INVESTIGATION REPORT

Preliminary ☒
Final ☐

Accident ☒ **Incident** ☐

Reference	**WPR17LA133**	**Commercial File**	**N/A**
Accident / Incident report	**RA-2017-152 / A-2017-008**	**Preliminary Information report A**	**Onsite Investigation Report A-2017-008**

Data

Date of occurrence	**Occurrence place**	**Operator**
27JUN2017	Boulder City, Nevada USA	Papillon Grand Canyon

Aircraft type	**S/N**	**Registration**
EC130 B4	4402	N151GC

Engine type	**S/N**	**TSN**	**TSO**
Arriel 2B1	23013	2711.60	N/A

Accessories

Designation, P/N	S/N	Work performed	TSN	TSO
P/N: 0292861880 P/N: 70BMF01020	230 1007	Bench test auto curve download	2649.60 N/A	N/A N/A

Circumstances reported to SAFRAN HELICOPTER ENGINES

In flight, the pilot noticed an engine power loss. He performed an autorotation during which he hit a power line.

Conclusion

The engine exam revealed a blockage of the oil jet for the MO2 rear bearing resulting in bearing oil starvation / failure. This caused a misalignment of the gas generator rotating assembly resulting in the centrifugal compressor contacting the cover, burning a hole in it. The resulting inefficiency caused the command for higher fuel flow eventually resulting in an overtemp / high pressure turbine failure and seizure of the gas generator and flameout. The download of the DECU and overlimits identified on the VEMD support this conclusion. A detailed inspection of the oil jet / obstruction will be performed in France with a separate report issued.

VALIDATION		APPROVAL	
DATE	Bryan Larimore	DATE	
19JUL17			

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SUMMARY

1 HISTORY

1.1 TECHNICAL DOCUMENTATION

Maintenance:

Date	TSN (TSO)	Task	Operated by	Remarks
6JUN17	2602.0	Engine 23013 installed on A/C	Papillon	

Remarks:

Modular composition:

Modules	S/N	TSN	TSO	CSN	CSO	Remarks
70BMO10030	18211	3596.70	1773.20	N/A	N/A	N/A
70BMO22010	616	2711.60	N/A	N/A	N/A	N/A
70BMO32020	629	2522.87	N/A	4170.70	N/A	N/A
70BMO41720	876TEC	3228.40	N/A	2574.15	N/A	N/A
70BMO52000	1803	6313.80	109.60	N/A	N/A	N/A
Items	**P/N**	**S/N**	**Remarks**			
HMU	0292861880	230	N/A			

1.2 RESULTS OF FIELD INVESTIGATION

The aircraft had been recovered to the operator's hangar prior to examination and placed in quarantine.
The engine did not sustain any visual external damage.
There was no evidence of fuel leaks. There was evidence of a slight oil leak at the rear bearing scavenge union but of no real significance. All fuel, oil, and air lines were found tight and properly saftied.
Both the gas generator and power turbine were seized and could not be rotated by hand.
There was no evidence of FOD on the axial compressor.
The presence of oil in the aircraft engine oil tank was confirmed.

A boroscope inspection of hp turbine revealed a significant amount of heat damage to the turbine blades and thermocouples.

The VEMD recorded overlimits during the accident flight. (See photo page 14)

Metal was found on the MO1 magnetic plug. The MO5 and electric ship detectors were clean minus sludge.

Upon inspection of the engine oil filter it was discovered that no oil filter was installed. The last maintenance performed on the engine was 109.6 hours prior to the event.

The engine and DECU were removed from the aircraft for detailed engine exam and DECU download at the Safran HE USA facility.

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2 REVIEW OF INVESTIGATION

Description of equipment	P/N S/N	Date of review	Work performed	In the presence of
DECU	70BMF01020 / 1007	6 JUL 2017	Download	FAA
HMU	0292861880 / 230	7JUL 2017	Bench test	FAA
Engine	0292005410 / 23013	6,7 JUL 2017	Teardown / exam	FAA

2.1 ENGINE EXAMINATION

2.1.1 Findings on arrival

Engine arrived in a sealed crate in the condition it was shipped in.

2.1.2 Engine disassembly

Before beginning the disassembly, all the magnetic sensors (N1A, N2A,B,C), the MO1,5 strainers and magnetic plugs and the main oil strainer were removed. All were clean except for the MO1 magnetic plug.

