the crew carried out their duties very efficiently to enable the commander to carry out a successful landing in a period of approximately one minute from the initial onset of the emergency; this reflected extremely well on the individuals concerned and on their training.

Flight recorder information

The helicopter was fitted with a combined cockpit and flight data recorder (FDR). This records the most recent five hours of data and one hour of voice information; all available data was recovered successfully and preliminary analysis has indicated that the time interval between onset of the original fire warning and touchdown was 80 seconds. The helicopter was also equipped with a Health and Usage Monitoring System (HUMS) recorder, which was destroyed by the fire and thus data for the accident flight was lost. However, historical data is available and will be subject to analysis. Work will continue to refine the information from the recorders.

Initial engineering information

Shortly after the helicopter landed the fire took hold and, before the Fire and Rescue Services were able to extinguish it, some 75/80% of the helicopter had been consumed. After initial examination on site, the wreckage has been recovered to the AAIB at Farnborough. Preliminary indications are that the fire began in and around the No 2 engine, and there is some evidence of mechanical distress towards the rear of the No 2 engine in the region of the high speed shaft.

The initial findings of the engineering investigation conducted in the field are that a Thomas flexible coupling in the No 2 main drive shaft had run eccentrically, for reasons yet to be confirmed. Radial play was found at the Thomas coupling, and it is considered that this was associated with the No 5 engine bearing and/or the two couplings between the power turbine shaft and the main drive shaft. The resulting radial movement at the Thomas coupling had allowed it to come into contact with the tubular aft engine support in which the main drive shaft ran. As a result of this contact, the aft engine support had been progressively severed. This condition probably led to the release of engine oil into the area of the gearbox, and this is thought to be the cause of the fire in that area, as reported by the crew and witnesses. Both engines will be shipped as soon a practicable to an overhaul facility in the UK where the AAIB, in conjunction with the engine and airframe manufacturer, will conduct a detailed strip examination.

The failure mode described has occurred on previous occasions and in 1988 another S-61, G-BEID, was lost in apparently similar circumstances. AAIB Report 3/90 refers.

The last major work in this area of the helicopter had been a Main Rotor Gearbox change carried out in November 2001 at 29754:40 hours TSN, about 100 hours before the accident. Since that time only routine minor maintenance had been carried out in the affected area.

Additional information

Helicopter

TSN	29853:55 at 14/7/02
LDGS	26465 at 14/7/02

Engine

No 2 type	General Electric CT58-140-2
Serial number	295289
Year of manufacture	1980
TSN	13417:14 at 14/7/02
TSO	1562:58 hrs, 8002 cycles

Future Investigation

The Chief Inspector of Air Accidents has ordered an Inspector's Investigation into the circumstances of this accident under the provision of the Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996. Investigation will continue on engineering and operational aspects of this accident.

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Safety Recommendations issued during the Investigation

EW/C2002/7/3

AIR ACCIDENTS INVESTIGATION BRANCH

Safety Recommendations: Accident to Sikorski S61N at the Royal Marines Barracks, Poole, Dorset, on 15 July 2002

History of the flight

The helicopter, which was based at Portland, was being operated in the Search and Rescue role by a commercial company on behalf of HM Coastguard. The crew came on duty at 08:00 hrs on 15 July and completed serviceability checks on their respective equipment. This included the commander checking the aircraft and setting it up for a scramble start. No unserviceabilities were noted.

The crew received their first alert at 14:25 hrs and were airborne within five minutes. Their task was to look for a possible 'person in the water' in Poole harbour. During the subsequent search, the commander was handling the aircraft and maintained approximately 200 feet amsl with an airspeed of between 30 kt and 80 kt. The cabin sliding door was open and the winchman was seated in the open aperture with a safety harness. After about 40 minutes, the crew were requested to investigate reports of a vessel emitting a lot of smoke to the north of their position. From his location to the west of Brownsea Island, the commander headed 350° at 80 kt and at 200 feet amsl.

