EASA
European Aviation Safety Agency

Final Report EASA_REP_RESEA_2007_1

Research Project:

Investigation of the Technical Feasibility and Safety Benefit of an Integrated Engine/Rotor/Transmission Health Monitoring and HOMP System for Part 27 Piston Engine Small Helicopters

An agency of the European Union

EASA 2007/C37

Investigation of the technical feasibility and safety benefit of an Integrated Engine / Rotor / Transmission Health Monitoring and HOMP System for Part 27 Piston Engine Small Helicopters

Final Report

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Document:	EASA.2007/C37
Revision:	05
Date:	19 October 2009

APPROVAL SHEET

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DOCUMENT CONTROL

REV	DATE	DESCRIPTION OF UPDATES
00	07/11/2008	Draft Report
01	27/02/2009	Draft Report
02	15/06/2009	Draft Report
03	29/06/2009	Final Report (Except flight trial results)
04	09/10/2009	Final Report
05	19/10/2009	Final Report

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SECTION 1 ACKNOWLEDGEMENTS

The Investigation of the technical feasibility and safety benefit of an Integrated Engine / Rotor / Transmission Health Monitoring and HOMP System for Part 27 Piston Engine Small Helicopters has been funded by EASA.

ECT would like to thank all people who worked in this study.

Special thanks to EASA people for the quality of the discussions and for their help during the project.

Our partner Eurotech Srl in Italy represented by Roberto Grazzioli has been very helpful during this study. Thanks a lot for sharing your knowledge of Piston Engines Robinson Helicopters, for allowing people from your company helping us so much.

All people in ECT having worked in this study must also be mentioned here (Design Office, Technical Office). They have spent a lot of time on the project to achieve requested targets in requested delay.

Finally, special thanks to french customers who trust this system and accepted to install and use the Prototype system for the flight trials.

SECTION 2 EXECUTIVE SUMMARY

The aim of this study is to investigate the technical feasibility and potential safety benefits of an integrated Engine / Rotor / Transmission and HOMP system for Part 27 small piston engine helicopters.

After analyzing EASA's tender specification, piston engine helicopters documentation and accident report analysis and defining potential safety benefits of each parameter, the selection of the parameters to be recorded for 100 hours flight trials was done.

Manifold pressure /torque (CO)
Engine oil pressure
Altitude (pressure) (ZP)
Air speed pressure (optional)
Engine tachometer
Rotor tachometer (NR)
Outside Air Temperature (OAT)
Engine oil temperature
Cylinder head temperature
Carburettor air temperature
Battery voltage
Gov warning off
TRGB chip detector (optional)
MRGB chip detector (optional)
Clutch warning (optional)
Carbon monoxide warning (optional)
MRGB over temperature (optional)
Engine fire warning (optional)
Air/ground switch
Engine oil pressure contact
Low fuel alarm (optional)
Cabin vibration

Additionally, the exceedances monitoring has been performed for:

- Manifold pressure / torque
- Engine oil pressure
- Engine tachometer
- Rotor tachometer (NR)
- Cylinder head temperature

A system has been built according to cost and weight targets in order to record (embedded unit) and display recorded data through a ground station tool.

The study demonstrates:

- The technical feasibility of an integrated system on small piston engine helicopters to monitor data and their potential exceedances within cost target but acceptable exceeded weight targets.
- The flight safety benefits of such system and the way they are achieved (maintenance, pilots' training...)
- Vibrations and trends for a helicopter simplified health

Despite the low cost and weight targets, the recorders may be available on Part 27 small piston engine helicopters. Therefore, flight safety improvement should be closely linked to maintenance and operating costs benefits for operators.
Indeed, despite its low cost, and unless such a system becomes mandatory, the only way to convince operators to use it is to have a quick Return on Investment (ROI).

SECTION 3 BACKGROUND

During the 1980s, the technical reliability was identified as a focus area for research to improve helicopter safety and advocated the development and installation of monitoring systems. Helicopters are potentially more vulnerable to mechanical failures than fixed wing aircraft because of the number of critical parts.

In Europe, over the last 15 years much effort has been directed at improving the flight safety of large helicopters certificated to Part 29 operating primarily for Oil and Gas Producers (OGP) in Northern Europe. Over this period there has been a significant reduction in the accident rate as a result of changes that have been made to helicopter design and operation.

Two successful safety enhancements are:

- Health and Usage Monitoring Systems (HUMS)
- Helicopter Operation Monitoring Programs (HOMP).

By extending the benefit of these technologies to smaller helicopters it should be possible to make a safety improvement, however in order to do this a number of technical, physical and operational challenges first need to be addressed.
Vibration Health Monitoring (VHM) of Part 29 large helicopter engines, rotors and rotor drive systems is standard practice in the UK and Norway. Service experience (<1000000 hours) has shown that this technology can indicate problems including incipient component fatigue failures, worn bearings and rotor and transmission maintenance errors. This technology can provide early warning and allow intervention to prevent potentially catastrophic failure modes from occurring. However, the equipment has been too heavy, expensive and resource intensive to be applied to small helicopters certificated to CS-27/Part 27.
Over the same period there have been trials of Helicopter Operations Monitoring Program (HOMP) systems to evaluate the benefits of frequently reviewing downloaded operational parameters to improve the safety of flight operations. Regarding the potential safety benefit to Part 27 small helicopters, most designs have a single turbine or piston engine. In Europe operating rules state that these helicopters should only be flown over terrain where an immediate forced landing can be executed safely. However service experience shows that there is a high accident rate due to total loss of power. Consequently, there is a potential safety benefit from a system that could reduce the in-flight-shut-down rate of engines installed on single engine helicopters. Rotor and rotor drive systems can be less complex on Part 27 small helicopters; nevertheless they still contain hundreds of parts the failure of which could be catastrophic.

Contemporary advances in electronic technology should make it possible to provide the functionality of VHM and HOMP systems in an integrated in-board system at a fraction of the weight and cost of the original systems fitted to Part 29 large helicopters in the 1990s.
Prior to advocating such a safety enhancement, for practical reasons it is necessary to show that a system for Part 27 small helicopters could be developed,

produced and supplied at low-cost. Typically in order to meet potential cost benefit analysis criterion such systems should be available at a minimum cost per installed system.

SECTION 4 AIMS AND OBJECTIVES

The aim and objective of the study are to investigate the technical feasibility and safety benefits of an Integrated Engine / Rotor / Transmission Health Monitoring and HOMP System for Part 27 Piston Engine Small Helicopters
This requires:

The availability of the functionalities is defined in Table 1 according to required cost and weight targets of 3000 € and 500 grams and the explanation of the choice of these parameters.

PARAMETER	HOMP / Exceedance Monitor	Health monitoring
Outside Air Temperature	Y	
Engine RPM	Y	
Rotor RPM	Y	
Torque	Y	
Other Cockpit Instruments	M	
External conditions (camera)	M	
Fuel Flow	M	
Cyclic Position	M	
Collective position	M	
Helicopter Air Speed	M	
GPS position / speed	M	
Cylinder Head Temperature	M	Y
Vibration Monitor: Main Rotor		Y
Vibration Monitor: Tail Rotor		Y
Vibration Monitor; Tail Rotor Drive System		Y

Table 1 - Tender specification

The demonstrator development provides the minimum functionalities “Y” and the economically feasible “M” regarding to the cost target.

A system is mounted on a small helicopter and operates for at least 100 hours recording, downloading and analyzing data.

The supply of a data interface allows pilots and maintenance team to access HOMP data, it demonstrates if it is suitable for use by small helicopter operators and it advises a pilot or maintenance personnel of any vibration indication (on ground only).

Despite the fact that the exceedance monitoring could be easily feasible, the vibration health monitoring might need more time to achieve within time scale and 100 flight hours. The study will demonstrate it.

Regarding requested targets, the cost (3000 €) should be respected but the weight (500 grams) may be more difficult to achieve and could be exceeded.

It was established that the suitable parameters selection would be based on helicopters available parameters and selected additional ones. The selection will be be supported by the review of accident reports from BEA, NTSB data base and other organization.

All piston engine helicopters should be covered by the study but it was agreed that Robinson R44 and R22 would be designed as a basis for the study and flight trials (100 flight hours).

Then, a functional matrix identifying the functionalities, related safety benefits and weight/cost penalty is part of the study outcomes.

SECTION 5 LITERATURE REVIEW

Aviation Research Paper n° BE04/73 on Light Utility Helicopter Safety in Australia:
Aerial stock mustering is one of the many uses of helicopters in Australia.
The study was initiated to understand the forces acting on R22 aircraft in mustering operations.

Aerial stock mustering involves operating in an inherently hazardous environment Aircraft are manoeuvred at very low level, close to obstacles. When helicopters are used, dust from rotor blade downwash can reduce visibility. Outside air temperature in these parts of Australia is also generally high, and this can degrade aircraft performance.

An analysis of the types of accidents involving light utility helicopters between 1996 and 2003 was also conducted. For the period examined, there were 120 accidents involving R22 helicopters, which identified two main types of accident. The vast majority (103) involved a collision with terrain, trees, or other obstacles. The remaining 17 accidents were the result of the loss of normal flying capability.

In 2004, the ATSB decided to perform an analysis on the flight characteristics of an R22 helicopter during aerial mustering operations. A monitoring system was mounted on an R22 helicopter. Data was collected from the helicopter over a 26 week period starting on 30 April 2005.

The system records 16 parameters including main rotor speed, engine manifold pressure, aircraft indicated airspeed, and yaw, pitch and roll rates, and angles that describe the flight condition.

A total of 299 files containing data from the system were recorded, providing information on 350 hours of R22 flight.

A preliminary analysis of the flight data indicated that aerial mustering flight involved a much higher proportion of low speed flight compared with the flight condition used for initial certification.

As expected, the analysis of this data showed that aerial mustering flight involve a lot of periods of low speed flight and sudden manoeuvring with rapid power changes.

Review of accident and / or incident reports:
Review of accident and/or incident reports from BEA, NTSB, AAIB… have been used for the study. Sum ups of the content of these writings will not be performed in this section but they will be used in the report (See paragraph 6.1.2).

SECTION 6 METHODOLOGY, IMPLEMENTATION, OUTPUT AND RESULTS

This section comes from the 4 logical steps of the study that were requested in tender specification:

- The selection of the parameters to be recorded
- The design of the prototype system
- The manufacturing and the installation of the system
- The 100 hours flight trials

The methodology, the implementation, the output and the results of each item will be given for each step of the study.

6.1 STEP1: PARAMETERS TO BE RECORDED FOR FLIGHT TRIALS

6.1.1 GENERALITIES AND NEEDS DESCRIPTION

The aim of this study is to investigate the technical feasibility and to analyze the potential safety benefit of an integrated monitoring and HOMP system to Part 27 small engine helicopters. The aims are given in EASA Tender Specification.

The technical feasibility must be performed with a product at a cost less than 3000 € and a weigh less than 500 grams.

The analysis of accidents reports and helicopter manuals is necessary to specify the product.

The developed system must be installed thanks to a Supplemental Type Certificate in order to be used on helicopter. Indeed, a permit to fly allows only technical flights and may not be enough to reach 100 flight hours.

R22 and R44 type helicopter are chosen to perform the flight trials. These helicopters are the most sold in the world and. The Lycoming engines equipped the most of piston engine helicopters: e.g Robinson,Enstrom, Hugues/Schweizer, Bell and Agusta Bell. The method of data analysis is similar for these helicopters.

The recorder has to record parameters available in the helicopter or being provided by added sensors:

- Parameters with limitations given in pilot manual
- Parameters useful for HOMP and pilot learning in conformity of the pilot manual
- Parameters for health in conformity of the maintenance manual.

The analysis begins with a documents review in order to define parameters to be recorded and its use for safety benefit.

6.1.2 REVIEW OF ACCIDENTS REPORTS

6.1.2.1 BEA REPORTS STUDY

Accidents and incidents figures on R22 and R44 from 2005 to 2008:

Type		2005	2006	2007	2008
R22	Incidents	29	34	19	27
	Accidents	3	14	12	12
	TOTAL	32	48	31	39
R44	Incidents	51	37	65	30
	Accidents	5	6	6	6
	TOTAL	56	43	71	36

Table 2 - Accident and incident statistics on R22 and R44

Distribution by types of accidents between 1991 and 2001:

Accident type	%	Involved parameters
LOC (loss of control)	47,5 %	Manifold pressure (OAT & Zp) Airspeed Rotor RPM Engine tachometer GOV warning Clutch warning Carb air temperature Attitude
Collisions	16.4%	
Rollovers	3,3 %	Collective pitch position Cyclic pitch position Attitude
Autorotation Training	11,5 %	Airspeed Rotor RPM Collective pitch position Cyclic pitch position Ground height Attitude
Mechanical problems	21,3 %	Manifold pressure (OAT & Zp) Rotor RPM Engine tachometer Clutch warning Vibration Carb air temperature Engine oil and temperature Cylinder air temperature TRGB and MRGB chip detection MGB over temperature

Table 3 - Accidents' distribution between 1991 and 2001

Mechanical problems
Accidents due to mechanical problems:

1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
3	0	2	3	2	0	1	1	0	1	0

The mechanical problems are translated by:

- Rotor speed loss
- Vibrations.
- A deterioration of the tail drive-shaft by a main blade rotor due to rotor speed loss.
- A tail rotor shaft damage.
- An exhaust valve area seizing.
- Carburettor Icing.

A maintenance and/or an unsuitable helicopter use conditions can be at the origin of the effects described previously.
E.g.: the carburettor icing has been identified as possible cause of accident.

Basic notions summary which can prevent the case of accidents:

- Cruising flight over 500 feet.
- Speed of climb or Cruising at 60 knots minimum
- Hovering done at a safety height in compliance with the flight manual.
- An engine control done at a minimum safety height in relation to the ground level and to the obstacles clearance.
- Power increase or collective decrease in case of low rotor speed.
- Translation flight done at a minimum safety height.
- Autorotation training performed above a surface specially prepared and by favourable conditions (mass, wind, temperature).
- Hold of a sufficient translation speed throughout the final for the autorotation done in PTU (U landing process)
- Autorotation training, engine control performed at a minimum height of 500 feet in case of not getting the nominal parameters: rotor speed rpm located in the green range and a 65 knots speed.
- Use of the reheating carburettor.
- No rough actions on the controls.
- In altitude flight, hold of a sufficient available power.

6.1.2.2 R22 ACCIDENTS ANALYSIS

The R22 helicopter which has the peculiarity to be light and equipped with a system of pendulum rotor fitted with sensitive flight controls. Sudden action can lead to dangerous situations as rollover or mast bumping with low load factor. The most currently accidents types are described below.

Loss of control (LOC)
The loss of control is due to an important variation between the parameters of helicopter flight and the parameters wanted by the pilot. In this case, the pilot cannot do anything to control the aircraft trajectory.

The LOC between 1991 and 2001, close to the ground (take off or land) essentially comes from an aircraft limitations insufficient consideration translated by:

- An inappropriate mixing on the control actions.
- An insufficient coordination of collective pitch, cyclic pitch and yaw pedals.
- A translation flight performed with a very low altitude.
- An inappropriate management of the main rotor speed rpm.
- A very fast approach.
- An incomplete procedure execution : a negligence to engage the rating governor e.g.

Indeed, the low main rotor inertia leads a tendency to the fast and important variations of the rotor rate. This phenomenon is getting worse by the low margin power, mainly between translation flight and hovering, while the main rotor speed tends to decrease.

In this case, it is important to anticipate or to apply rapidly the appropriate action to recover a normal flight condition. A pilot who has no experience on helicopter or a student pilot can jeopardize the situation and loose rapidly the main rotor lift or the yaw control.

Autorotation
In case of an engine failure, the main rotor is driven under the action of the relative wind, benefits from a lift which, while inferior to the aircraft weight, is sufficient to slow down the descent and maintain the control until the landing.

The R22 autorotation training stays a particularly delicate exercise and the error margin is very weak regarding the helicopter specificities. On one hand, this operation requires a very high precision for keeping the parameters and on the other hand a drop zone prepared for this exercise. Furthermore, this training must be done only with good conditions: in particular a sufficient margin regarding to the maximal mass and with favourable weather conditions.

Rollover
This phenomenon occurs when the helicopter tilts with a skid blocked by an obstacle or by the ground (mud, sand, root, frost), the lift being applied.
The R22 seems more sensitive to this phenomenon than most of the other helicopters regarding the high position of the main rotor centre of pressure, if the slope exceeds 15 ° with a skid on the ground and with lift, the rollover becomes practically irreversible.

Mast bumping:
Sudden actions on the controls can lead to situations potentially dangerous with a low load factor. The whole balancer rotor can take excessive amplitude regarding to the axis of the mast and generate shocks at the level of the mast in case of inappropriate pilot action.

The load factor decreases e.g., when the pilot quickly pushes on cyclic pitch.
In these conditions, the rotor reversal torque risks to combine its effect in the action of the tail rotor, leading a slope of the airframe towards the right side.
The immediate stop location to the left of the cyclic pitch will be then ineffective on the position of the airframe, because this one being under low load factor will not react any more to the main rotor requests which will tilt on the left side.