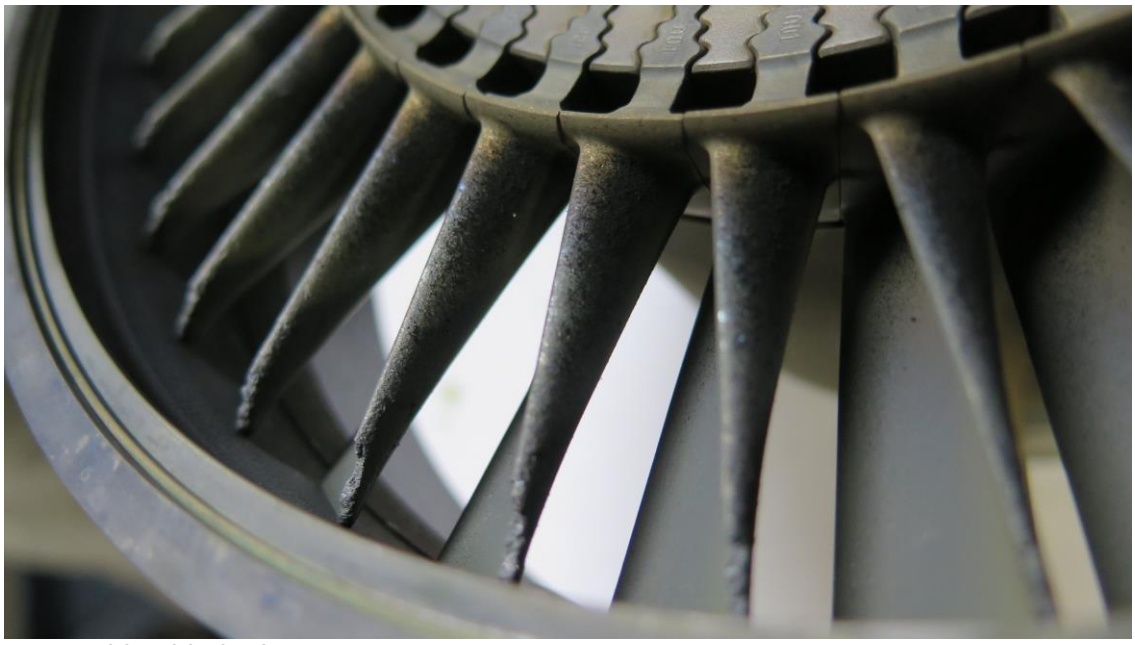
Metal on Module 1 (Accessory gearbox) magnetic plug
(probably M50 material from failed MO2 bearing)
Source of metal will be verified by lab analysis

All engine accessories were removed from the engine. The thermocouple harness had sustained thermal damage.

Thermal damage on thermocouple probe

The module 5 (reduction gearbox) was removed and turned freely by hand after being separated from the module 4. The module 5 was not disassembled.

The MO4 (free turbine) was removed. After being separated from the gas generator it could be identified that the turbine was seized at the blade tip / shroud section and that the MO4 bearings spun freely by hand. There was evidence of thermal and impact damage on the leading edge of the free turbine blades.