Shortly afterwards, the two rear crew members noticed an unusual noise and commented on this on their intercom. Almost immediately, the 'NO 2 ENG FIRE WARN' light illuminated accompanied by the audio alert. As the crew were completing the appropriate checks, smoke was seen to be coming out, under pressure, from the area of No 2 engine exhaust; smoke was also seen in the cabin. The crew continued with the fire drill as the commander initiated a climb and a turn towards Bournemouth Airport, some 7 nm away. The sliding door was closed and an emergency was declared on the coastguard radio frequency. Following discharge of

the extinguisher system, the fire light remained illuminated. Shortly after, the 'TRANS OIL PRESS' light illuminated on the caution panel accompanied by the 'MASTER CAUTION' light. By now the co-pilot had identified a suitable landing field to the left of the helicopter and called this to the commander's attention. The commander called "Immediate Landing" and this decision was transmitted on the coastguard frequency. As the commander established his approach to the selected sports field to the west of Poole, the 'PRI SERVO PRESS' light illuminated followed by the 'AUX SERVO PRESS' light. He was also aware of an uncommanded lateral movement on the cyclic control. On final approach, the co-pilot lowered the landing gear and also noted that the 'NO 1 ENG FIRE WARN' light had illuminated. Within the cabin, the smoke was becoming more dense as the commander made a successful landing on the sports field. After touchdown, the crew shut down No 1 engine and quickly vacated the helicopter. G-BBMH was destroyed by fire shortly after the crew were clear.

Recorded Data

The helicopter was fitted with a combined cockpit and flight data recorder (FDR) and this records the most recent five hours of data and one hour of voice information; all available data was recovered successfully and preliminary analysis has indicated that the time interval between onset of the original fire warning and touchdown was 80 seconds. During the last hour or so of recorded data, increasing noise on the No 2 engine free turbine speed (N_F) trace was present.

The helicopter was also equipped with a Health and Usage Monitoring System (HUMS) recorder, which was destroyed by the fire and thus data for the accident flight was lost. However, historical data was available, although the data download for the previous short flight had been unsuccessful. The available data did not show any clear trend related to the accident, nor was any parameter threshold exceeded.

Interim engineering information

The interim findings of the engineering investigation to date are that the Thomas coupling in the No 2 main drive train had run eccentrically, due to gross deterioration of the No 5 bearing in the free turbine stage of the No. 2 engine, and consequent

'orbiting' of the free turbine shaft. The resulting radial movement at the Thomas coupling had allowed it to come into contact with the engine rear support mounting tube in which the shaft ran. As a result of this contact, the engine rear support mounting tube had been progressively severed. This condition rapidly led to displacement of the No. 2 engine, breach of the associated fire zone into the main rotor gearbox bay, and initiation of a oil-fed fire in that bay. The magnesium alloy gearbox and the flexible hydraulic pipes for the flight control hydraulic main and auxiliary systems were destroyed by the fire, with flight control malfunctions occurring as the helicopter landed.

A similar failure mode has occurred on previous occasions and in 1988 another S-61, G-BEID, was lost in apparently similar circumstances. AAIB Report 3/90 refers.

Six hours before the accident all the magnetic chip detectors on the engine were inspected and were found to be free of debris. No oil leaks or other evidence of deterioration of the bearing were observed during the daily checks. There was no indication to the crew of the failure of the bearing until the noise was heard immediately before the first fire warning. The reasons for the bearing failure are as yet undetermined.

Once the free turbine began to orbit, deterioration was extremely rapid. The severance of the engine rear support mounting tube occurred very rapidly and, in effect, without warning. The generation of the oil fed fire probably occurred when the tube was damaged. The consequential breach of the fire zone allowed the fire to rapidly enter the unprotected main rotor gearbox bay, where it was soon intense enough to trigger the fire warning for the number one engine, and other high priority warnings.

Safety Recommendations

AAIB considers that the severity of this event, and the apparent higher than expected probability of its occurrence, combined with the lack of warning and the short period in which control of the helicopter can be lost, is unacceptable. Therefore the following Safety Recommendations are made that:

Recommendation 2002-51

The US Federal Aviation Administration, in conjunction with UK CAA and the airframe and engine manufacturers, implement a means of providing a suitable warning to aircrew and/or engineering staff, of any impending loss of integrity of the drive shaft system of the S61N helicopter which could lead to failure of the engine rear support mounting tube.

Recommendation 2002-52

The US Federal Aviation Administration, in conjunction with UK CAA and the airframe manufacturer, ensure that the integrity of the engine fire zones on the S61N helicopter is not breached by a failure of the engine rear support mounting tube

Recommendation 2002-53

The US Federal Aviation Administration, in conjunction with UK CAA and the airframe manufacturer, devise a means of protecting essential systems in the main rotor gearbox bay of the S61N helicopter from the effects of fire.