In that limit case, there is a risk of bumping and break of the rotor mast, and\or risk of contact of a main blade with the airframe.
If during an operation of avoidance, the pilot decides abruptly to go down and e.g, by reflex acquired on plane, pushes on the cyclic pitch, he is under low load factor with a bumping / cutting possibility of the rotor mast if he puts then abruptly of cyclic pitch to the left side to cancel the slope.

Analysis of the pilots experience and knowledge
The most sensitive pilot's population to the accidents is the one having less than 100 R22 flight hours (56 % of the accidents) and than 84 % of the accidents concern pilots having less than 500 R22 flight hours.
We know that having a lot of experience on the other types of helicopters did not reduce the vulnerability to the R22 fatal accidents, what underlines the specificities of the piloting of this helicopter
After school accidents, some instructors precise that their experience would have allowed them to maintain the parameters of flight in their limits (during their R22 type qualification), but sometimes, they had difficulties recovering normal flights parameters during an instruction flight when the student lost them.
Indeed, not knowing well enough the R22 peculiarities, the instructors have no means to anticipate or to react in front of the speed of parameters variation.

In conclusion
The most frequent causes of an accident are:

- Very experimented pilots habit and over trust on plane or on the other types of helicopters.
- An insufficient consideration of the aircraft limitations and its peculiarities.
- A parameters control done out the instructor knowledge.
- An instructor late response.
- A flare done too late and too low, as e.g. during autorotation.
- A hovering or in translation flight done too low.

Development of the maintenance means improves the flight safety.

Operating the aircraft components as much as possible decreases considerably the maintenance operation cycles, enhancing the availability. Every supplementary cycles obtained between the maintenance operations brings what we call the maintenance credit. The safety flights must keep in line or improve its level.

A data recording system has to improve the safety flights with an earlier detection of damaged critical component (Before failure).

Its main function consists in monitoring permanently the components health as deterioration level of the critical mechanical components (engine, driving shafts, mechanical assemblies) and aircraft operating conditions: real operating of the helicopter in its flight envelope (rating and cycle's engine, number of landing, height, outside air temperature, limitations exceedance).

6.1.3 R22 AND R44 PILOT'S OPERATING HANDBOOK

6.1.3.1 LIMITATIONS

It is possible to get all the limitations from the flight manual which are given in paragraph 12.2.

Airspeed indicator: The embedded unit records this parameter but does not detect automatically the exceedance. It is possible to visualize it on ground station by viewing data or curves. Note that the maximum airspeed depends on the OAT and altitude pressure. These two parameters are recorded. In the future, this exceedance could be automatically recorded.

Rotor tachometer: The embedded unit records this parameter and detects automatically the exceedance in low and high value.

Engine tachometer: The embedded unit records this parameter and detects automatically the exceedance in low and high value. The min and max values are very close and it is necessary to get a very acurate measure: about 0.1%.

Oil pressure: The embedded unit records this parameter and detects automatically the exceedance in high value. In the future, it would be interesting to record also exceedance in min value. It is possible to visualize it on ground station by viewing data or curves.

Oil temperature: The embedded unit records this parameter but does not detect automatically the exceedance. It is possible to visualize it on ground station by viewing data or curves. In the future, this exceedance could be automatically recorded.

Cylinder head temperature: The embedded unit records this parameter and detects automatically the exceedance in high value. Only the high exceedance is necessary.

Manifold pressure: The embedded unit records this parameter and detects automatically the exceedance in high way. Only the high exceedance is necessary. Note that the maximum manifold pressure depends on the OAT and altitude pressure. But this placard is not taken into account by the recorder.

Carburetor air temperature: The embedded unit records this parameter but doesn not detect automatically the exceedance. It is possible to visualize it on ground station by viewing data or curves. In the future, this exceedance could be automatically recorded.

Altitude pressure - Zp -: The embedded unit records this parameter but does not detect automatically the exceedance. It is possible to visualize it on ground station by viewing data or curves. In the future, this exceedance could be automatically recorded.

Oil quantity, min to takeoff: The embedded unit does not record this parameter. This parameter could be recorded in the future. But this parameter is not really important to record because there is no consequence for maintenance operating, thus for safety. It could only be interesting for incident or accident analysis.

There are also weight and center of gravity limits but it is difficult to measure them by a sensor inside the helicopter. Except if the helicopter is designed with these sensors.

6.1.3.2 PROCEDURES

The normal and emergency procedures are described into the Pilot's Operating handbook. Thanks to the embedded system, it will be possible to visualize the good application of the procedures.

Airspeed for safe operation

It is possible with the ground station to detect the different flight configurations where it is important to acquire specific air speed. However it is also possible to check if the airspeed is correct.

Taking off and climbing, landing approach and autorotation procedure are important flight configurations for safety operation with specific air speed.

Rotor RPM

If the rotor RPM is too low, the pilot must decrease the collective pitch. Due to a low inertial rotor and low engine power (particularly on R22 helicopter), it is particularly important to keep enough rotor RPM.
If the rotor RPM is too high, the pilot must increase the collective pitch.
The R22 and R44 pilot's operating handbook recommends the following procedure: "Do not slow rotor by raising collective during shutdown. Blades may flap and strike tail cone."

Bearing noise

The R22 and R44 pilot's operating handbook recommends the following procedure: "During run up and shutdown, pilot should uncover right ear, open right door, and listen for unusual bearing noise. Failing bearings will produce an audible whine or growl well before final failure".

Vibration records could help improving it but it needs to be checked and confirmed.

Approach and landing

To reduce airspeed below 30 KIAS, the helicopter rate of descent must be less than 300 FPM. With the measure of altitude pressure, we can get the rate of descent and check this procedure.

6.1.3.3 SAFETY NOTICES ISSUED FROM R22 AND R44 PILOT'S OPERATING HANDBOOK

General

This section provides miscellaneous suggestions to help the pilot operate the helicopter more safely.

All the following safety notices have been issued by Robinson Helicopter Company as a result of various accidents.

ACCIDENTS INVOLVE DYNAMIC ROLLOVER: Safety Notice - 9

A dynamic rollover can occur whenever the landing gear contacts a fixed object, forcing the aircraft to pivot about the object instead of about its own center of gravity. The fixed object can be any obstacle or surface which prevents the skid from moving sideways. Once started, dynamic rollover cannot be stopped by application of opposite cyclic alone. E.g, assume the right skid contacts an object and becomes the pivot while the helicopter starts rolling to the right. Even with full left cyclic applied, the main rotor thrust vector will still pass on the left side of the pivot point and produce a rolling moment to the right instead of to the left. The thrust vector and its moment will follow the aircraft as it continues rolling to the right. A quick push down on the collective is the most effective way to stop a dynamic rollover.

In that case, the collective pitch position parameter can be recorded and analyzed after the flight.

FATAL ACCIDENTS CAUSED BY LOW RPM ROTOR STALL Safety Notice - 10:

A primary cause of fatal accidents in light helicopters is failure to maintain RPM. To avoid this, every pilot has conditioned reflexes so he will instantly add throttle and lower collective to maintain RPM in any emergency.

The R22 and R44 have demonstrated excellent crashworthiness as long as the pilot flies the aircraft all the way to the ground and executes a flare at the bottom to reduce his airspeed and rate of descent. Even when going down into rough terrain, trees, wires or water, he must force himself to lower the collective to maintain RPM until just before impact. The ship may roll over and be severely damaged, but the occupants have an excellent chance of walking away from it without any injuries.

No matter what causes the low rotor RPM, the pilot must first roll on throttle and lower the collective simultaneously to recover RPM before investigating the problem. It must be a conditioned reflex. In forward flight, applying aft cyclic to bleed off airspeed will also help recover lost RPM.

In this case, the main rotor speed parameter can be recorded and analyzed after the flight.

LOW-G PUSHOVERS – EXTREMELY DANGEROUS Safety Notice - 11:
Pushing the cyclic forward following a pull-up climb, or even from level flight, produces a low-G flight condition. If the helicopter is still pitching forward when the pilot applies aft cyclic to reload the rotor, the rotor disk may tilt aft relative to the fuselage it is reloaded. The main rotor torque reaction will then combine with tail rotor thrust to produce a powerful right rolling moment on the fuselage. With no lift from the rotor, there is no lateral control to stop the rapid right roll and mast bumping cam occurs. Severe in-flight mast bumping usually results in main rotor shaft separation and/or rotor blade contact with the fuselage.
The rotor must be reloaded before lateral cyclic can stop the right roll. To reload the rotor, apply an immediate gentle aft cyclic, but avoid any large aft cyclic input.
Never attempt to demonstrate or experiment with low-G manoeuvres, regardless of your skill or experience level.
Even highly experienced test pilots have been killed investigating the low-G flight condition. Always use great care to avoid any manoeuvre which could result in a low-G condition. Low-G mast bumping accidents are almost always fatal.

In this case, the cyclic pitch position parameter can be recorded and analyzed after the flight.

ALWAYS REDUCE RATE OF DESCENT BEFORE REDUCING AIRSPEED Safety Notice - 22
Many helicopter accidents have been caused by the pilot reducing his airspeed to near zero during an approach before reducing his rate of descent. As the pilot then raises the collective and flares to stop his rate of descent, he flares into his own downwash, greatly increasing the power and collective pitch required. The aircraft begins to enter the vortex ring state and a hard landing occurs, often followed by a rollover. This can occur during a steep approach either power-on or power-off.
This can be avoid by always reducing your rate of descent before reducing your airspeed. A good rule to follow is never allow your airspeed to be less than 30 knots until your rate of descent is less than 300 feet per minute.

In this case, the airspeed parameter can be recorded and analyzed after the flight.

LOW RPM ROTOR STALL CAN BE FATAL Safety Notice -24
Rotor stall due to low RPM causes a very high percentage of helicopter accidents, both fatal and non fatal. Frequently misunderstood, rotor stall is not to be confused with retreating tip stall which occurs only at high forward speeds when stall occurs over a small portion of the retreating blade tip. Retreating tip stall causes vibration

and control problems, but the rotor is still very capable of providing sufficient lift to support the helicopter weight.
Rotor stall, on the other hand, can occur at any airspeed and when it does; the rotor stops producing the lift required to support the helicopter and the aircraft literally falls out of the sky. Fortunately, rotor stall accidents most often occur close to the ground during takeoff or landing and the helicopter falls only four or five feet. The helicopter is wrecked but the occupants survive. However, rotor stall also occurs at higher altitudes and when it happens at heights above 40 or 50 feet AGL it is most likely to be fatal.

In this case, the main rotor speed parameter can be recorded and analyzed after the flight.

CARBURETOR ICE   Safety Notice - 25
Carburettor ice can cause engine breakdown and is most likely to occur when there is high humidity or visible moisture and air when these conditions exist, the following precautions must be taken:

- During take off.
- During climb or cruise.
- During descent or autorotation.

In that case, the carburettor air temperature parameter can be recorded and analyzed after the flight.

SURPRISE THROTTLE CHOPS CAN BE DEADLY Safety Notice - 27
Many flight instructors do not know how to give a student a simulated power failure safely. They may have learned how to respond to a throttle chop themselves, but they haven’t learned how to prepare a student for a simulated power failure or how to handle a situation where student’s reaction is unexpected. The student may freeze on the controls, push the wrong pedal, raise instead of lower the collective, or just do nothing. The instructor must be prepared to handle any unexpected student reaction.
The manifold pressure should be less than 21 inches and the throttle should be rolled off smoothly, never “chopped”. Follow through on all controls and tighten the muscles in your right leg to prevent the student from pushing the wrong pedal.
There have been instances when the engine has quit during simulated engine failures. As a precaution, always perform the simulated engine failure within glide distance of a smooth open area where you are certain you could complete a safe touch-down autorotation should it become necessary. Also, never practice simulated power failures until the engine is thoroughly warmed up. Wait until you have been flying for at least 15 or 20 minutes.

In that case, the collective pitch and yaw pedal position parameter can be recorded and analyzed after the flight.

CLUTCH LIGHT WARNING Safety Notice -28
It is normal for the cutch light to occasionally come on while in flight for a short time to re-tension the vee-belt as they become warm and stretch slightly.

However, if the clutch light flickers or stays on for a longer time than usual, it can indicate a belt or bearing failure in the vee-belt drive. If that occurs, immediately pull the clutch circuit breaker. Select the closest safe landing site and make a normal power on landing. Be prepared to enter autorotation should failure of the drive system occur. The smell of burning rubber may also indicate an impending belt failure.

In that case, the clutch warning parameter can be recorded and analyzed after the flight.

OVERSPEEDS DURING LIFTOFF Safety Notice - 36
Helicopters have been severely damaged by RPM over speeds during lift-off. The over speeds caused a tail rotor drive shaft vibration which led to immediate failure of shaft and tail cone. Throughout the normal RPM range tail rotor shaft vibration is controlled by damper bearing. However, damper is not effective above 120 % RPM.
Mechanical correlation can cause over speed during lift-off if RPM is increased to normal flight setting and collective raised before governor is switched on. Over speed can also occur if throttle is gripped too firmly during lift-off causing governor to be overridden. Inexperienced pilots, who are most likely to be nervous or distracted, are particularly susceptible to this type of over speed.

In that case, the main rotor speed parameter can be recorded and analyzed after the flight.

EXCEEDING APPROVED LIMITATIONS CAN BE FATAL Safety Notice -37
Many pilots do not understand metal fatigue. Each time a metal component is loaded to a stress level above its fatigue limit, hidden damage occurs within the metal. There is no inspection method which can detect this invisible fatigue damage. The first indication will be a tiny microscopic crack in the metal, often hidden from view. The crack will grow with each repetition of the critical stress until the part suddenly breaks. Crack growth will occur quite rapidly in drive system parts from the high frequency torsion loads. It will also occur rapidly in rotor system component due to the high centrifugal force on the blades and hub. Damaging fatigue cycles occur with every revolution of an overloaded drive shaft or rotor blade.
If a pilot exceeds the power or airspeed limits on a few occasions without failure, he may be misled into believing he can safely operate at those high loads. Every second the limitations are exceeded, more stress cycles occur and additional fatigue damage can accumulate within the metal. Eventually, a fatigue crack will begin and grow until a sudden failure occurs. If the pilot is lucky, the part will have reached its approved service life and be replaced before failure. If not, there will likely be a serious or fatal accident.

In that case, the power or airspeed parameters can be recorded and analyzed after the flight.

UNUSUAL VIBRATION CAN INDICATE A MAIN ROTOR BLADE CRACK Safety Notice -39

A catastrophic rotor blade fatigue failure can be averted if pilots and mechanics are alert to early indications of a fatigue crack. Although a crack may be internal to blade structure and not visible, it will likely cause a significant increase in rotor vibration prior ton final failure. If a rotor is smooth after balancing but then goes out of balance again within a few lights, it should be considered suspect. Have the rotor system thoroughly examined by a qualified mechanic before further flight.

In that case, the vibration level parameter can be recorded and analyzed after the flight.

6.1.4 MAINTENANCE MANUAL

The maintenance manual was analyzed to determine if any records can help to detect over limits conditions:

- Track and balance procedures:
These procedures must be performed every 100 hours. If it is possible to record parameters able to check track or balance during commercial flight, we will detect too much vibration as soon as the vibration appears. So the problem can be corrected immediately and the helicopter will accumulate less stress.
- Telatemp indicators
There are also some self-adhesive Telatemp indicators which record changes in operating temperatures of bearings and gearboxes.
- Exceedances

Main rotor tracking procedure

The aim is to check if the two blades are in the same level.
On Robinson helicopters, the checking of tracking is performed with a stroboscope and targets on the blades. The aim is to fit the targets of the two blades. This checking is performed in flight with different speeds.
A camera could record blades images and analyze on ground station to check the adjustment.

Main rotor balancing procedure

An accelerometer or velocimeter measures the imbalance amplitude which is given in IPS (inches per second).
A magnetic top sensor gives the phase reference.
A measuring unit processes and analyzes the signal to provide the imbalance amplitude and location.
The accelerometer is mounted in the cabin near co-pilot yaw pedals.

The accelerometer can be connected to the recorder and record vibration level on demand. So we can detect too high vibration level at each hovering. The accelerometer cannot be located at the exact place described in the maintenance manual for commercial flights. Note that the aim is not to perform the adjustments but only to detect over vibration.

Tail rotor balancing procedure
An accelerometer or velocimeter measures vibrations in the radial plane.
A stroboscope or a photo cell gives the phase reference. A measuring unit processes and analyzes the signal to provide the imbalance amplitude and location. This measure is performed on ground. It is forbidden to fly with the installation described in the maintenance manual to check the tail rotor balance. We can first analyze data on the accelerometer in cabin and check if it is possible to correlate record data and measures made by maintenance means.

Balancing fan wheel
An accelerometer or velocimeter measures vibrations. A stroboscope or a photo cell gives the phase reference.
A measuring unit processes and analyzes the signal to provide the imbalance amplitude and location. This measure is performed on ground. It is forbidden to fly with the installation described in the maintenance manual to check the fan balance.
First, a data analyze is performed on the accelerometer in cabin to check if it is possible to correlate record data and measures performed by maintenance means.