Free turbine blade damage

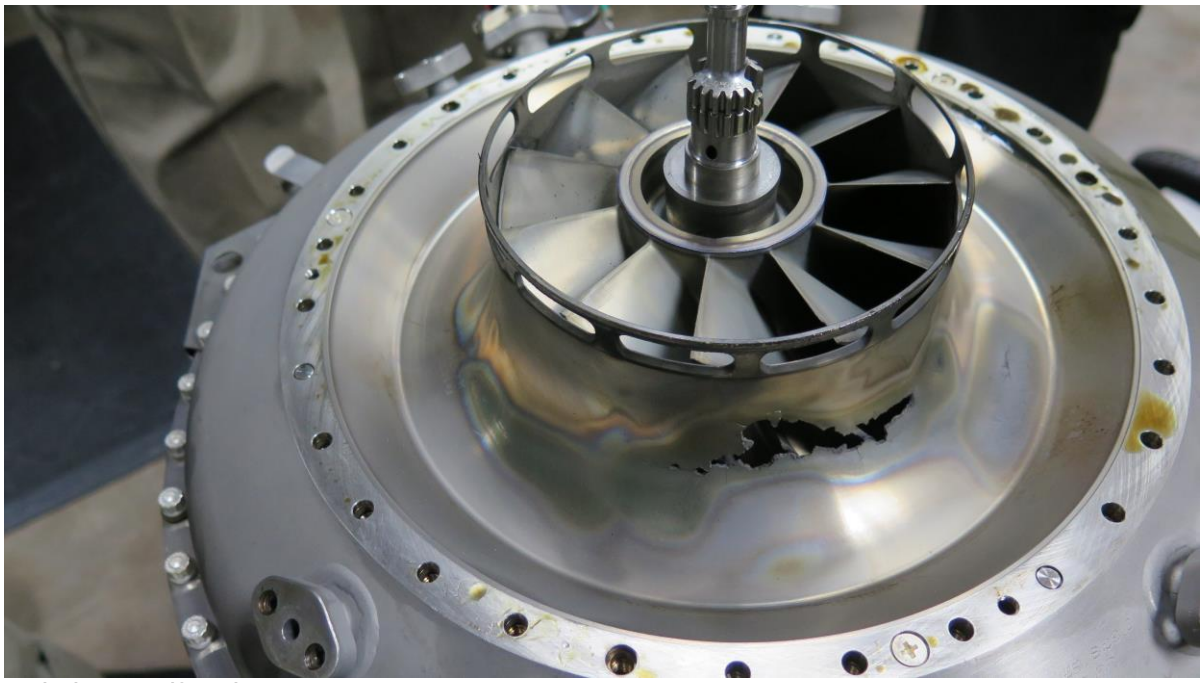
The Module 4 was not disassembled further. The free turbine nozzle guide vane was removed revealing the hp turbine.

High pressure turbine with FTNGV removed

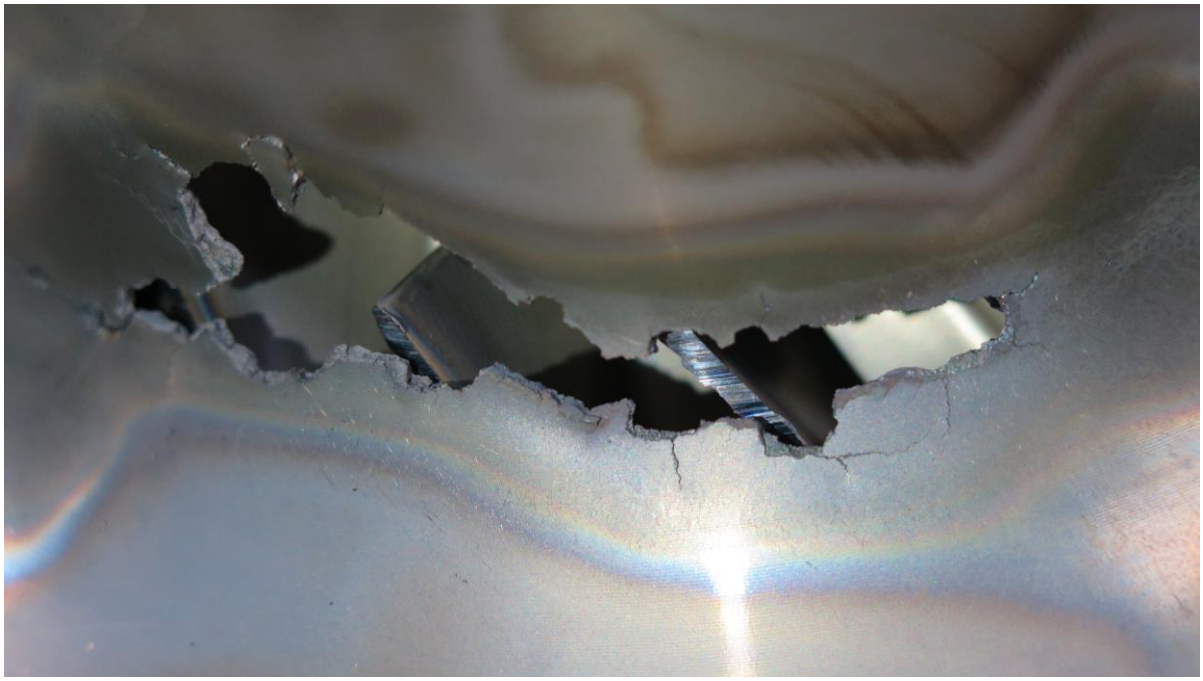
The MO2/3 was removed from the module 1. The module 1 (accessory gearbox) could be turned easily by hand and continuity through the entire gear train was confirmed.