21 November 2002

CAA and FAA Responses
to AAIB Safety Recommendations 2002-51, 2002-52 and 2002-53

Safety Regulation Group
Safety Investigation & Data Department

Mr P T Claiden
Principal Inspector of Air Accidents
Department for Transport
Air Accidents Investigation Branch
Berkshire Copse Road, Aldershot
Hants GU11 2HH

12 February, 2003

Our Ref: 2002/04849
Your Ref: EW/C2002/7/3

Dear Mr Claiden

ACCIDENT TO SIKORSKY S61N, G-BBHM, NEAR POOLE DORSET, ON 15 JULY 2002

With reference to your letter of 21 November 2002 arising from the investigation of the above accident, the CAA Response to the Recommendations made jointly to the CAA, iaw Regulation 14, are forwarded to you.

RECOMMENDATION 2002-51

The US Federal Aviation Administration, in conjunction with UK CAA and the airframe and engine manufacturers, implement a means of providing a suitable warning to aircrew and/or engineering staff, of any impending loss of integrity of the drive shaft system of the S61N helicopter which could lead to failure of the engine rear support mounting tube.

CAA Response

The CAA accepts this Recommendation.

In accordance with standard practice the CAA stands ready to support the US Federal Aviation Administration and the airframe and engine manufacturers to implement a means to provide a suitable warning to aircrew of any impending loss of integrity of the drive shaft system of the S61N helicopter which could lead to failure of the engine rear support mounting tube. In the meantime, in order to address one possible source which could lead to failure of the engine rear support mounting tube, the CAA UK issued Additional Airworthiness Directive (AAD) number 002-12-2002 on the 17th December 2002. This AAD requires UK operators of S61N helicopters, by the 31st January 2003, both to install electrical chip detectors (ECDs) on each engine's power turbine accessory drive, and to modify the aircraft to enable monitoring of these ECDs to be conducted by means of in situ continuity checks by engineering staff after each engine shutdown.

CAA Status:- OPEN

Civil Aviation Authority
Aviation House 2W Gatwick Airport South Crawley West Sussex England RH6 0YR www.caa.co.uk
Telephone 01293 573211 Fax 01293 573972

RECOMMENDATION 2002-52

The US Federal Aviation Administration, in conjunction with UK CAA and the airframe manufacturer, ensure that the integrity of the engine fire zones on the S61N helicopter is not breached by a failure of the engine rear support mounting tube.

CAA Response

The CAA accepts this Recommendation.

In accordance with standard practice the CAA stands ready to support the US Federal Aviation Administration and the airframe manufacturer in developing any airworthiness measures that are deemed necessary to ensure safe operation of the S61N helicopter. To that end, on 13 November 2002, CAA wrote formally to the US Federal Aviation Administration and the airframe manufacturer with a request for consideration of appropriate actions that may be necessary to meet the intent of this Recommendation.

CAA Status:- CLOSED

RECOMMENDATION 2002-53

The US Federal Aviation Administration, in conjunction with UK CAA and the airframe manufacturer, devise a means of protecting essential systems in the main rotor gearbox bay of the S61N helicopter from the effects of fire.

CAA Response

The CAA does not accept this Recommendation.

The current design requirements for fire protection of essential systems, as contained within JAR 29.1191, have given, over many years, a satisfactory level of safety for large helicopters of all types. These requirements specify that essential systems need be fireproof only in cases where they are not isolated from potential powerplant fires by a firewall shroud. In that respect, assurance of the integrity of the engine fire zones has been covered by the CAA response to Recommendation 2002-52.

CAA Status:- CLOSED

Yours sincerely

T J Whittle
Head SDU

U.S. Department
of Transportation

**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, DC 20591

APR 30 2003

RECEIVED
13 MAY 2003
AIR ACCIDENTS
INVESTIGATION BRANCH

Mr. P. T. Claiden
Principal Inspector of Air Accidents
for Chief Inspector of Air Accidents
Berkshire Copse Road
Aldershot
Hants GU11 2HH

Dear Mr. Claiden:

The Office of Accident Investigation convened a Safety Recommendation Review Board to review the enclosed responses to FAA Safety Recommendations 02.347 through 02.349. As a result, the Review board classified your recommendations as follows:

02.347 - "Open-Acceptable Response," pending issuance of final rule.