Telatemp temperatures
Telatemp indicators could be improved by adding temperature sensors to check the variation of maximum temperature as described in the maintenance manual. The outside air temperature can be also a case of maximum temperature variation during a flight. It could be easier to correlate the two temperatures by recording them.

Exceedances
For each exceedance described in the pilot’s operating handbook , a maintenance operation must occur. The recording allows getting good exceedance values and duration without pilot interference. And the pilot can confirm or infirm the exceedance. Nevertheless maintenance team knows necessarily what is recorded.

6.1.5 PARAMETERS TO BE RECORDED

It was agreed that the study should cover most types of piston engine rotorcrafts but the development of the embedded unit is focused on R22 and R44 Robinson helicopters.
During a first step of the study, investigations on parameters which could be recorded have been performed. The review of documentation shows that these parameters should be interesting to be recorded:

Parameter	Advantages (potential safety benefit)	Penalty	Recording
Outside Air Temperature	No connection to the existing electronic system Useful to determinate the limit manifold pressure and limit airspeed.	Weight: 90g	Yes
Rotor RPM	Useful to record exceedance - Refer to flight manual - Damage of main rotor components at too high speed rotor RPM involves maintenance operation. Accidents due to low rotor RPM are frequent and involve complementary pilot training(HOMP) Refer safety notice: SN10, SN24, SN36	Connected to an instrument Weight: 62g	Yes
Torque / Manifold pressure	Useful to record exceedance - Refer flight manual - Damage of rotating components with over manifold pressure involves maintenance operation. Accidents can occur with several limit exceedances. Refer SN37 and 20/12/2004 safety alert	Connected on manifold pressure pipe Weight: 100g	Yes
Engine oil pressure	Useful to record exceedance – Refer to flight manual Useful to get the operating time for maintenance inspection - R22 - Engine damage can occur which involves a maintenance operation	Connected to an instrument Weight: 62g	Yes
Engine oil temperature	Useful to record exceedance - Refer to flight manual Engine damage can occur which involves a maintenance operation	Connected to an instrument Weight: 62g	Yes
Cylinder head temperature	Useful to record exceedance - Refer to flight manual Engine damage can occur which involves a maintenance operation	Connected to an instrument Weight: 62g	Yes
Carburettor air temperature	Useful to record exceedance - Refer to flight manual Icing carburettor can occur but the record is only useful to pilot training(HOMP)	Connected to an instrument Weight: 62g	Yes

Parameter	Advantages (potential safety benefit)	Penalty	Recording
Engine tachometer	Useful to record exceedance – Refer to flight manual Over speed engine damage can occur which involves a maintenance operation. Under speed RPM engine is a consequent of bad power management and the record allows the pilot replaying the flight. (HOMP, pilot training)	Connected to an instrument Weight:	Yes
Chip detectors Clutch warning Carbon monoxide warning MRGB over temperature Engine fire warning	The warning lights are recorded and involve maintenance operation. It is useful to perform a warnings history. (Warnings frequency)	Connected to an instrument Weight: 360g	Option
Gov warning off	The warning lights are recorded. It is useful to perform a warning history. It is also a state of the helicopter without governor. It can be useful for pilot training (HOMP).	Connected to an instrument Weight: 60g	Option
Altitude pressure	No connection to the existing electronic system Useful to record exceedance - Refer to flight manual Useful to determinate the limit manifold pressure and limit airspeed. So after flight, it is possible to check if the power and the airspeed are correct regarding the altitude pressure.(HOMP, training pilot)	Weight: 56g Price: 90€	Yes
Vibrations Main rotor	No connection to the existing electronic system It can avoid component damage risk by perform maintenance operation (eg crack on blade SN39) as soon as exceeding appears. Without record, the maintenance operation is performed every 100H. This accelerometer is perhaps able to record tail rotor and fan vibrations: but are they usable?	Weight: 90g Price: 260€	Yes
Vibrations: Tail rotor	No connection to the existing electronic system It can avoid component damage risk by perform maintenance operation as soon as exceedance appears. Without record, the maintenance operation is performed every 100H.	The installation as described in the maintenance manual is prohibited in flight. Price: 260€	No

Parameter	Advantages (potential safety benefit)	Penalty	Recording
Vibrations: fan	No connection to the existing electronic system Useful to get a recording history It can avoid component damage risk by perform maintenance operation as soon as exceedance appears. Without record, the maintenance operation is performed every 100H.	The installation as described in the maintenance manual is prohibited in flight. Price: 260€	No
Air / Ground switch	To calculate the flight time for maintenance inspections - R44 -	Connected to an instrument Weight: 60g	Yes
GPS	Use for trajectory HOMP, training pilot Weight: 46g if the GPS already exists Price: insignificant if the GPS already exists	Helicopter must be equipped with a GPS with a RS232 serial link. Software development for each GPS type.	Option
Accelerometer (3 axes)	Use for load factor: hard landing, low G condition Risk of landing gear damage Require a maintenance operation Risk of lateral control loss HOMP, pilot training	Price:500 to 1000€ Weight: 100g	option
Gyro	Use for helicopter attitude: HOMP, pilot training	Price: 2000€ with 3 accelerometers 3000€ with 3 accelerometers, GPS Weight: 200g	option
Collective pitch position	Risk of rotor RPM loss by rapid and excessive collective pitch demand HOMP, pilot training	Difficult to install. Expensive. Installation flight commands Weight: tbd Price:tbd	No
Cyclic pitch position	Risk of lateral control loss at low g cyclic pushovers - prohibited - HOMP, pilot training	Difficult to install. Expensive. Installation flight commands Weight: tbd Price:tbd	No
Yaw pedal position	HOMP, pilot training	No particular caution in flight and maintenance manuals Difficult to install. Expensive. Installation flight commands Weight: tbd Price:tbd	No

Parameter	Advantages (potential safety benefit)	Penalty	Recording
Fuel flow	Risk of fuel leak or obstruction of fuel system Require a maintenance operation HOMP, pilot training if governor failure	Weight: tbd Price:tbd	No
Air speed	Exceedance in flight manual Risk of airframe damage Require a maintenance operation HOMP, pilot training	The measure is not correct at low speed - <50knots -. The accuracy of the measure is about 6knots over 50knots. Note also that the airspeed given by the instrument is not the real airspeed: there an error graph given in the pilot manual. A calibration of this parameter according the reading is necessary. Weight: 56g Price: 280€	Option
External conditions (Camera)	To film the instruments, pilot workload HOMP, pilot training	Price: expensive for an aeronautical camera	No

Table 4 – Helicopter Parameters definition

Origin of the each recorded parameter:
Analogical parameters (data coming from existing instruments or sensors)

Data Description:	Sensor:
Manifold pressure /torque (CO)	Pressure sensor or electrical signal
Engine oil pressure	On an existing sensor
Altitude (pressure) (ZP)	Added Pressure sensor
Air speed pressure (optional)	Added Pressure sensor
Engine tachometer	On an existing sensor
Rotor tachometer (NR)	On an existing sensor
Outside Air Temperature (OAT)	Added temperature sensor
Engine oil temperature	On an existing sensor
Cylinder head temperature	On an existing sensor
Carburettor air temperature	On an existing sensor
Battery voltage	Electrical measure on battery
Compensation temperature	Added temperature sensor
Recorder internal temperature	Sensor included in recorder's PCB

Logic parameters

Data Description	Comments:
Gov warning off	If available on the rotorcraft
TRGB chip detector	If available on the rotorcraft
MRGB chip detector	If available on the rotorcraft
Clutch warning	If available on the rotorcraft
Carbon monoxide warning (optional)	If available on the rotorcraft
MRGB over temperature	If available on the rotorcraft
Engine fire warning (optional)	If available on the rotorcraft
Air/ground switch	Up collective on R22/R44 helicopter
Engine oil pressure contact	If available on the rotorcraft
Low fuel alarm	If available on the rotorcraft

Vibration parameters
The embedded unit may record 4 vibration signals.

Parameters send by serial link

Data Description	Comments:
GPS data by serial link (optional)	If a GPS GN430 or GN 420 is available
3 axes load factor by serial link (optional)	Not yet available
Gyro meter by serial link (optional)	Not yet available

Result in terms of flight safety benefits

The helicopter is the only means of transport to perform certain specific tasks (such as EMS, transport of charges in inaccessible locations…). It is also a regional development tool, because it can complete the supply of transport without requiring important airport infrastructure creation.

Its development remains limited mainly, because of the high costs involved in ownership of these aircraft. Nowadays, the maintenance position is too great.

It seems essential to reduce maintenance costs in order to help its development.

Furthermore, the improvement of flight safety is a key issue for the development of this industry. Maintenance has an important role in this field.

The system may undoubtedly help improving flight safety by providing early detection of an element critical damage, recording and alerting pilots and technical teams of exceedances (warning lights) and optimize maintenance through better knowledge of flight envelope.

Flying at aircraft operating limits implies the pilot attention on numerous parameters. Some of them are very useful, and their constant monitoring is not so easy.

When pilots meet difficult flight condition, the most important is too keep the helicopter in the best configuration to avoid parameters loss like: helicopter limitations, engine limitations.

As a general rule, every time a component is subjected to stress and exceedances, invisible damages occur. Visually, certain cracks are invisible, only an x-ray inspection can detect them. A fatigue crack will begin and grow until a sudden failure occurs. It is possible that the part will reach its approved service life and be replaced before failure. However, there is also likely to happen a serious or fatal accident.

The vast majority involved the loss of normal flying capability:

- Refer to the Safety Notice SN 37 published by Robinson Company which explains that exceeding limitations (airspeed, manifold pressure limit) can be fatal.
- Refer to the Safety Notice SN 10 published by Robinson Company which explains that fatal accidents are caused by low RPM rotor stall (Rotor RPM).
- Refer to the Safety Notice SN 36 published by Robinson Company which explains that fatal accidents are caused by over speeds during lift-off. (Rotor RPM)
- Refer to the Safety Notice SN 22 published by Robinson Company which explains that fatal accidents are caused by reducing airspeed during an approach. (airspeed)

Even if the system in not crash protected, and except in case of an in-flight or post-crash fire, recorded data should be available thanks to both memories (the internal one and SD-card one).

Note: According to United States NTSB database, during time frame 2003-2007, either in flight and post-crash fires, 69 accident recorder with fire mentioned out of 905 accidents, so an average of 7.6%.
Note 2: During the same timeframe, In 56 accidents the helicopter was considered destroyed either by fire damage and/or impact damage.

To sum-up, it could be consider than in more than 90 percent of the accidents, data might be analyzed after an accident.

Another interest to record the flight parameters is in the debriefing phase. At this precise moment, a student pilot and his instructor can become aware of the values recorded which correspond to the duration and condition flight. So, helped by these values, the instructor pilot can visualize and explain the critical flights configuration with the exceedances values, with the possibility to replay the flight on the ground station.
It can result in a complementary training for the student to know better the aircraft limitations and insisting on the parameters requiring a greater monitoring.

The flight safety improvement depends on a good knowledge of:

- Aircraft limitations.
- Aircraft emergency procedures.
- Aircraft normal procedures.
- Aircraft performances.

<u>The system may help improving maintenance program</u> in the way it provides valuable help for the maintenance and allows trend monitoring of the helicopter thanks to a constant records and follow-up.

The maintenance team has an important role to play in the flight safety improvement.
Its main role is to check the aircraft components and their condition. It will be helpful if the components stress will be stored for all their life. The deterioration speed of engine, rotating assemblies, instruments depends on the helicopter operating envelop limits use.
Maintain manually in good flying condition the helicopter mechanical assemblies are not so easy. It may be performed with a regular and permanent recording of the most critical parameters on ground or in flight.
The most effective solution consists in recording engine and helicopter parameters thanks to a data monitoring system.

Nowadays to facilitate the maintenance program, it is possible to record these parameters which will be analyzed after the flight.

The system installed on the helicopter could anticipate anomalies and could provide the opportunity to also perform predictive maintenance before the critical defects emergence.

It consists in comparing the helicopter vibration characteristics in flight with the characteristics of a normal configuration pre-defined.

Vibration analysis is the process used to detect and diagnose malfunctions of mechanical assemblies. To perform it, predictive maintenance is a practice whose aim is to anticipate the deterioration of equipment. These practices must get the greatest precision possible.

The system is going to record parameters with a big accuracy to detect exceedances most often due to an incorrect helicopter use.
The major mission of this system is to improve the fleet availability and safety flight after.

Given its cost, it is wise to establish a good balance between preventive and corrective maintenance.

In all cases, the recorded parameters will not avoid an accident, but will have first the benefit to involve a maintenance operation. The second aim is to reinforce the training pilots and the knowledge of helicopter limitations and performances to avoid fatal flight configurations.

6.1.6 OUTPUTS AND RESULTS: SYSTEM SPECIFICATIONS

6.1.6.1 PRINCIPLE

The system aims are numerous as checking the use of the helicopter envelope limit, providing information to maintenance team, providing a help to increase Flight safety.
Information coming from the system may also be used as input to HOMP.
Further to this, in case of crash, except if data are destroyed, the system may help in finding the causes of an accident.

In that context, the system provides the following functionalities:

- Parameters acquisition and displaying of flight exceedances.
- Transmission of the recorded flights to a ground station.
- Data capture.
- Fleet display.
- Helicopters flight capacity display.
- Parameters analysis and displaying: trends of the parameters evolutions or parameters function.
- Exceedances displaying and the embedded boxes messages.

The system is composed with an embedded unit allowing the recording of the parameters defined in the introduction, a mounting kit, and a ground station to display data and configure the embedded unit.

The embedded unit should be available for most piston engine helicopters but as a first step, Robinson piston engine helicopter.

The detail of the mounting kit and the embedded unit configuration is linked to each helicopter.

6.1.6.2 FEATURES OF THE EMBEEDED UNIT

The embedded unit has to acquire and to record following aircrafts and engine parameters:

- The power supply voltage.
- Engine head cylinder temperature.
- Engine oil pressure.
- Engine oil temperature
- Carburettor air temperature
- Engine rpm speed.
- Torque.
- Main rotor speed.
- Outside air temperature.
- Pressure altitude.
- Indicator air speed.
- Warnings.
- A signal allowing the ground / flight detection: collective pitch switch installed on Robinson helicopters.
- Position and/or speed GPS on connection puts into series optional RS232.
- Load factor of and gyroscopic measures on connection puts into series optional RS232.
- Vibrations defined in the maintenance manual for the helicopter main blades balancing or the helicopter health.

It also has to detect the following aircrafts phases as helicopter battery switch on, the electrical supply cut off, the engine start and breakdown and the helicopters taking off and landing.

It has also to detect parameters exceedances according to thresholds chosen by the user (generally, engine and main rotor parameters).

6.1.6.2.1 Mounting kit

The mounting kit has to connect the recorder to the existing sensors or instruments, to add other sensors and to install the recorder and all the items of the mounting kit.

Potential sensors able to be connected are:

- Temperature sensor.
- Pressure sensor.
- Accelerometers.
- Tachymeter, phonic wheel, engine magneto.
- GPS by an RS232 serial link.
- MEMS sensors by an RS232 serial link.

6.1.6.2.2 Ground station functions

The ground station should provide the following functionalities around a database:

- Database management.
- Recorder identification and management.
- Helicopter identification and management.
- Helicopter type identification and management.
- Operating base identification and management.
- AG crew identification and management.

It should also provide the configurations of:
- Operating base.
- Engine part number.
- Engine module part number.
- Engine component part number.
- Rotating assembly part number.
- Rotating module part number.
- Rotating component part number.
- Maintenance description.
- Technical activity.
- Recorders time and time adjustment.
- Recorders exceedance thresholds adjustment.
- Helicopters identification and type.

It should also perform the assemblies of:
- Helicopters.
- Engines.
- Engine modules.
- Engine components.
- Rotating modules.
- Rotating components.
- Recorders.

and the following actions:
- Download recorded data.
- Flight validation.
- Acknowledge exceedance.
- Maintenance operations.
- Management of the users to allow each of them specific tasks regarding their qualification.

It will display data as follows:
- Fleet tree (with filters).
- Summary about helicopters and flights.
- Trends.
- Vibration information.
- Operations tree (with filters)
- Flight data: summary, sec by sec table, graph, messages, default, exceedances, event marker, flight replay.
- Properties and related data about AG crew.

6.2 STEP2: DESIGN OF PRODUCT

6.2.1 DESIGN GENERALITIES

The aim is to develop a prototype unit according to specification given in paragraph 6.1.6
The system contains an embedded unit and a mounting kit for each helicopter type. A ground station tool is used to download and display recorded data.

The program development is the description of the project organization in terms of human management, project cycle, quality management and product development.

It contains the hardware and mechanical design of embedded unit, the software design of the embedded recorder and thee software design of ground station.

A development plan was drafted to describe measures taken to manage the project in the best possible conditions by taking into account:

- The restraints revealing by the EASA demand and the follow-up of the R22 and R44 light helicopters type.
- The conditions coming from our APDOA organization.
- Specific arrangements / adaptations resulting from specificities of the project (complexity, time scale, risks)
- Capacities concerning the quality and its follow-up.