The MO2 (axial compressor) was removed from the MO3. The axial compressor could be turned by hand however it was rough and noisy. The MO3 still could not be turned by hand.

After removal of the MO2 the damage to the centrifugal compressor cover was exposed.



Hole in centrifugal compressor cover



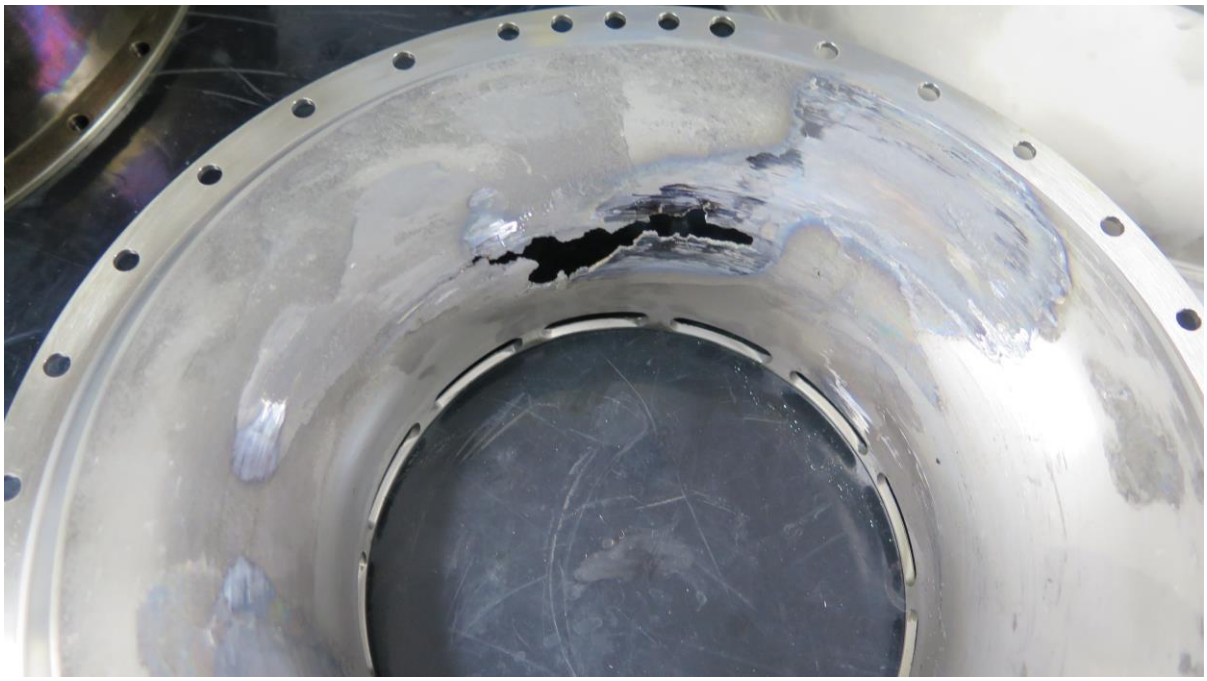
Hole in centrifugal compressor cover

The MO2 was disassembled. The MO2 rear bearing had completely failed and was in pieces. The oil jet was checked by covering each hole and blowing through it. It was found that the jet for the rear MO2 bearing was obstructed. The jet was bagged for further investigation in France.

MO2 oil jet

MO2 rear bearing

The MO3 (gas generator) was completely disassembled.


View of compressor cover from compressor side

High pressure turbine

Gas generator rear bearing appeared normal and rolled freely. There was no damage to the piston shaft or rear bearing housing. This would indicate that the rear of the gas generator stayed in alignment during the failure of the module 2 bearing.

No damage

Rear bearing housing

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2.2 EQUIPMENT

2.2.1 Testing (HMU)

The HMU was tested on the LRUS test bench in order to check the automatic mode/ curves. All parameters checked were within tolerance with the exception of 25% of channel 2 which was .1 lph out of tolerance. This would have no effect on normal operation and is normal for an HMU with time in operation.