02.348 - "Closed-Acceptable Alternate Action"

02.349 - "Closed-Acceptable Alternate Action"

If you have any questions, please contact Mr. Jeff Gorney, AAI-210, at (202) 267-8748.

Sincerely,

Frank Del Gandio

Frank Del Gandio
Manager, Recommendation and
Analysis Division

Enclosures

cc: ASW-111 (M.Bruner)

U.S. Department of Transportation
Federal Aviation Administration

Memorandum

Subject: **INFORMATION:** FAA Safety Recommendations 02.347, 348, and 349; AAI Memo of 12/04/02

Date: APR 9 2003

Reply to Attn. of:

From: Manager, Rotorcraft Directorate, Aircraft Certification Service, ASW-100

To: Manager, Recommendation and Analysis Division, AAI-200

The FAA concurs with FAA Safety Recommendation 02.347 regarding a means of providing a suitable warning to aircrew of impending loss of integrity of the drive shaft system of the Sikorsky Model S61N helicopter. General Electric has developed a #5 engine bearing chip detector with an on-board cockpit annunciation system that warns the aircrew of a potential bearing deterioration condition. The interfacing components are in the final stages of design. The manufacturer expects to issue a service bulletin within 2 months that specifies installing this system including the associated operating instructions. We are confident that this detection and annunciation system will satisfactorily identify the early stages of bearing failure before hazardous consequences develop. The Boston ACO plans to issue a notice or proposed rulemaking to mandate installing this system soon after the instructions and components are approved and released to service.

The FAA does not concur with Recommendations 02.348 and 02.349 to incorporate improvements to the existing fire zone and additional fire protection for transmission components. The current fire zone design provides satisfactory protection and containment under fire conditions normally considered. We do recognize the need to address extraordinary circumstances and believe the chip-detecting system previously discussed satisfies the intent of these recommendations.

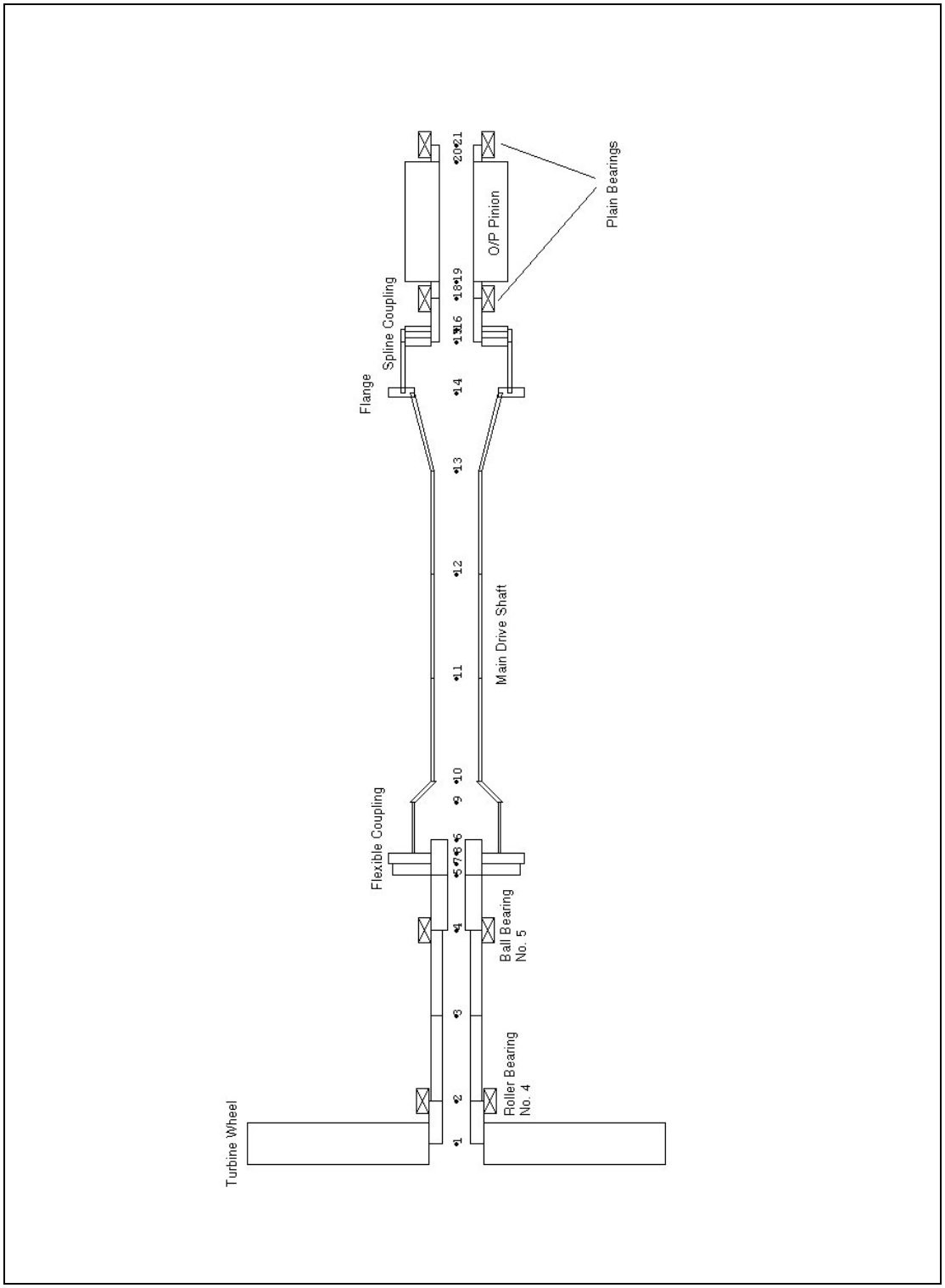
We will continue to review service experience to ensure the proper operation of the chip detector system and the performance of the propulsion system fire protection system.