At first, the step 2 summarises the development plan and the system functions by software design description.
Then it develops the design of the parameters acquisition, the installation kit and the ground station.
Finally, it presents the results of helicopter measures and a synthesis regarding cost and weight targets.

6.2.2 PROGRAM DEVELOPMENT

The manufacturing of the STC qualified system has to be performed in conformity with alternative procedure to DOA. So the following documentation has to be written to obtain the STC:

- Conformity statement and documentary architecture.
- Certification plan.
- Ground and flight test program.
- Ground and flight test report.
- DO160 conformity report.
- Technical description.
- Definition files.
- Mounting instruction.
- PSAC (Plan for Software Aspect of Certification)
- SAS (Software Accomplishment Summary).
- SCI (Software Configuration Index)

- Pilot's Operating Handbook.
- Maintenance manual.

Software embedded development has to be done according to the DO178 level D approved software development management. The level D has been chosen because the embedded unit has no pilot display in flight and no functional action on the helicopter.

The manufacturing of the system has to be done by the PART21G approved organization according the industrial files of the system: manufacturing and control files.

The maintenance of the system has to be done by PART145 approved organization according to the maintenance manual of the system.

The project comports several phases. The passages from one step to the other one are performed by a publication set described in this development plan.

The different phases are following:

- Specification phase.
- Preliminary Conception Phase.
- Detailed Phase Conception.
- Realization Phase.
- Phase of Test - unit and integration.
- Qualification phase.
- Functional validation phase (including the functional validation, Qualifications compliant with DO160E and DO178, Helicopter Ground tests and flight tests
- Industrialization phase.

6.2.3 SOFTWARE DESIGN OF EMBEDDED UNIT

The embedded unit software manages the hardware items, performs the recorder functions and schedules them.

This diagram represents the interactions between the actors and the embedded unit. Every arrow represents an action activated by one of the actors.

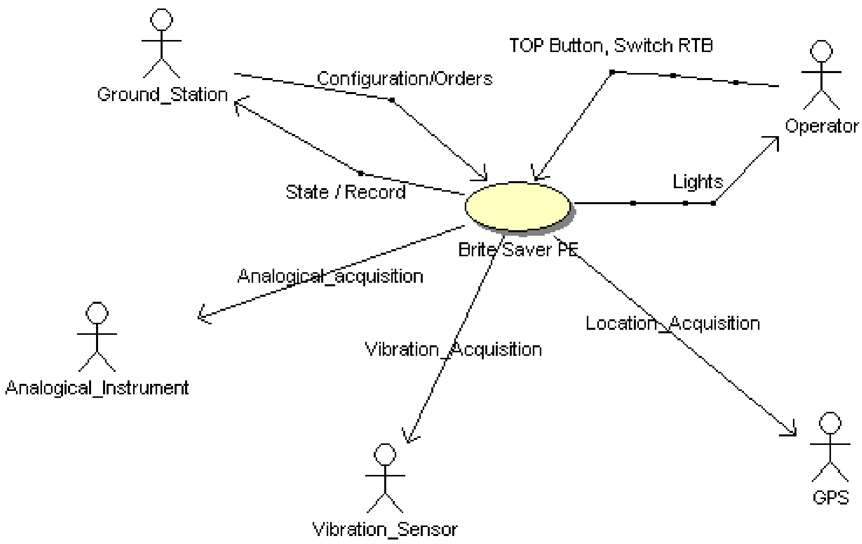


Figure 1 - Embedded unit context diagram

6.2.4 DESIGN OF PARAMETERS ACQUISITIONS

6.2.4.1 OVERVIEW

The parameters can be defined as follows:

- Analogical data on existing sensors.
- Analogical data with added sensors.
- Existing digital signals.
- Existing counter signals.
- Vibration acquisition.

These different parts have specific problems for design and also for mounting in helicopter.

The best way to have data close from helicopter display is to use existing sensors. The benefit is also a low cost with only some wires to connect. The drawback is a bad knowledge of the sensor, the difficulty to get data sheet about sensors used, the interaction of the instrument and in consequence, the need to do measure on helicopter.

Some parameters are displayed on helicopters but there is no electrical access. In this case, sensors must be added because there is not choice: but the solutions are often expensive to get accurate sensors and more difficult to install.

This paragraph explains also how the record data are decided valid or not by the system.

6.2.4.2 ANALOGICAL DATA ON EXISTING SENSORS

The existing sensors to record are engine head cylinder temperature, engine oil pressure and temperature and carburettor temperature.

Measures on these sensors are necessary to get curves of physical values regarding voltages.
On R22 and R44 helicopters, these curves are not linear and often not accurate, particularly in limit values. So the exceedances detections are not so good.
And it is impossible - and undesirable - to reach limit values on helicopter. However, the Robinson maintenance manuals give the impedance of the sensors for limits values. The measure of voltages on resistances instead of sensors allows having a good accuracy warranted by the helicopter manufacturer.

The measures are independent of supply voltage fluctuations except for carburettor air temperature: for this sensor, the fluctuation is about 3°C for 1V of supply voltage fluctuation. It is enough regarding the graduation every 5°C and the fact that this parameter has no maintenance use.

6.2.4.3 EXISTING COUNTER SIGNALS

The measure of engine RPM is performed on engine magneto.
The measure of rotor RPM is on a rotor phonic wheel connected on the drive line after the clutch.
The signal is filtered to avoid high frequency noise perturbations. Then the recorder counts between 2 rising slopes and decreases noise by average on 25 samples. It is possible to divide the signal frequency by the number of poles of the measure - tachy, phonic wheel, etc - to avoid erratic measures if the different poles are not adjusted with enough accuracy.

Some frequencies on the R22 and R44 helicopters:

Helicopter	Rotor RPM	Rotor phonic wheel frequency	Engine RPM	Engine magneto frequency
R22	104% 530RPM	75.485Hz 2 poles	104% 2652RPM	88.4Hz 2 poles
R44	102% 408RPM	70.472Hz 2 poles	102% 2718RPM	135.9Hz 3 poles

For these frequencies, the number of pole and a counting frequency at 130000Hz minimum involves accuracy better than 0.05%.

A good accuracy is important for counter signal where the valid values are very short: between 101% and 102% for rotor RPM on R44. So 0.1% accuracy is necessary.

6.2.4.4 EXISTING DIGITAL SIGNALS

These following digital signals are recorded:

- Governor warning off
- TRGB chip detector
- MRGB chip detector
- Engaged clutch warning

- Non engaged clutch warning
- Carbon monoxide warning (optional)
- MRGB over temperature
- Engine fire warning (optional)
- Air/ground switch
- Engine oil pressure contact
- Low fuel alarm

These signals are filtered and then compared with a hysteresis to acquire more stable signals.

6.2.4.5 ANALOGICAL DATA WITH ADDED SENSORS

The following signals need external sensors because there is no electrical access on the instruments where the measures are already performed in the helicopter:

- Torque - manifold pressure -
- Zp
- Airspeed
- OAT
- Vibration accelerometers

Torque and Zp measures need an absolute pressure sensor to measure from 300 mbar to 1100 mbar.
Manifold pressure is graduated each IN.HG. So the accuracy is about 0.5IN.HG. It is accuracy we can get with a low price sensor.
The accuracy of Zp in absolute value is important to check the manifold pressure and airspeed limits. But the placards are only graduated every 2000 feet. So an absolute accuracy of 200 feet is enough and a cheap sensor is enough.
The relative sensibility of the manifold pressure measure is important to observe the helicopter up and down attitude: about 2 meters because of recorder analogical to digital converter.

The **airspeed** sensor must have an absolute accuracy better than 5knots which corresponds to the instrument graduation. The sensor is not really cheap but it is correct for an optional item.

OAT sensor
An OAT sensor already exists on the R22 and R44 helicopter. Moreover, no cutting or splicing of OAT probe wires is permitted. An additional OAT sensor is added.
The accuracy of OAT in absolute value is important to check the manifold pressure and airspeed limits. But the placards are graduated only every 10°C. So the temperature sensor must have an absolute accuracy better than 5°C which is also the graduation of the instrument. A cheap sensor can be found with better accuracy.

6.2.4.6 VIBRATION ACQUISITION
There is not continuous vibration acquisition on this type of helicopters. But vibrations accelerometers are mounted for scheduled maintenance inspection. Only the cockpit accelerometers can be mounted during a flight. And it must be installed not exactly at the same location that described in the maintenance manual.

The accelerometer has to measure the helicopter vibration and particularly the main rotor RPM:

6.2.4.7 SERIAL LINK ACQUISITIONS
It is possible to acquire attitude, load factors and GPS parameters by serial link:

The **attitude and load factors** acquisitions need another unit with 3 axes accelerometer, 3 axes gyro, and magnetic sensors. This unit calculates roll, pitch and yaws and load factors of the helicopter. The position and the velocity can be calculated, but it is necessary to correct it by a GPS to avoid important cumulated error by the integration of the acceleration.

These sensors must be calibrated. And the gyro bias must be reset at each flight.
These sensors are not yet mounted on helicopter because of the high price.

The GPS is only a cable and an embedded software development. The difficulty comes from the software which is different for each GPS.
That is why the hardware is developed for these functions but not the software.

6.2.4.8 DATA RECORD VALIDITY
It is primordial to assure the validity of our recorded data:
First, the recorder must know if the battery supply is at a correct level: if not, the data acquisition is stopped and last data are recorded: a super capacitor allowed ending the treatments correctly.

Secondly, all data are recorded with redundant data to validate the recorded data.

Third, the recorder is developed to get enough accuracy:
- 1% for analogical data -without sensors accuracy -
- 0.1% for counter data

Fourth, the data accuracy is checked in manufacturing phase.

6.2.5 DESIGN OF MOUNTING KIT

6.2.5.1 GENERALITIES
The mounting includes the elements used to connect existing sensors to the recorder, added sensors items to mount them - mechanical items, electrical wires, pipe items -

The reading of maintenance manual helps to get an idea to mount the items. But it is necessary to observe different helicopter and to get the help of helicopter maintenance teams: they know what is possible or not.

The details of the time scale necessary for the system installation are given in paragraph 6.2.7.6.

6.2.5.2 THE EMBEDDED UNIT

The first step is to find a location to mount the embedded unit.
Possible locations are central console, between seats or under the pilot seat.

In the central console, the free space depends on the helicopter type. For the R22 helicopter, there is often a room For the R44 helicopter, there nearly never any room in the console.

Between the two seats, it is feasible but not so easy to connect the recorder to the instruments. The solution is more expensive than the other one. The interest is the access by pilot and co pilot if necessary.

Under the pilot seat, there is already the heating unit in R22 but it is always free on R44.

Therefore, the embedded unit is located in the console on R22 and under the seat on R44.

Figure 2 - Recorder location on R22 and R44

6.2.5.3 HARNESS ROUTING

For R22, the harness is very easy to route because the recorder is located in the console.

For R44, the recorder cannot be in the console, the harness has to route near the flight controls in order to access to the console. Two holes need to be drilled.
Then because of the light airframe of this helicopter, it is necessary to reinforce the airframe with plates when we drill holes.

It is necessary to install a cut off plug before connecting wires to the upper console connections to perform the installation easier and shorter.

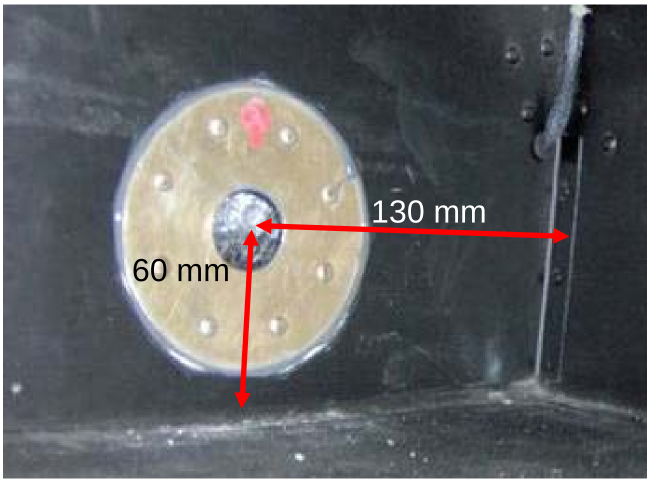


Figure 3 : Reinforced plate location on R44

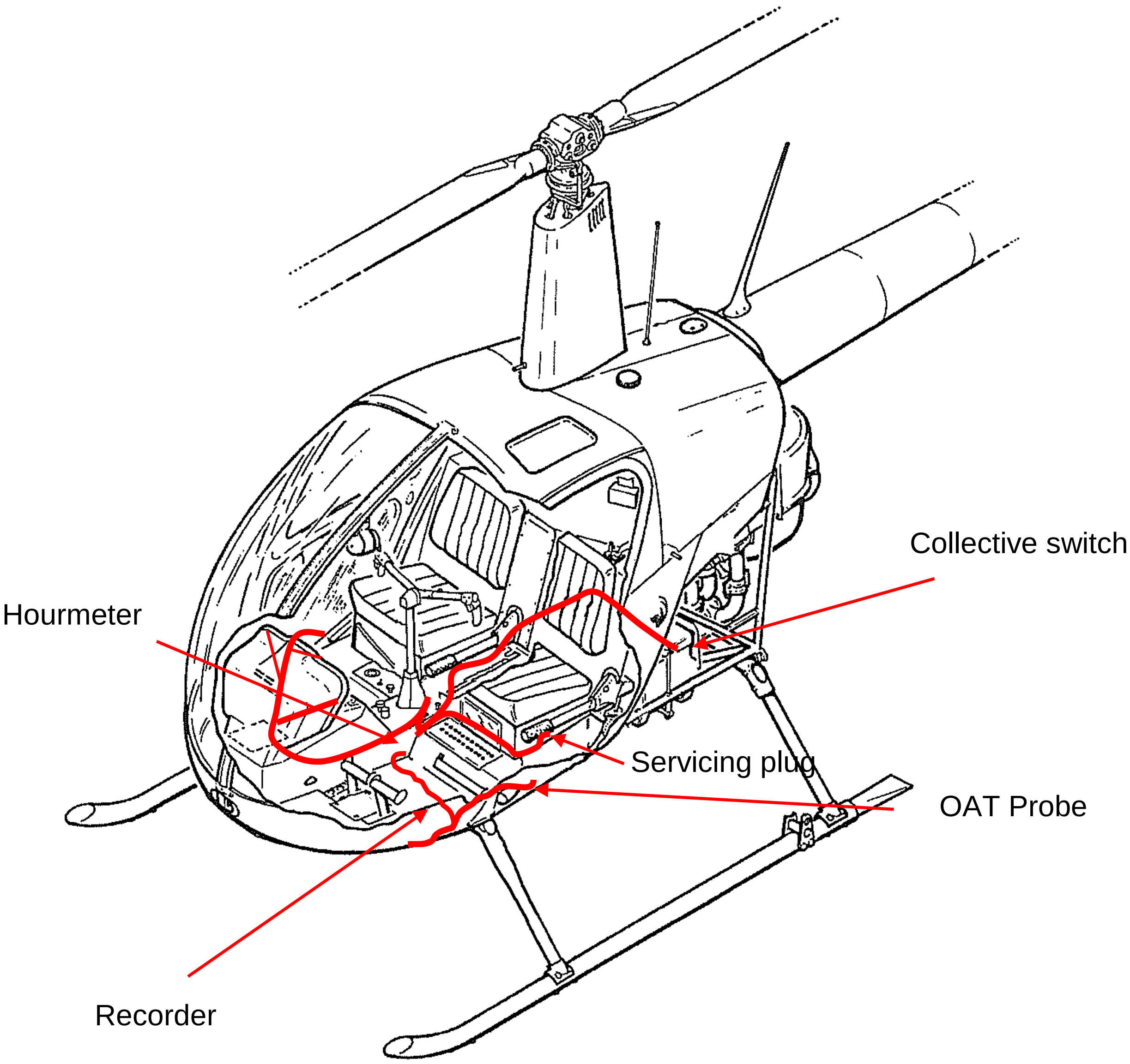


Figure 4 - R22 Wire harness routing.

6.2.5.4 SENSORS MOUNTING

OAT sensor mounting

Helicopter OAT sensor is mounted through a fibber cowling under the helicopter. The recorder OAT sensor is mounted in a removable aluminium panel and is not far from the other OAT sensor to avoid too big difference of temperature.
It is not mounted just close the helicopter OAT sensor because it is really easier to mount it through an aluminium removable panel.