TURBOMECA
COMPONENT MAINTENANCE MANUAL
0292928++0

- Record the flows of the metering valve in Auto mode for channel 2 according to the set point values that follow:

	HP/LP pump speed		Actuator		Resolver α in °		Pressure (kPa)		Q(l/hr)	
	(%)	(rpm)	Hex. set point value	Decimal	Accepted	Read	Metering valve dowstream pressure	LP outlet, read	Accepted	Read
	10	1,188	000	0	353 ± 0.8	353	350		5^{0}_{-5}	5
	25	2,970	015	21	358.2 ± 0.8	358.34	370		10^{+2}_{-3}	12.1
1	30	3,565	020	32	1.05 ± 0.8	1.08	400	120	25 ± 2	25.8
	57	6,773	033	51	5.75 ± 0.8	5.85	475		49^{+4}_{-3}	47.6
	68	8,080	046	70	10.5 ± 0.8	10.6	560		67^{+5}_{-4}	66.5
	75	8,912	062	98	17.5 ± 0.8	17.68	740		87^{+5}_{-4}	87
	85	10,100	09A	154	31.5 ± 0.8	31.75	1,140		137^{+6}_{-4}	136.6
	92	10,932	0D2	210	45.5 ± 0.8	45.8	1,580		192^{+7}_{-4}	192.8
	98	11,645	10A	266	59.5 ± 0.8	59.8	2,060		245^{+7}_{-4}	245.3
	101	12,000	142	322	73.5 ± 0.8	73.95	2,660		301^{+8}_{-4}	301.2
2	102.5	12,180	173	371	85.75 ± 0.8	86.3	3,110	782	334 ± 4	336.5

- Note the values recorded in table 1.2 of the "HMU Note Book". Refer to TASK 73-23-05-290-001 (TEST OF HP/LP PUMP AND METERING VALVE – Test of the HP/LP pump and metering valve assembly).
- If the flow is out of tolerance, stop the bench and remove the HP/LP pump assembly. Refer to the Fault Analysis tables TASK 73-23-05-813-001.

HMU automatic mode curves (channel 2)

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COMPONENT MAINTENANCE MANUAL
0292928++0

- Record the flows of the metering valve in Auto mode for channel 1 according to the set point values that follow:

	HP/LP pump speed		Actuator		Resolver α in °		Pressure (kPa)		Q(l/hr)	
	(%)	(rpm)	Hex. set point value	Decimal	Accepted	Read	Metering valve dowstream pressure	LP outlet, read	Accepted	Read
	10	1,188	000	0	353 ± 0.8	353.1	350		5^{0}_{-5}	<5
	16.5	1,960	00E	14	356.5 ± 0.8	356.65	350		4 ± 2	3
	25	2,970	015	21	358.2 ± 0.8	358.4	370		10^{+2}_{-3}	11.7
	28	3,327	01C	28	0 ± 0.8	0.12	385		20 ± 2	21
1	30	3,565	020	32	1.05 ± 0.8	1.15	400	120	25 ± 2	25.6
	45	5,345	02A	42	3.5 ± 0.8	3.66	430		$38^{+3.5}_{-3}$	36.8
	57	6,773	033	51	5.75 ± 0.8	5.89	475		49^{+4}_{-3}	47.2
	68	8,080	046	70	10.5 ± 0.8	10.61	560	HP > 350	67^{+5}_{-4}	66.6
	75	8,912	062	98	17.5 ± 0.8	17.74	740		87^{+5}_{-4}	87
	81	9,625	07E	126	24.5 ± 0.8	24.75	920		$110^{+5.5}_{-4}$	110.6
	85	10,100	09A	154	31.5 ± 0.8	31.83	1,140		137^{+6}_{-4}	136.3
	90	10,695	0B6	182	38.5 ± 0.8	38.84	1,350		165^{+6}_{-4}	164.8
	92	10,932	0D2	210	45.5 ± 0.8	45.83	1,580		192^{+7}_{-4}	192.5
	95	11,289	0EE	238	52.5 ± 0.8	52.8	1,800		219.5^{+7}_{-4}	220.5
	98	11,645	10A	266	59.5 ± 0.8	59.88	2,060		245^{+7}_{-4}	245
	100	11,883	126	294	66.5 ± 0.8	66.92	2,380		273^{+8}_{-4}	274
	101	12,000	142	322	73.5 ± 0.8	74	2,660		301^{+8}_{-4}	301.5
	102	12,120	15E	350	80.5 ± 0.8	81.02	2,900		322^{+8}_{-4}	321.6
2	102.5	12,180	173	371	85.75 ± 0.8	86.3	3,110	HP > 700	334 ± 4	335.8