for David A. Downey

cc: Boston ACO

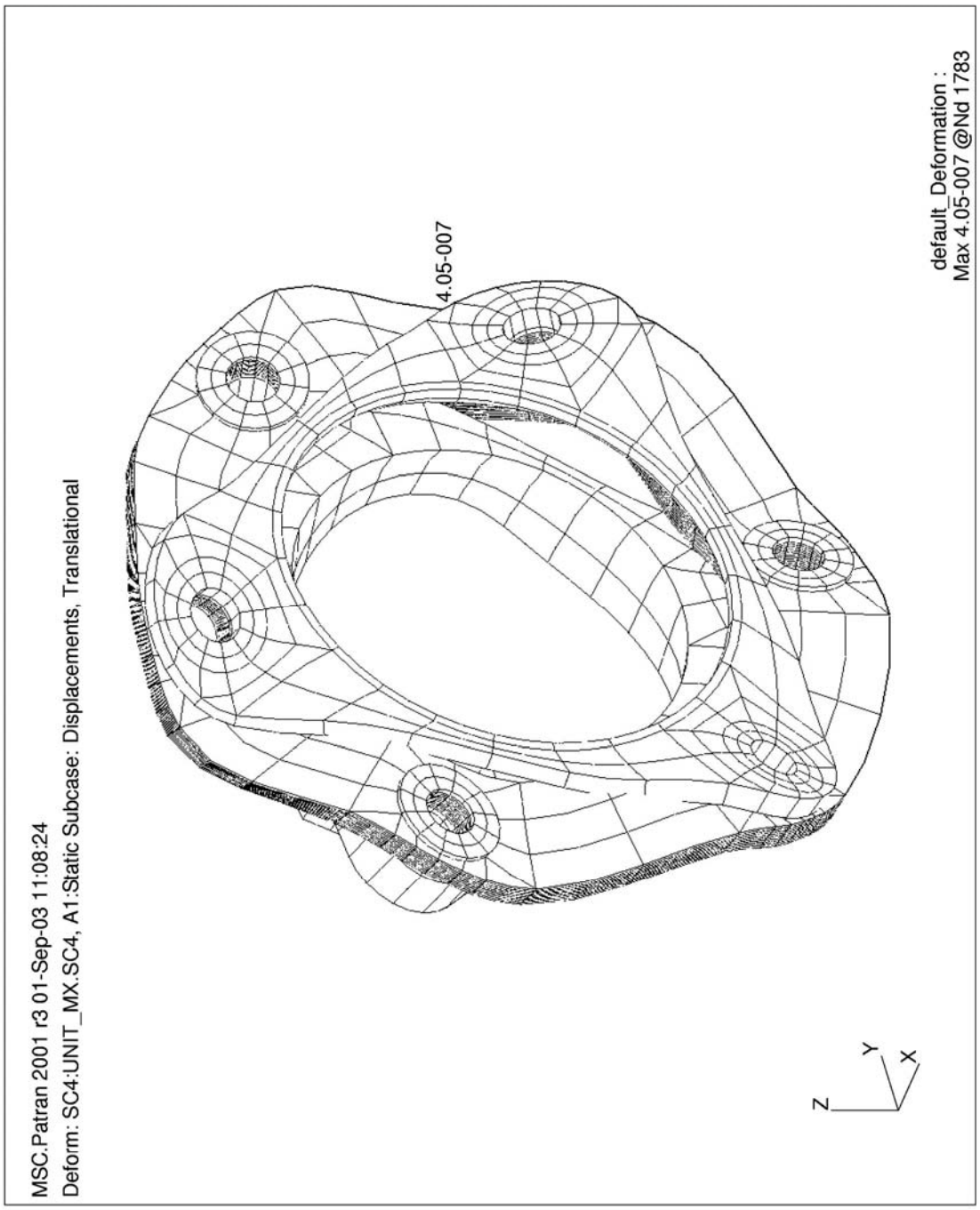
RECEIVED
13 MAY 2003
AIR ACCIDENT