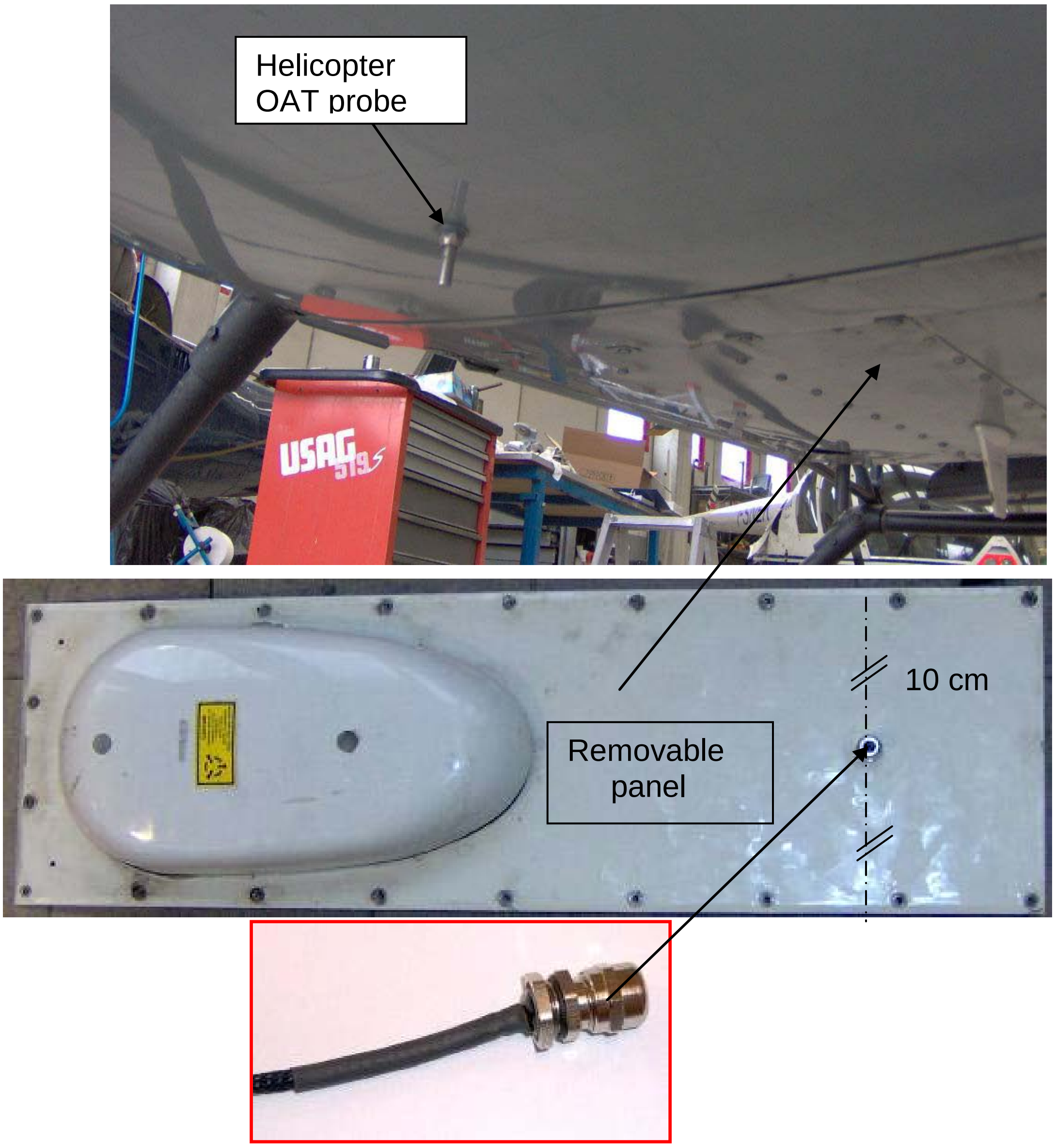


Figure 5 - OAT probe

Altitude, manifold and airspeed pressure sensors mounting

Three pressure sensors are mounted in the console: the pipe systems and wire harness are located in the console; the manipulation is easy to perform.

Altitude pressure sensor is connected to the pitot-static system.

Airspeed sensor is connected between the pitot-static system and the pitot total system.

Manifold pressure sensor is connected to the engine intake manifold.

Because of room lack, the pipes can be compressed, be careful during the mounting.

Sensors are connected to harness with plastic clamps because sensors are very light.

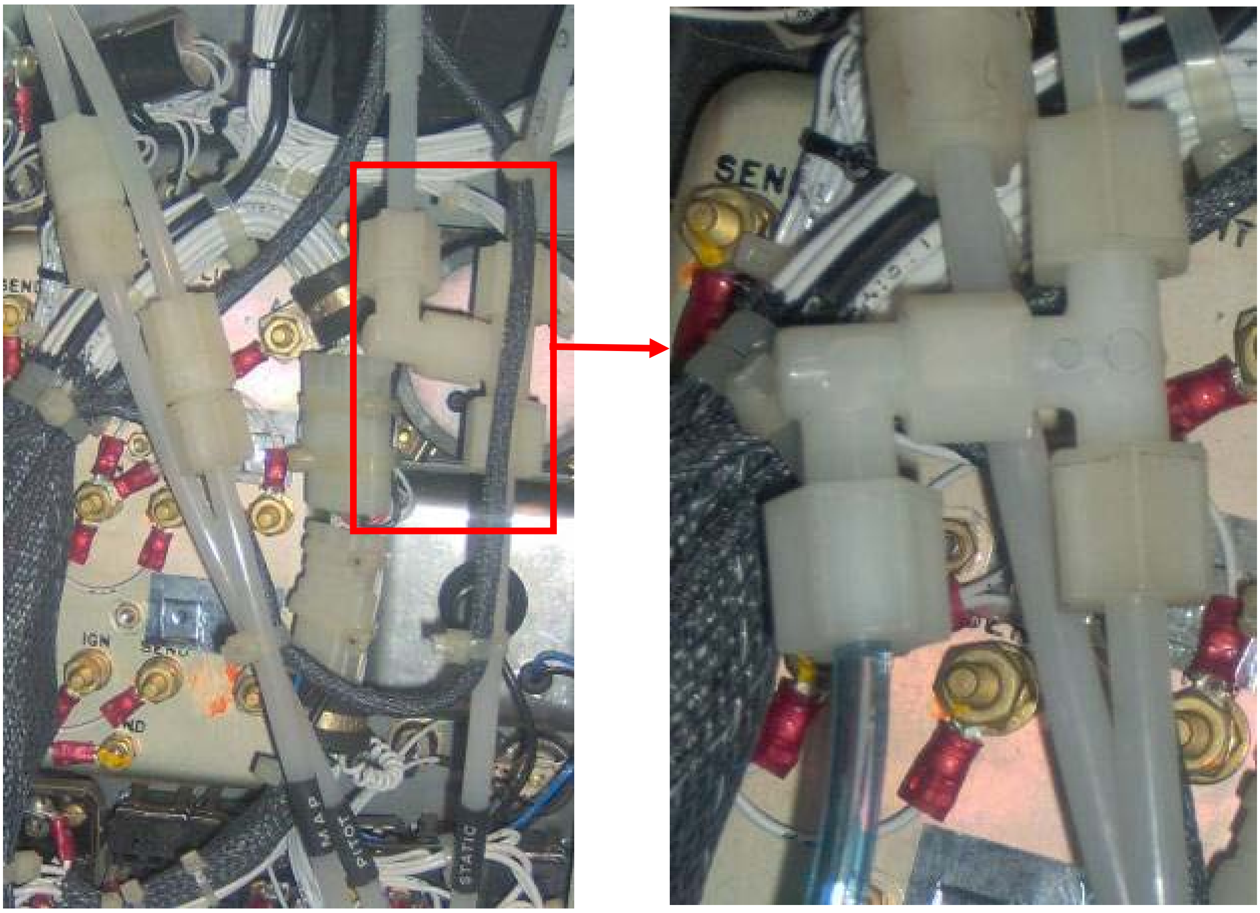


Figure 6 - Pressure pipe connection

Accelerometer mounting

For balance checking, the accelerometer is mounted in vertical position in the R22 helicopter and horizontally position in R44 - according Robinson maintenance manuals -. The Vibrex instrument measures the vibration level at nominal rotor RPM.

For tracking check, the operator visualizes the target patch location with a stroboscope light. As soon as the blades are well adjusted, the vibration level is too high. Therefore, it is necessary to dismantle the blades adjustment to decrease the vibration level.

The Chadwick operating manual recommends using two accelerometers to measure vibration for balance and tracking checking. Some expert technicians perform the checking with this method. The recorder also uses this method to check vibration levels.

Only a vertical accelerometer has been mounted but another one will be mounted soon for the vibration analysis.

It should be noted that without magnetic pickup mounted close to the main rotor hub, it's possible to perform the adjustment but it is not the aim of the vibration record.

The maintenance test accelerometers are mounted outside the console with cable inside the cabin. It is suitable for security to perform the same for commercial

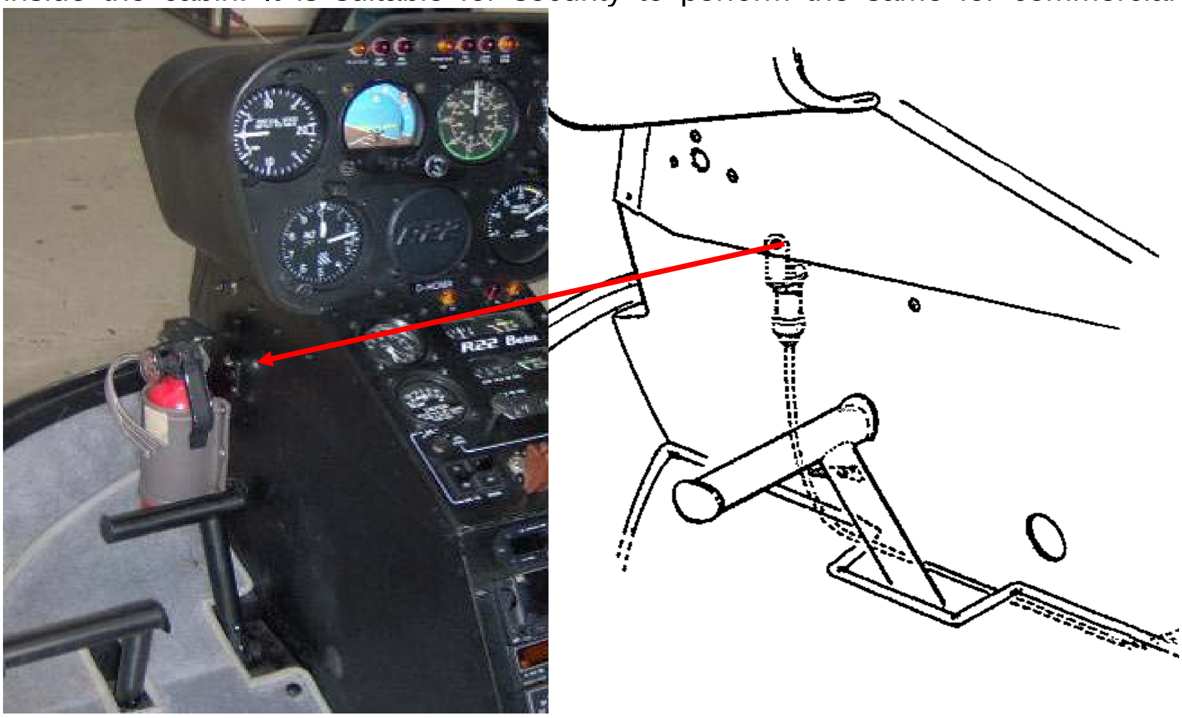


Figure 7 - Main rotor accelerometer on R22

Attitude and load factors unit mounting

This unit could be mounted close to the recorder under the seat.

The functionality is not provided in the prototype system but could be performed in the future.

6.2.6 SOFTWARE DESIGN OF GROUND STATION

A ground module with the Ground Station Software is installed on windows PC to analyze data and ensure long-term storage in the database.

The choice of windows PC is the standard used by every company: so the windows system is well known by customer and users training is easier.

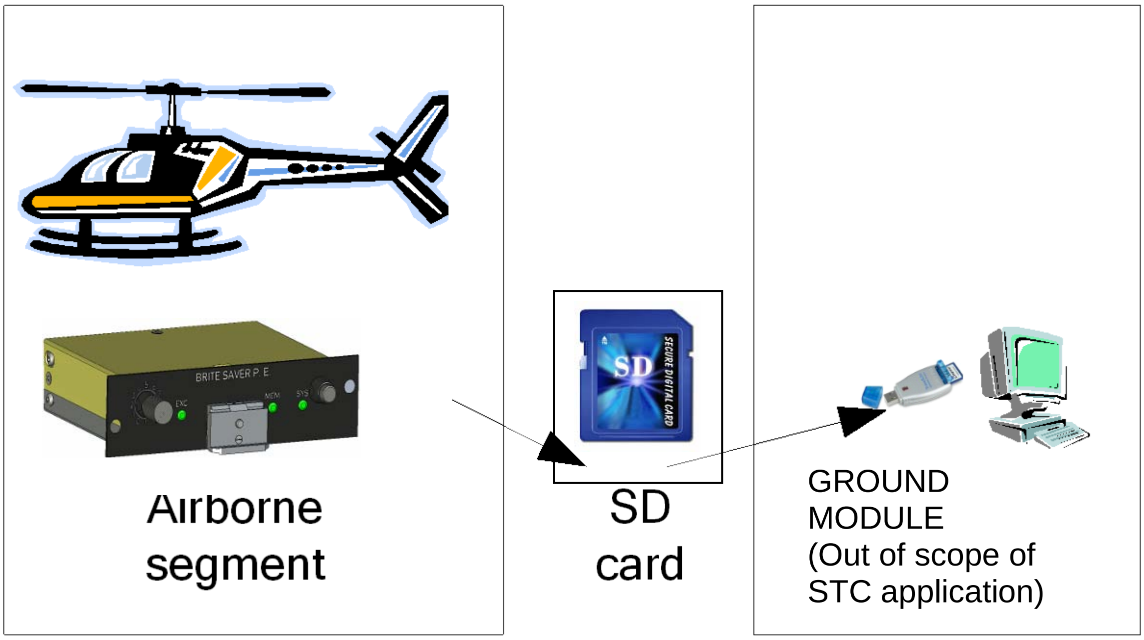


Figure 8 - Airborne and Ground modules

The database allows managing, identifying and configuring recorders, helicopter types, helicopters, engine and rotary, engine and rotating module, engine and rotating components, operating bases and AG crews.

The user can manage helicopter, engine and rotating assemblies, engine and rotating modules, engine and rotating components capabilities. He can also manage pilots' flight time. This management is performed automatically with only a pilot flight validation and exceedances acknowledgement by maintenance technicians.

It allows also adjusting recorders time and recorders exceedance thresholds.

The ground station can also download recorded data from SD card, perform recorder maintenance operations and change user.

The user is also able to display the fleet tree with filters, summaries about helicopters and flights, flight data, trends, vibration analysis, operations tree with filters and data about AG crews.

The flight data display is performed by the following means: summaries, sec by sec table, graph, messages, default, exceedances, event marker and flight replay. Flight replay is particularly interesting for pilots training because they know this interface with instruments display.

Data download possibilities

The technologies available for data downloading could be:

- Cable.
- Transportable means - USB key, SD card, compact flash, etc.
- Radio means - Bluetooth, WIFI, GPRS, Iridium system, etc.

Using a cable is not easy, but it can be a mean of maintenance, the embedded unit has this possibility.

The transportable mean is very interesting because of its small size and high capacity. SD card has been chosen for its small size, the possibility to be inside the recorder during the flight and no wasting time to download data on the helicopter. The compact flash is bigger and its electrical interface more complex and expensive. The USB key is bigger and more difficult to be located inside the recorder during flight. Its capacity could be higher than a SD card but there is no need.

Radio means could be very interesting because the data could not be lost. Bluetooth and WIFI can download only in a short perimeter around the ground station but the data transfer is fast. These means do not need subscription cost. GPRS and Iridium system can download data nearly anywhere in the world but the data transfer is low and needs a subscription cost. There is also a cost according data size. GPRS is prohibited by telecom administration in flight.
So Iridium system is particularly interesting for security benefit because the helicopter can send automatics messages to a maintenance centre when an exceedance is detected. The crew can be contacted by radio if necessary.
Therefore, that kind of solution might be more difficult to implement because of qualification requirements.

6.2.7 OUTPUTS AND RESULTS FOR STEP 2

In this step, the outputs are the measures of helicopter signal, instruments curves allowing accurate measures for exceedances detection.