- Note the values recorded in table 1.1 of the "HMU Note Book". Refer to TASK 73-23-05-290-001 (TEST OF HP/LP PUMP AND METERING VALVE – Test of the HP/LP pump and metering valve assembly).
- If the flow is out of tolerance, stop the bench and remove the HP/LP pump assembly. Refer to the Fault Analysis tables TASK 73-23-05-813-001.

HMU automatic mode curves (channel 1)

2.2.2 Equipment disassembly

The HMU was shown to be operating properly so no disassembly was necessary.

2.3 EQUIPMENT

2.3.1 Testing (DECU)

Note: DECU (digital engine control unit) is not a “black box”. It is not a flight data recorder. It will record recognized faults and certain engine parameters at the time of the recorded fault.

Both channels A and B were downloaded on bench p/n TM2825G001.

A total of 3 faults were recorded during the accident flight.

Fault context (tooling mode) - RS422 - TL0248G108

Tooling mode OK | Reception: Good | Channel A | 2/8

Fault words

[64] Fault flags 1 Channel A
Watchdog trip 0
N2 trim fault 0
Start selector fault 0
At least one failure on channel A 1
Collective pitch fault 0
Raw T4 fault 0
T0 helicopter fault 0
P3 fault 0
Raw torque fault 0
T4 conformation fault at power-up 0
Torque conformation fault at
T4 conformation fault after
Torque conformation fault after power-up
EECU internal fault 0
P3 drift or engine flame-out 1
P0 engine fault 0

[66] Fault flags 2 Channel A
Fuel metering valve resolver fault 0
Stepper motor fault 0
Bleed valve fault 0
T4 helicopter fault 0
T0 fault 0
Reception fault between channel 0
N2 fault 0
N1 fault 0
P0 helicopter fault 0
No ARINC message from helicopter 0
Alternator fault 0
28 volts fault 0
P0 incoherence 0
Stop electro-valve fault 0
At least one fault on channel B 0
Real time software fault 0

[68] Fault flags 1 Channel B
Watchdog trip 0
N2 trim fault 0
Start selector fault 0
At least one failure on channel A 0
Collective pitch fault 0
Raw T4 fault 0
T0 helicopter fault 0
P3 fault 0
Raw torque fault 0
T4 conformation fault at power-up 0
Torque conformation fault at
T4 conformation fault after
Torque conformation fault after power-up
EECU internal fault 0
P3 drift or engine flame-out 0
P0 engine fault 0

[70] Fault flags 2 Channel B
Fuel metering valve resolver fault 0
Stepper motor fault 0
Bleed valve fault 0
T4 helicopter fault 0
T0 fault 0
Reception fault between channel 0
N2 fault 0
N1 fault 0
P0 helicopter fault 0
No ARINC message from helicopter 0
Alternator fault 0
28 volts fault 0
P0 incoherence 0
Stop electro-valve fault 0
At least one fault on channel B 0
Real time software fault 0

First fault recorded (P3 drift or engine flame-out)
Note: In this case the engine is at NG 83.82%, so this a P3 drift.
The fuel system allowed P3 (predicted value) to go from 4.027 to a value of 13 bar. (see fault context 2/8 and 3/8). Doing this removes the predicted P3 value restriction and allows the engine to accelerate by increasing fuel flow.

Fault context (tooling mode) - RS422 - TL0248G108

Tooling mode OK Reception: Good Channel A 2/8

Numerical param.