INVESTIGATION BRANCH

FINITE ELEMENT AND DYNAMIC ANALYSIS OF MAIN DRIVE SHAFT

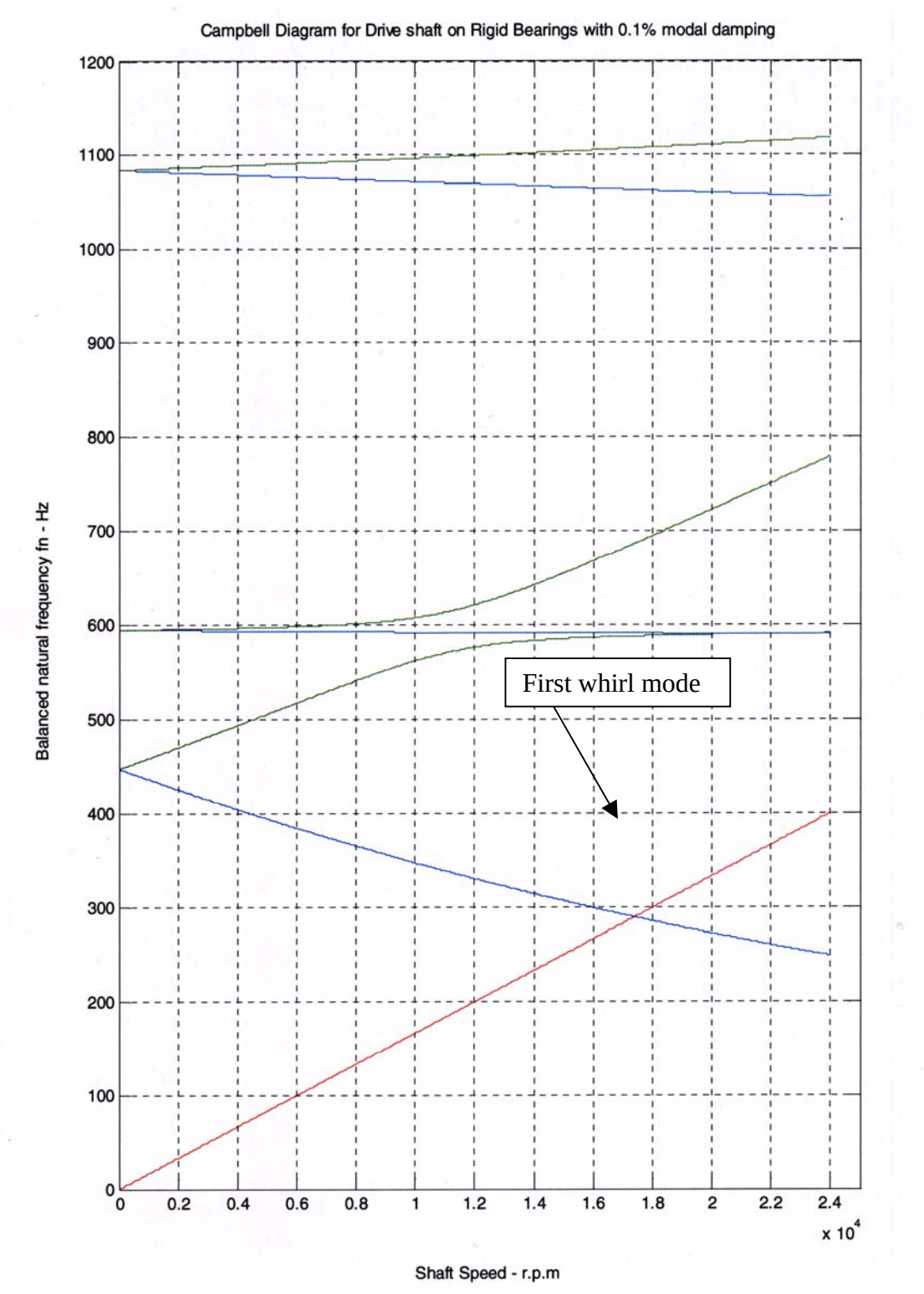