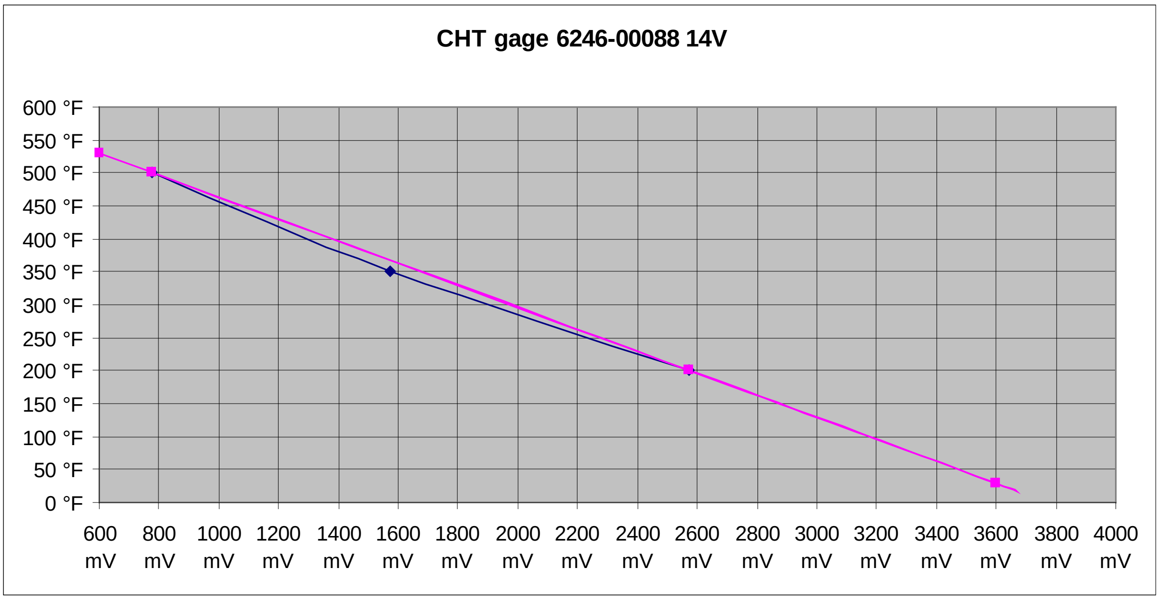
6.2.7.1 MEASURES REPORT

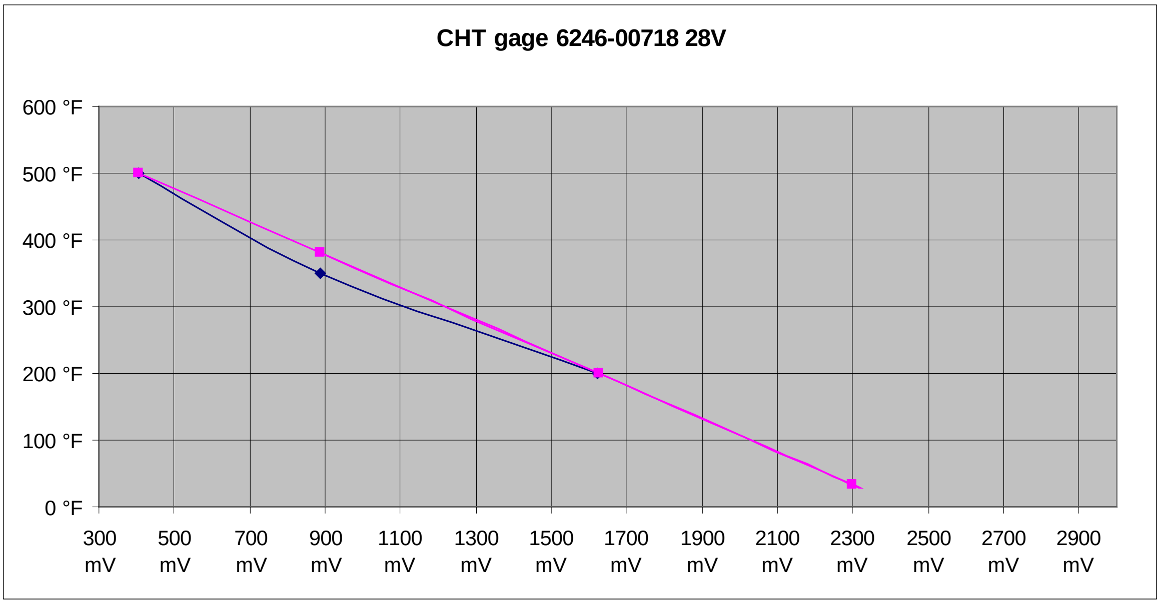
Measures have been performed for several instruments.

Black curves relate measures performed with resistance instead of sensors.

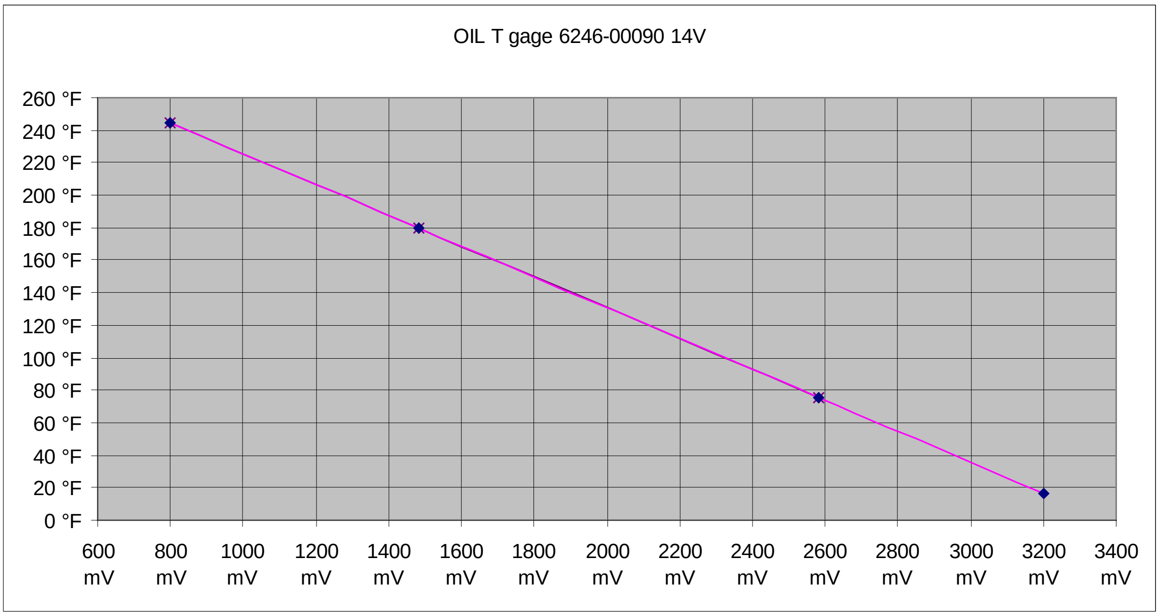
Pink one relates measures performed with the prototype system.

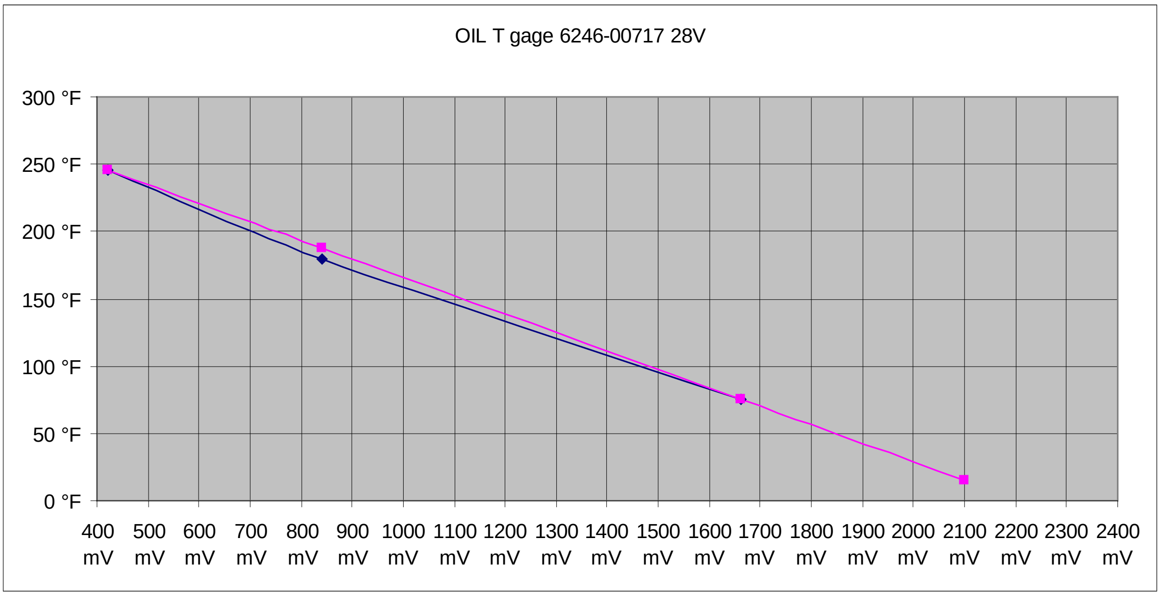
For CHT gage, it is necessary to achieve the best accuracy around 500°F (threshold values of the CHT according to Robinson manuals).



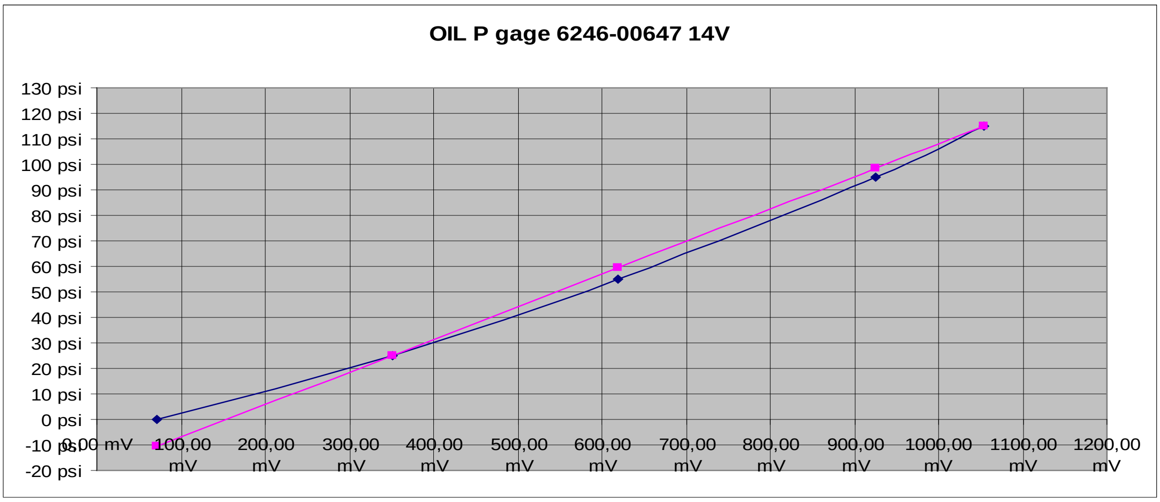


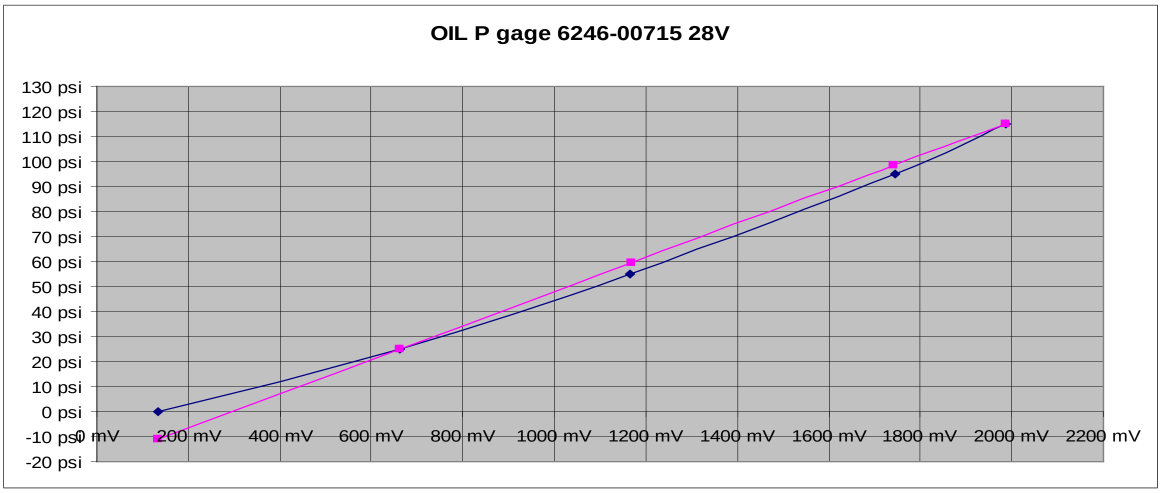
For oil temperature gage, the accuracy has to be optimized around 245°F.

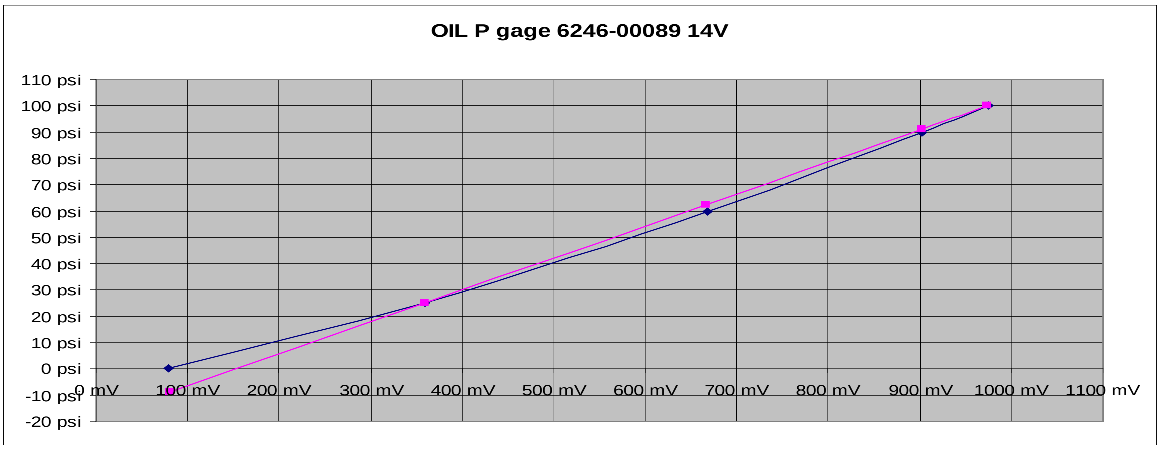




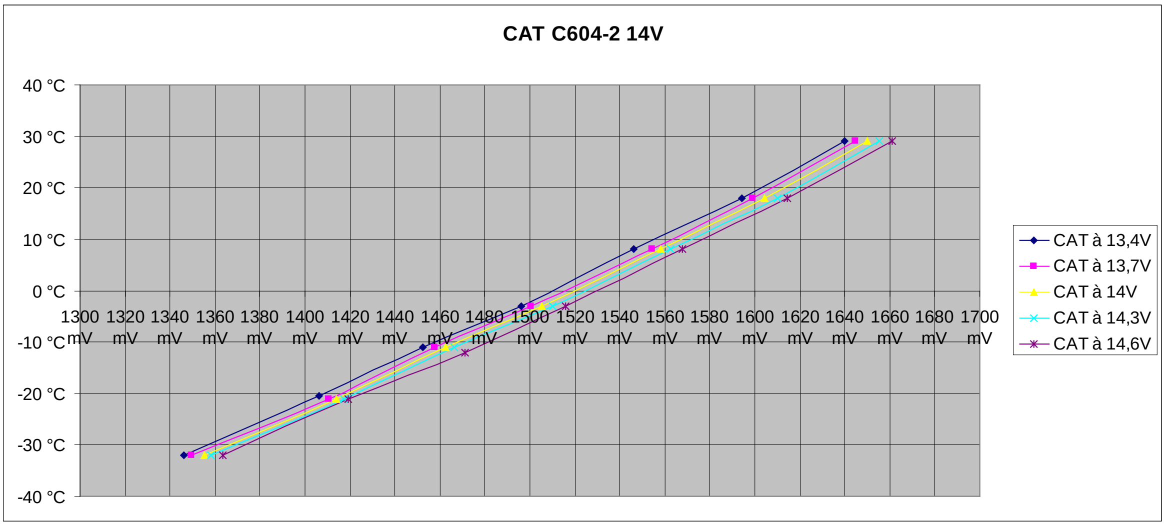
For oil pressure gage, it has to be done around at 25 and 115 PSI - 100PSI for the last gage -. Note that two different gages can be mounted in same type helicopter (old and new one).