[013] N1 (%)	83.82	[015] N2 filter (%)	93.88
[017] P0 engine (mbar)	912.1	[019] P3 (bar)	4.027
[021] T1 (DegC)	35.40	[023] T4 conformation (DegC)	932.7
[025] Collective pitch (XPC) (%)	69.52	[027] T4 conformation offset (DegC)	-32.1
[029] T4 conformation slope	0.99	[031] Torque conformation offset (%)	-0.51
[033] Torque conformation slope	1.05	[035] Trim position (%)	34.77
[037] Torque indication	24.92	[039] XR measurement (Deg)	31.94
[041] Actuator position offset (Deg)	-0.19	[043] Corrected N1 demand (%)	86.08
[045] Limited flow demand (l/h)	139.6	[073] dN1/dt	-3.97
[075] dN2/dt	-8.91	[077] Max N1 since last use of OEI (%)	97.49

Engine parameters recorded at time of first fault.

N1 = 83.82% N2 = 93.88% Fuel flow = 139.6 lph T4 = 932.7°C

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Fault context (tooling mode) - RS422 - TL0248G108

Tooling mode OK | Reception: Good | Channel A | 3/8

Fault words

[64] Fault flags 1 Channel A

Watchdog trip 0
N2 trim fault 0
Start selector fault 0
At least one failure on channel A 1
Collective pitch fault 0
Raw T4 fault 1
T0 helicopter fault 0
P3 fault 0
Raw torque fault 0
T4 conformation fault at power-up 0
Torque conformation fault at
T4 conformation fault after
Torque conformation fault after power-up
EECU internal fault 0
P3 drift or engine flame-out 1
P0 engine fault 0

[66] Fault flags 2 Channel A

Fuel metering valve resolver fault 0
Stepper motor fault 0
Bleed valve fault 0
T4 helicopter fault 0
T0 fault 0
Reception fault between channel 0
N2 fault 0
N1 fault 0
P0 helicopter fault 0
No ARINC message from helicopter 0
Alternator fault 0
28 volts fault 0
P0 incoherence 0
Stop electro-valve fault 0
At least one fault on channel B 0
Real time software fault 0

[68] Fault flags 1 Channel B

Watchdog trip 0
N2 trim fault 0
Start selector fault 0
At least one failure on channel A 0
Collective pitch fault 0
Raw T4 fault 1
T0 helicopter fault 0
P3 fault 0
Raw torque fault 0
T4 conformation fault at power-up 0
Torque conformation fault at
T4 conformation fault after
Torque conformation fault after power-up
EECU internal fault 0
P3 drift or engine flame-out 0
P0 engine fault 0

[70] Fault flags 2 Channel B

Fuel metering valve resolver fault 0
Stepper motor fault 0
Bleed valve fault 0
T4 helicopter fault 0
T0 fault 0
Reception fault between channel 0
N2 fault 0
N1 fault 0
P0 helicopter fault 0
No ARINC message from helicopter 0
Alternator fault 0
28 volts fault 0
P0 incoherence 0
Stop electro-valve fault 0
At least one fault on channel B 1
Real time software fault 0

Second fault recorded within the same second as first fault (Raw T4 fault)
This is most likely caused by thermocouple thermal damage due to overtemperature.

Fault context (tooling mode) - RS422 - TL0248G108

Tooling mode OK | Reception: Good | Channel A | 3/8

Numerical param.

[013] N1 (%)	81.48	[015] N2 filter (%)	90.67
[017] P0 engine (mbar)	911.7	[019] P3 (bar)	13.000
[021] T1 (DegC)	35.30	[023] T4 conformation (DegC)	917.2
[025] Collective pitch (XPC) (%)	63.71	[027] T4 conformation offset (DegC)	-32.1
[029] T4 conformation slope	0.99	[031] Torque conformation offset (%)	-0.51
[033] Torque conformation slope	1.05	[035] Trim position (%)	34.51
[037] Torque indication	24.37	[039] XR measurement (Deg)	70.95
[041] Actuator position offset (Deg)	-0.20	[043] Corrected N1 demand (%)	91.99
[045] Limited flow demand (l/h)	291.8	[073] dN1/dt	-7.35
[075] dN2/dt	-4.27	[077] Max N1 since last use of OEI (%)	83.52

Engine parameters recorded at time of second fault.