DRIVE SHAFT ROTORDYNAMIC MODEL

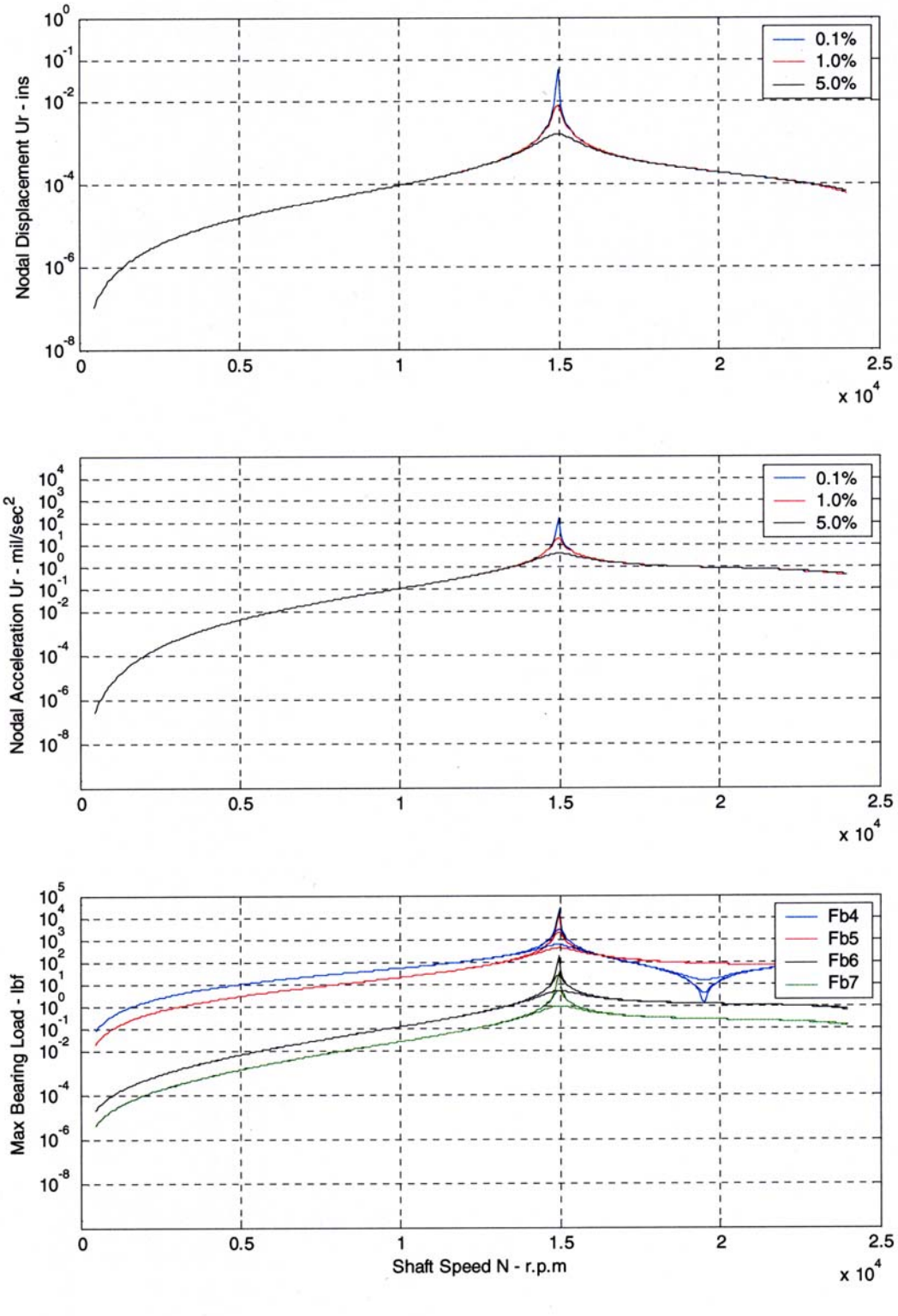
DEFLECTIONS IN THOMAS COUPLING DUE TO AXIAL TORQUE LOAD.