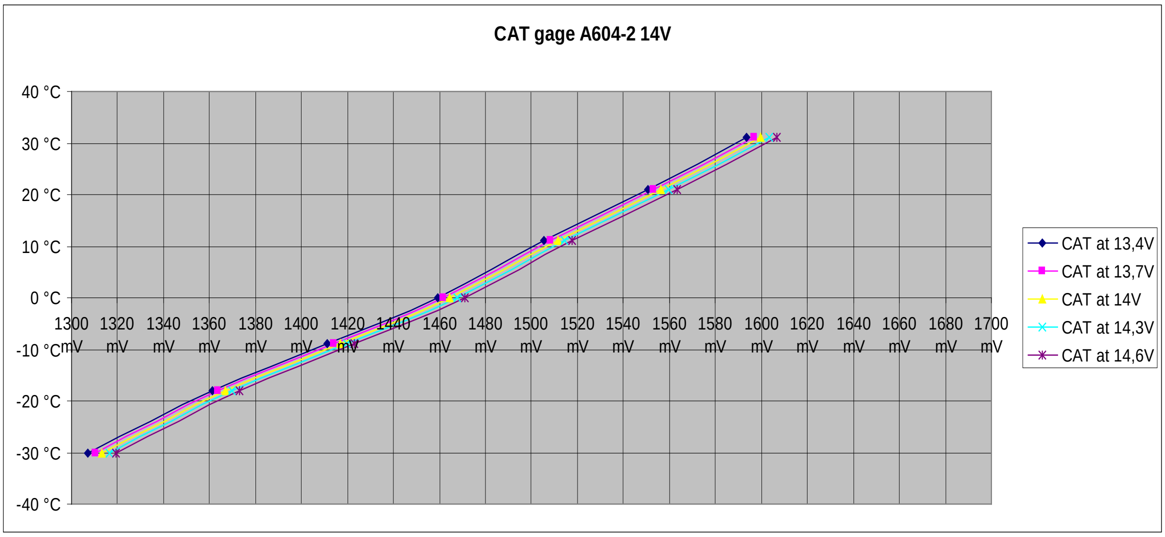






For the carburettor air temperature measure, the threshold is 5°C. The curves represent the CAT at different supply voltage. Note that two different gages can be mounted in same type helicopter - old and new gage-





6.2.7.2 STC WITH DOCUMENTATION

The Supplement Type Certificate (See STC n° EASA R.S.01494 in appendices) has been achieved for the embedded items: the recorder and its installation kit.

6.2.7.3 RECORDERS INSTALLATIONS

2 recorders have been mounting: the first one on a R44-I 14V helicopter and the second one on R44-II 28V helicopter.

3 other helicopters could be soon equipped.

The first installation for the qualification phase has taken about 30 hours because only at this first step, some reinforced mechanical items have been decided to be manufactured. A cutting junction has also been decided.

The second installation is easier but there are also some light evolutions because it is not exactly the same helicopter type.

6.2.7.4 COST TARGET

The cost target of 3000 € has been achieved for the standard Prototype system.
Even if the maximum functionalities have been implemented for flight trials in order to discuss about safety benefits of each of them, the standard system of BRITE SAVER is the one that fits closely to JAR OPS3 3 requirements.
All other parameters will be considered as optional and will generate additional costs to this standard version.

6.2.7.5 WEIGHT TARGET

The initial weight target was 500 g for the whole system (recorder and its installation kit).
The weight of the recorder developed is less than 400 g.
Due to the length of the wirings, the added sensors, the mechanical parts that needed to be implemented and added to the installation kit, the weight of the installation kit is around 1,700 g.

So the weight target of 500 g for the whole system has not been achieved.
In spite of this exceeded weight, the moment of the system has a negligible effect on the helicopter balance.

In any case, during flight trials, the weight of the system will be part of the questions that will be raised to the users we will interview.

6.2.7.6 COST OF THE INSTALLATION / MANPOWER

The cost of the installation is given in terms of duration of work. The installation requires 16 hours of work for an aircraft equipment engineer and 4 hours for a sheet metalworker.
These durations are given for R22 and R44 and might be different for other piston engine helicopters.

6.2.7.7 GROUND STATION SOFTWARE COSTS

The Ground station software of the Prototype system is part of the system price.
Each operator already uses a computer. So no additional one is necessary to install the GSS and no additional cost is generated.

6.3 STEP 3: MANUFACTURING AND INSTALLATION OF THE SYSTEM

6.3.1 OVERVIEW

The R22 helicopter is approved CS27 category.
So the embedded parts must also be approved CS27 category and AC27 MG15 guide for HUMS with the following items:

CS27_29 Amdt. 1:	Empty weight and corresponding centre of gravity
CS27_301 Amdt. 1:	Loads
CS27_303 Amdt. 1:	Factor of safety
CS27_305 Amdt. 1:	Strength and deformation
CS27_561 Amdt. 1:	Emergency landing condition, general
CS27_607 Amdt. 1:	Fasteners
CS27_609 Amdt. 1:	Protection of structure
CS27_611 Amdt. 1:	Inspection provisions
CS27_1301 Amdt. 1:	Function and installation
CS27_1309 Amdt. 1:	Equipment, systems, and installations
CS27_1322 Amdt. 1:	Warning, caution, and advisory lights
CS27_1351 Amdt. 1:	Electric systems, General
CS27_1357 Amdt. 1:	Circuit protective devices
CS27_1365 Amdt. 1:	Electric cables
CS27_1367 Amdt. 1:	Switches
CS27_1501 Amdt. 1:	Operating Limitations And Information, general
CS27_1529 Amdt. 1:	Instructions for Continued Airworthiness
CS27_Appendix A Amdt. 1:	Preparation of Instructions for Continued Airworthiness
Advisory Circular “AC 27 1B Chg 1, AC 27 MG 15”: Airworthiness approval of rotorcraft health usage monitoring system (HUMS)	Intent declaration Installation Credit validation Instructions for Continued Airworthiness (ICA) and Controlled Introduction to Service Criticality determination Mitigating action Ground Based Equipment Installation

Table 5 - FAR 27 and CS27 certification compliance

The embedded parts comports low risk for the helicopter security.

Hardware is designed to avoid the possibility of instrument perturbations by faulty electronic components. Only wires, connectors, printed circuits could induce instrument perturbations by faulty electrical insulation: the risk is the same that on all the mounted instruments.

Some risks are still possible with environmental conditions: so DO160E tests are performed, then helicopter non-disturbance tests are performed on ground and in flight - non influence tests and radio non interference tests -

Embedded software has few flight interactions because the lights are inactive by hardware and software only when the helicopter is detected in flight or when the top button is not pushed. So the embedded software has been developed with DO178B level D compliance as previous in ED112 specification.

Ground station software displays flight data which must help pilot and maintenance crew. So it is a tool without decision aspect. The ground station software is developed without DO178 compliance.

6.3.2 NON INFLUENCE TEST

Overview
The aim of this test is to demonstrate that the integration of the recorder in the aircraft doesn't perturb the instruments.
Measures are done for the following parameters if they are available:

Air carb temperature (CAT)	Engine rpm
Head cylinder temperature	Main Rotor rpm (NR)
Motor Oil Temperature	Chips Detector
Motor Oil Pressure	Warning alarm

Method:
For each parameter, the tests consist of measure the voltage of each acquired signal.
First, the measure is realized without recorder.
Then, the recorder acquisition input is replaced by an adjustable resistor on the concerned signal (refer to the following diagram).
To check the limits and evaluate the safety margin, the load is increased until a variation is observed on the instrument's indicator.
The same test is realized between the 0V (pin 37) and each parameters (positive and negative wire) to determine the influence threshold.
For this test, to keep safe the aircraft installation, remain the adjustable resistor higher than 10 KΩ.
After these tests, connect the recorder on the aircraft installation and note each recorded parameters on the engine run-up test sheet (appendix 1). For each parameter, press top button to make an event marker. If real time data are available, also note the read values on the laptop in the table.
After this engine run-up test, compare recorded values and read values on ground station.

6.3.3 RADIO NON INTERFERENCE TESTS PROCEDURE

These tests demonstrate that any radio equipment is affected by the system installed and by any functioning mode of this one.
Approved PART 145 organization domain A3 and rating C3 (radio navigation, radio communication and emergency).

Tests are performed with mobile test bench, or other compliant means, procedures or methods if equipment cannot be tested with the test bench.

The radio tests are performed on the following equipments:

- VHF Com
- HF Com
- VOR
- ILS Localizer
- ILS Glide Slope
- Marker
- Radio compass ADF
- DME
- ATC Transponder
- Radio altimeter
- GPS

Ground Tests
All radio non interference tests have to be performed by comparison between results obtained recorder OFF and results obtained recorder ON.
No perturbation must be received on the whole channel range of the different radios.
No interference must be identified on the parameters due to the functioning recorder.

Flight Tests
The recorder must be operating during all tests and measures listed here after.
Most of these measures aim at checking that there is no perturbation at the limit of range of the equipments.
The limit of range is given by the radio electric horizon of the aircraft.
Radio electric horizon $\mathbf{HR = 1{,}23\ \sqrt{A}}$ (HR in Nautical Miles and Altitude in ft)

6.3.4 VALIDATION

The most functionalities of the specification have been tested on test bench. But it is necessary to check the recorder on helicopter with the helicopter sensors.

The recorder is first checked in flight by compare of instruments readings and records identified by top event.
Flight time, messages, events, exceedances are also checked.

Check for vibration analysis is performed by comparing the measures of the recorder and those of the Vibrex as described in the maintenance manual.

After acquisitions phase, Fast Fourier Analysis is performed on ground station for recorder samples and on Vibrex for maintenance operation. And ray frequencies and levels - for ray level>0.02IPS - are compared between the means.

6.3.5 RESULTS OF DATA ACQUISITION TESTS

The validation allowed demonstrating the correct operations of the system. The flights parameters are completely coherent and the correct values for the levels reached in flight without reaching the limits.

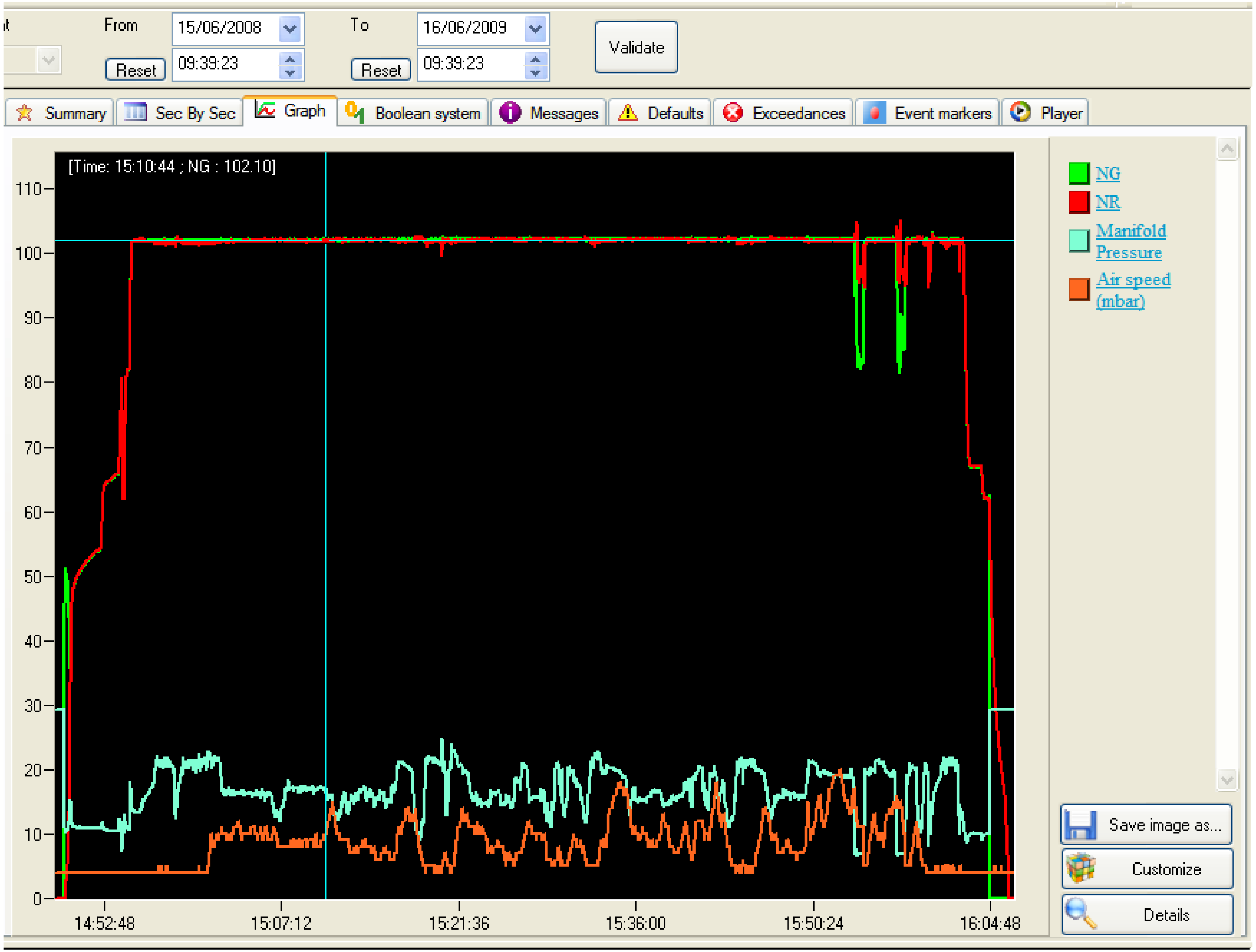


Figure 9 - Flight graph

These following messages are standard messages for flights:

- Messages at 14H48mn50s are for standard recorder power on.
- Then messages for a flight until the first landing which is not a real landing but an autorotation trial as we can see on the flight graph above. We can also remark a low engine RPM exceedance without low rotor RPM exceedance.
- Start fault light flash indicates a light is flashing on: the exceedance one because helicopter is seen on ground - not enough collective pitch and the collective up switch is off during the autorotation trial.
- Another autorotation trial is shown with another landing/ taking off messages.
- Then the real landing and the stop of engine and power.