N1 = 81.48% N2 = 90.67% Fuel flow = 291.8 lph T4 = 917.2°C

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Fault context (tooling mode) - RS422 - TL0248G108

Tooling mode OK | Reception: Good | Channel A | 4/8

Fault words

[64] Fault flags 1 Channel A

```
Watchdog trip 0
N2 trim fault 0
Start selector fault 0
At least one failure on channel A 1
Collective pitch fault 0
Raw T4 fault 1
T0 helicopter fault 0
P3 fault 0
Raw torque fault 0
T4 conformation fault at power-up 0
Torque conformation fault at
T4 conformation fault after
Torque conformation fault after
power-up
EECU internal fault 0
P3 drift or engine flame-out 1
P0 engine fault 0
```

[66] Fault flags 2 Channel A

```
Fuel metering valve resolver fault 0
Stepper motor fault 0
Bleed valve fault 0
T4 helicopter fault 1
T0 fault 0
Reception fault between channel 0
N2 fault 0
N1 fault 0
P0 helicopter fault 0
No ARINC message from helicopter 0
Alternator fault 0
28 volts fault 0
P0 incoherence 0
Stop electro-valve fault 0
At least one fault on channel B 0
Real time software fault 0
```

[68] Fault flags 1 Channel B

```
Watchdog trip 0
N2 trim fault 0
Start selector fault 0
At least one failure on channel A 0
Collective pitch fault 0
Raw T4 fault 1
T0 helicopter fault 0
P3 fault 0
Raw torque fault 0
T4 conformation fault at power-up 0
Torque conformation fault at
T4 conformation fault after
Torque conformation fault after
power-up
EECU internal fault 0
P3 drift or engine flame-out 1
P0 engine fault 0
```

[70] Fault flags 2 Channel B

```
Fuel metering valve resolver fault 0
Stepper motor fault 0
Bleed valve fault 0
T4 helicopter fault 0
T0 fault 0
Reception fault between channel 0
N2 fault 0
N1 fault 0
P0 helicopter fault 0
No ARINC message from helicopter 0
Alternator fault 0
28 volts fault 0
P0 incoherence 0
Stop electro-valve fault 0
At least one fault on channel B 1
Real time software fault 0
```

Third fault recorded approximately 6 seconds after 1st. (T4 helicopter fault)
This is a fault with the t4 indication to the cockpit most likely caused by the thermocouple thermal damage as well.

Fault context (tooling mode) - RS422 - TL0248G108

Tooling mode OK | Reception: Good | Channel A | 4/8

Numerical param.

[013] N1 (%)	44.62	[015] N2 filter (%)	78.57
[017] P0 engine (mbar)	913.4	[019] P3 (bar)	13.000
[021] T1 (DegC)	35.30	[023] T4 conformation (DegC)	1057.1
[025] Collective pitch (XPC) (%)	51.67	[027] T4 conformation offset (DegC)	-32.1
[029] T4 conformation slope	0.99	[031] Torque conformation offset (%)	-0.51
[033] Torque conformation slope	1.05	[035] Trim position (%)	29.79
[037] Torque indication	0.52	[039] XR measurement (Deg)	86.13
[041] Actuator position offset (Deg)	-0.38	[043] Corrected N1 demand (%)	89.31
[045] Limited flow demand (l/h)	330.0	[073] dN1/dt	-7.58
[075] dN2/dt	-5.82	[077] Max N1 since last use of OEI (%)	80.84

Engine parameters recorded at time of third fault.

N1 = 44.62 N2 = 78.57% Fuel flow = 330 lph T4 = 1057.1°C

The first fault recorded would indicate a P3 drift. Within the same second the next fault recorded is a raw t4 fault which was most likely caused by the thermal damage to the thermocouple harness. The third fault recorded 6 seconds later is a helicopter t4 indication fault which most likely is also caused by the thermal damage to the thermocouple harness. Over the course of the 6 seconds these three faults were recorded, the gas generator speed and free turbine speed are decreasing and the fuel flow is increasing. Torque indication at the last fault recorded is .52% consistent with the helicopter freewheeling at this point.

2.4 ADDITIONAL EXAMINATIONS

Several parts were retained for further analysis at the Safran HE factory laboratory in Bordes France. Below is a list of these parts and the planned analysis of each.

1. MO2 oil jet (oil flow test, followed by cut to identify obstruction)
2. HP disk and blades (analysis of failure mode of blades)
3. MO1 magnetic plug (analysis of metal on plug to identify origin)
4. MO2 rear bearing and cage (analysis of failure mode)
5. MO4 (analysis of blade damage)
6. Oil sample taken from MO5 (spectro analysis)

A separate report will be issued once this work is complete.