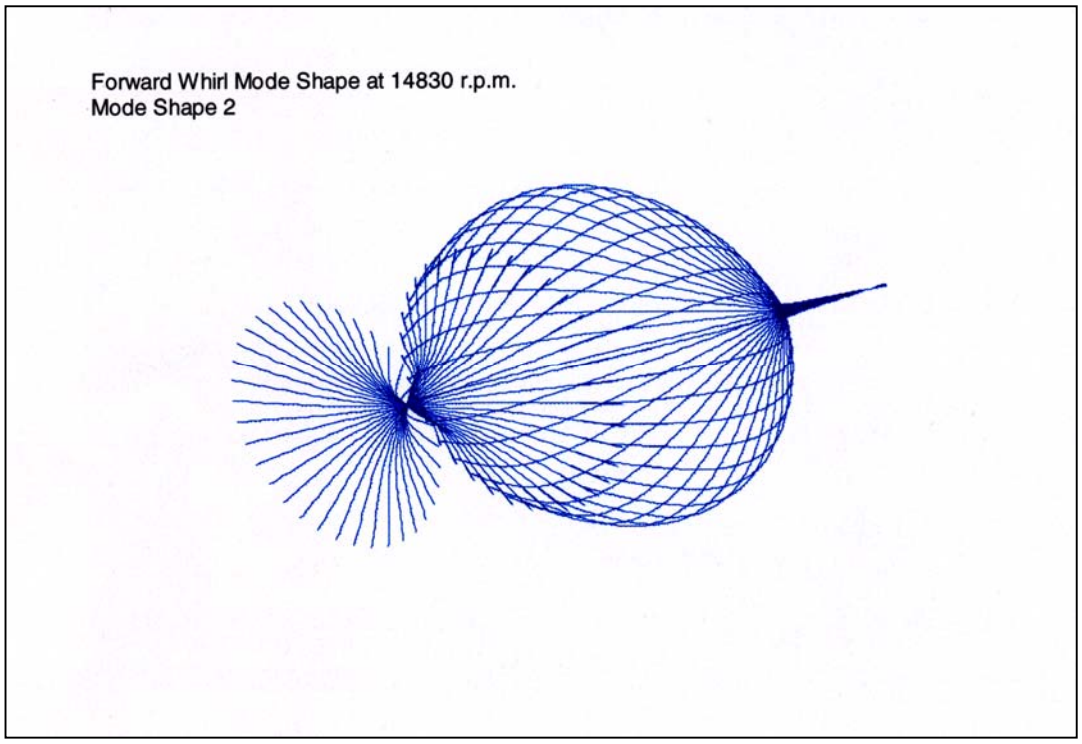
TYPICAL CAMPBELL DIAGRAM FOR THE SYSTEM SHOWING WHIRL MODE AT THE NATURAL FREQUENCY



TYPICAL UNBALANCE RESPONSE DIAGRAMS



Assumptions: $K_4 = 0.8\times10^6$lbf/in $K_5 = 0.5\times10^6$lbf/in;
0.001 ins mass offset at turbine wheel



Whirl mode shape

The left of the diagram shows nodes for bearings 4 and 5,
the pinion journals are to the right