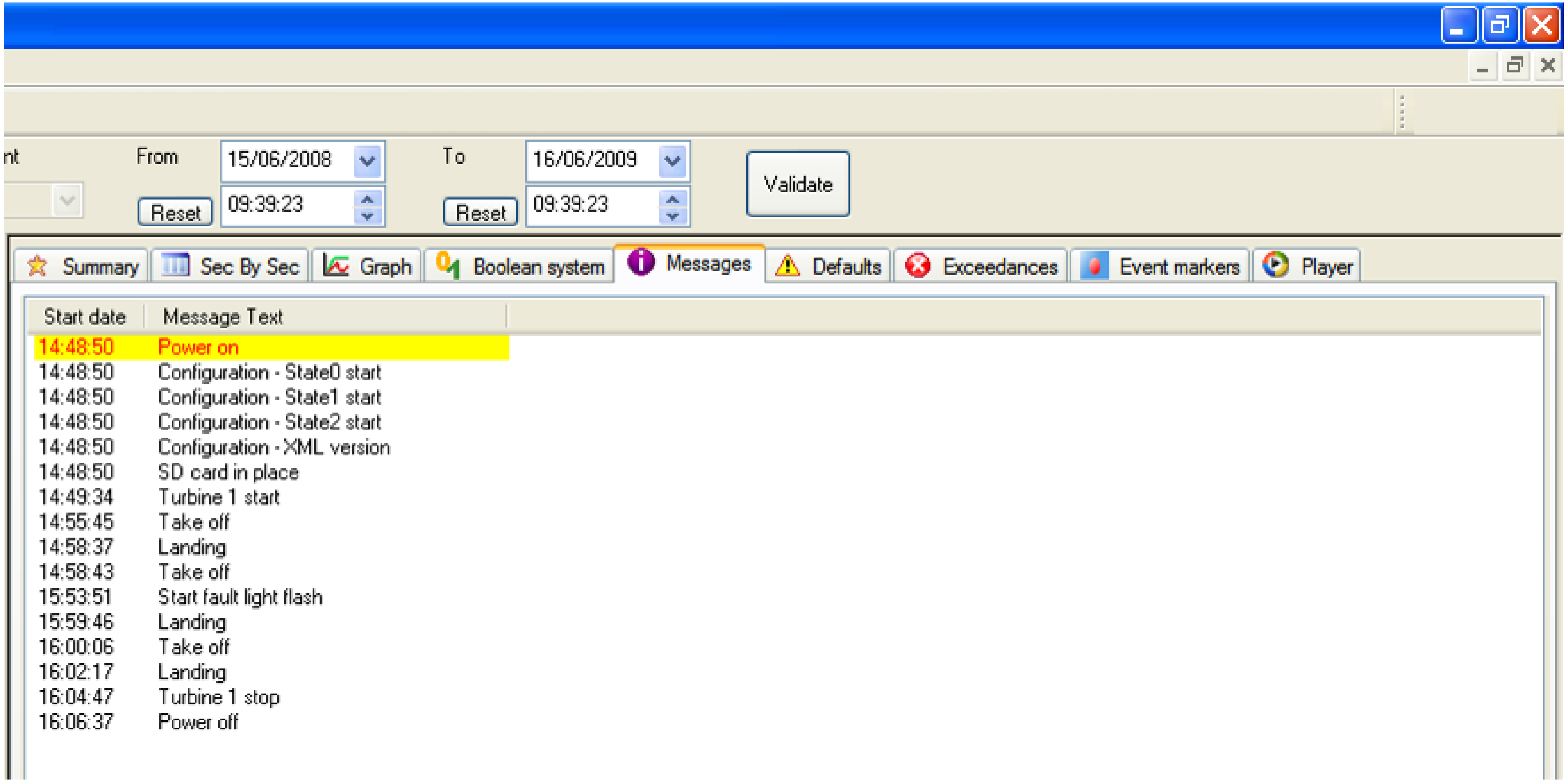


Figure 10 -Messages table

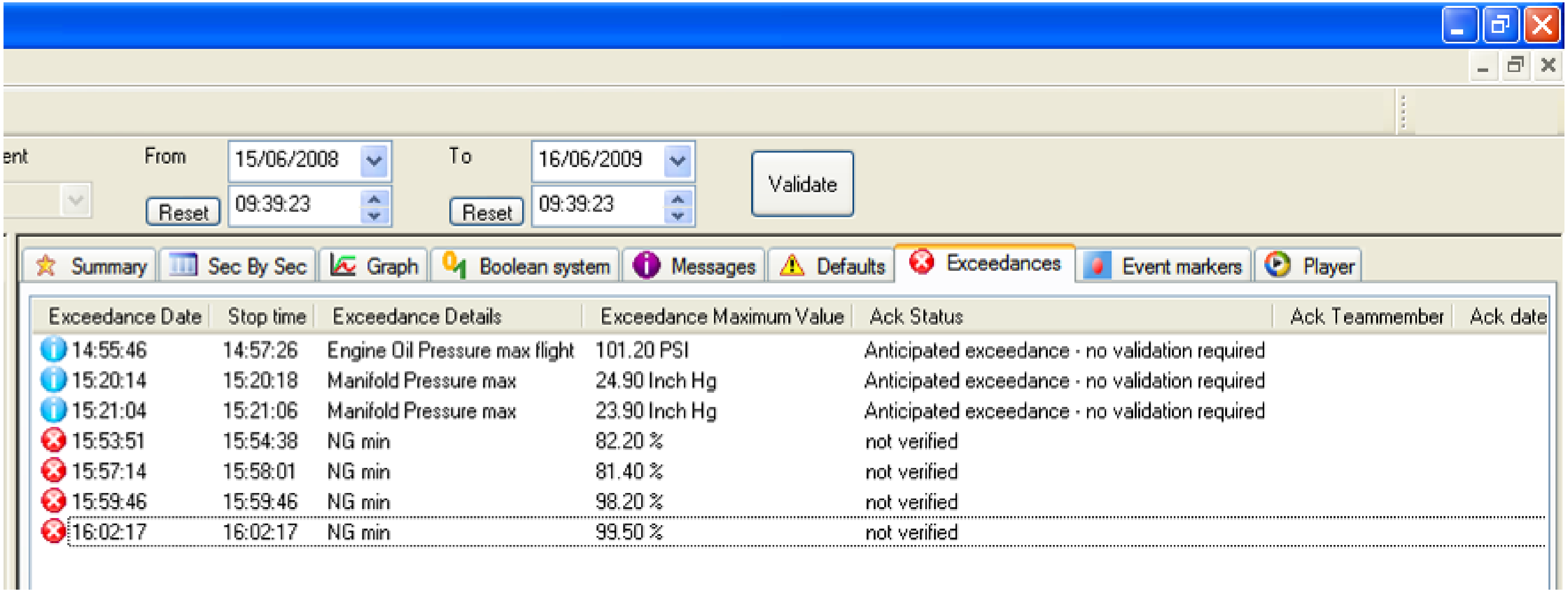


Figure 11 -Exceedances table

6.3.6 NON INFLUENCE TEST RESULTS

Parameter	Recorder Input Impedance	Influence threshold Load	Conclusions
CAT	240 KΩ	50 KΩ	O.K.
Head cyl. T°	10 MΩ	50 KΩ	O.K.
ENG RPM	〉160 KΩ	10 KΩ	O.K.
NR	〉160 KΩ	10 KΩ	O.K.
T° oil ENG	240 KΩ	50 KΩ	O.K.
P oil ENG	〉10 MΩ	10 KΩ	O.K.
Warning alarm	〉1 MΩ	10 KΩ	O.K.
Chip detector	〉1 MΩ	10 KΩ	O.K.

This table summarizes the influence tests results in order to compare the load's threshold giving an effect on an indicator and the corresponding recorder load input.

These tables summarize the influence tests results in order to compare the load's threshold giving an effect on an indicator and the corresponding recorder load between 0V and each parameter input.

Parameter	Recorder Input Impedance	Influence threshold Load	Conclusions
CAT+	120 KΩ	50 KΩ	O.K.
CAT-	120 KΩ	10 KΩ	O.K.
Head cyl. T°+	〉200 KΩ	50 KΩ	O.K.
Head cyl. T°-	〉200 KΩ	10 KΩ	O.K.
ENG RPM +	〉300 KΩ	10 KΩ	O.K.
ENG RPM -	〉300 KΩ	10 KΩ	O.K.
NR +	〉300 KΩ	10 KΩ	O.K.
NR -	〉300 KΩ	10 KΩ	O.K.
T° oil ENG +	120 KΩ	50 KΩ	O.K.
T° oil ENG -	120 KΩ	10 KΩ	O.K.
P oil ENG +	〉200 KΩ	10 KΩ	O.K.
P oil ENG -	〉200 KΩ	10 KΩ	O.K.

All the tests shown a large safety margin and give the insurance that there is no influence of the recorder on the indicated parameter.

6.3.7 GROUND TEST RESULTS

6.3.7.1 VHF COMMUNICATIONS (118.000 MHZ TO 136.975 MHZ)

<u>Sensitivity Measure</u>

Recorder ***OFF*** *VHF COM 1*

Frequency /MHz	*118.000*	*126.000*	*136.000*
Sensitivity /dbm	*-64 dB*	*-60 dB*	*-66 dB*

Recorder ***OFF*** *VHF COM 2*

Frequency /MHz	*118.000*	*126.000*	*136.000*

Sensitivity /dbm	*N.A.*	*N.A.*	*N.A.*

Recorder ***ON*** *VHF COM 1*

Frequency /MHz	*118.000*	*126.000*	*136.000*
Sensitivity /dbm	*-64 dB*	*-60 dB*	*-66 dB*

Recorder ***ON*** *VHF COM 2*

Frequency /MHz	*118.000*	*126.000*	*136.000*
Sensitivity /dbm	*N.A.*	*N.A.*	*N.A.*

6.3.7.2 VOR (108.000 TO 117.950 HZ)

Sensitivity Measure

Recorder ***OFF*** *VOR 1*

Frequency /MHz	*108.000*	*112.500*	*117.950*
Sensitivity /dbm	*-54 dB*	*-61 dB*	*-59 dB*

Recorder ***OFF*** *VOR 2*

Frequency /MHz	*108.000*	*112.500*	*117.950*
Sensitivity /dbm	*N.A.*	*N.A.*	*N.A.*

Recorder ***ON*** *VOR 1*

Frequency /MHz	*108.000*	*112.500*	*117.950*
Sensitivity /dbm	*-53 dB*	*-59 dB*	*-58 dB*

Recorder ***ON*** *VOR 2*

Frequency /MHz	*108.000*	*112.500*	*117.950*
Sensitivity /dbm	*N.A.*	*N.A.*	*N.A.*

6.3.7.3 ATC TRANSPONDER SYSTEM (1030 TO 1090 MHZ)

Measures of sensitivity and power

Recorder OFF	***ATC 1***	***ATC 2***
Power / W	*250*	*N.A.*
Sensitivity /dbm	*-75*	*N.A.*
Recorder ON	***ATC 1***	***ATC 2***
Power/ W	*250*	*N.A.*
Sensitivity/dbm	*-75*	*N.A.*

6.3.7.4 ILS LOCALIZER (108.100 TO 111.950 MHZ)

Sensitivity Measure

*Recorder **OFF*** *LOC 1*

Frequency /MHz	*109.100*	*110.550*	*111.900*
Sensitivity /dbm	*-53 dB*	*-56 dB*	*-59 dB*

*Recorder **OFF*** *LOC 2*

Frequency /MHz	*109.100*	*110.550*	*111.900*
Sensitivity /dbm	*N.A.*	*N.A.*	*N.A.*

*Recorder en **ON*** *LOC 1*

Frequency /MHz	*109.100*	*110.550*	*111.900*
Sensitivity /dbm	*-52 dB*	*-56 dB*	*-58 dB*

*Recorder en **ON*** *LOC 2*

Frequency /MHz	*109.100*	*110.550*	*111.900*
Sensitivity /dbm	*N.A.*	*N.A.*	*N.A.*

6.3.7.5 MARKER SYSTEM (75 MHZ)

Sensitivity Measure/dbm

Recorder OFF *MKR 1 & 2*

Modulation/Hz	*400*	*1300*	*3000*
Sensitivity MKR 1	*N.A.*	*N.A.*	*N.A.*
Sensitivity MKR 2	*N.A.*	*N.A.*	*N.A.*

Recorder ON *MKR 1 & 2*

Modulation/Hz	*400*	*1300*	*3000*
Sensitivity MKR 1	*N.A.*	*N.A.*	*N.A.*
Sensitivity MKR 2	*N.A.*	*N.A.*	*N.A.*

Sensitivity control in "Low", mode for indicators Mkrs lighting

6.3.7.6 ILS GLIDE SLOPE (328.60 TO 335.40 MHZ)

Sensitivity Measure/dbm

*Recorder **OFF*** *GLI 1*

Channel ILS/MHz	*110.550*	*109.100*	*111.900*
Freq. GLI/MHz	*329.450*	*331.400*	*331.100*
Sensitivity /dbm	*N.A.*	*N.A.*	*N.A.*

*Recorder **OFF*** *GLI 2*

Channel ILS/MHz	*110.550*	*109.100*	*111.900*
Freq. GLI/MHz	*329.450*	*331.400*	*331.100*
Sensitivity /dbm	*N.A.*	*N.A.*	*N.A.*

*Recorder **ON*** *GLI 1*

Channel ILS/MHz	*110.550*	*109.100*	*111.900*
Freq. GLI/MHz	*329.450*	*331.400*	*331.100*
Sensitivity /dbm	*N.A.*	*N.A.*	*N.A.*

*Recorder **ON*** *GLI 2*

Channel ILS/MHz	*110.550*	*109.100*	*111.900*
Freq. GLI/MHz	*329.450*	*331.400*	*331.100*
Sensitivity /dbm	*N.A.*	*N.A.*	*N.A.*

6.3.8 FLIGHT TEST RESULTS

6.3.8.1 ADF, RADIO COMPASS SYSTEM (190-850 AND 1615-1799 KHZ)

Precision on several local markers is not affected by the recorder operation.
*(Relative bearing and audio identifier)*____
______**PASSED**

6.3.8.2 DME SYSTEM (962 TO 1215 MHZ)

Precision on several local markers is not affected by the recorder operation.
*(Relative bearing and station identifier)*______________________________________
______**N.A.**

6.3.8.3 ATC TRANSPONDER SYSTEM (1030 TO 1090 MHZ)

The functioning recorder must not affect identification____________________
______**PASSED**

6.3.8.4 HF COMMUNICATIONS (2 TO 30 MHZ)

Several channels are tested among available "HF Channel"
while the recorder is running ____
______**N.A.**

6.3.8.5 GPS SYSTEM (1575.42 AND 1227.60 MHZ)

GPS reception must not be perturbed by the recorder.
*No satellite loss or position error must occur*__________________________________
______**N.A.**

6.3.8.6 AUDIO SYSTEMS

On board intercom, Public Address and all other communication facilities
*must not be perturbed by the recorder operation*______________________________
______**PASSED**

6.3.8.7 RADIO ALTIMETER

No interference must be identified on radio altimeter indication,
because of the recorder operation ____
______**N.A.**

6.3.8.8 OTHER EQUIPMENTS INCLUDED IN THE AIRCRAFT CERTIFICATION

No interference must be identified on the parameters due to the recorder operation
______**PASSED**

6.3.8.9 CONCLUSION

All non interference tests on ground and in flight have been successfully passed.

6.3.9 FLIGHTS RESULTS

AIRCRAFT TYPE		SERIAL		CALL SIGN		DATE	Test sheet N°
ROBINSON R44 RAVEN I		1168		I-SNEK		31/10/2008	1
OAT		P0/QFE		ZP		LOCATION	Airport altitude
Read	10°C	Read	979 mBar	Read	987 ft	CAIOLO	860 ft
Recorded	12.3°C	Recorded	972 mBar	Recorded			

ENGINE STARTING TIME	Read	20:20	Recorded	20:20	ENG oil P max	Read	78 PSI	Recorded	81 PSI

PARAMETERS	Top button	INSTRUMENTS VALUES	REAL TIME VALUES	RECORDED VALUES
ENG RPM	2	70 %	N/A	69.8 %
ENG RPM	16	102 %	N/A	101.9 %
ENG OIL P	7	85 PSI	N/A	80 PSI
ENG OIL T	5	150 ° F	N/A	163 ° F
CHT	4	220 ° F	N/A	226 ° F
MAP	10	14 inHg	N/A	13.64 inHg
CAT	3	18° C	N/A	17° C
MAP	1	12 inHg	N/A	10.33 inHg
ENG RPM	6	70 %	N/A	72.4 %
CAT	8	-3 °C	N/A	-5 °C
CAT	9	10 °C	N/A	9 °C
MAP	11	20 inHg	N/A	19.99 inHg
MAP	12	23.5 inHg	N/A	23.86 inHg
ENG OIL T	13	180 °F	N/A	195 °F
CAT	14	15 °C	N/A	13 °C
CHT	15	310 °F	N/A	317 °F

ENG SHUT-DOWN TIME				Remarks :
Read	20:40	Recorded	20:39	

6.3.10 VIBRATIONS RESULTS

For each acquisition group (5 seconds), the ground station calculates the vibration level filtered on the main rotor frequency at hovering as described in the maintenance manual.

This output is the only one which can be given to the customer because in the maintenance manual and validation, a spectral analysis is also performed to correlate the significant ray with frequencies of rotating mechanical items of helicopter.
We have also to check if the position of the accelerometer on the cabin allows a pertinent measure of the element.

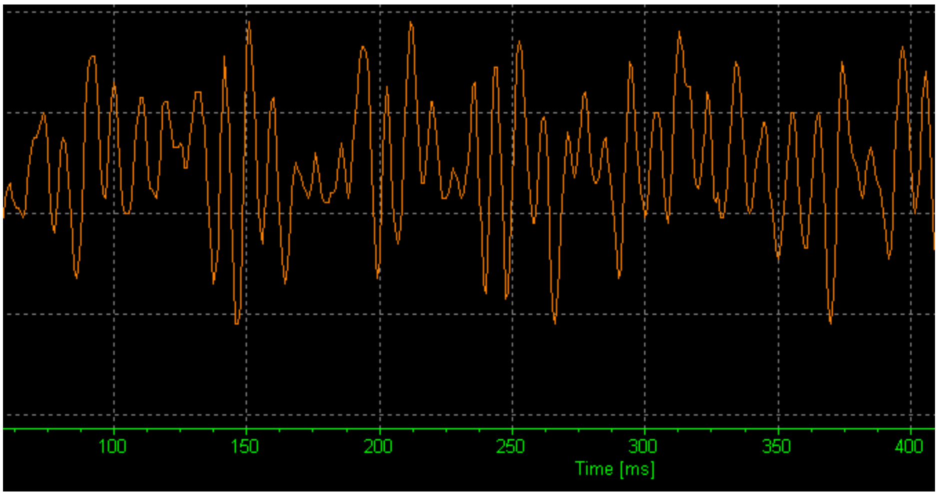


Figure 12 - Analogic signal acquired from the accelerometer (time domain)

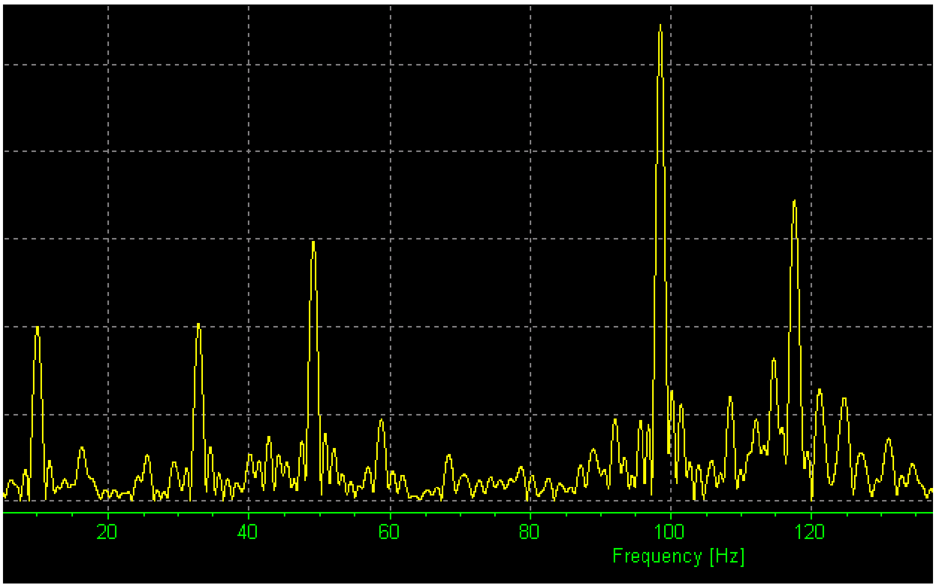


Figure 13 -Spectral analysis performed by the ground station (frequency domain) (Each ray represents a filtered vibration level)

Comparison between recorder system measures and VIBREX measures on a Robinson 44 Raven 1:

		Recorder measures		Vibrex measures	
	RPM	Ray frequency (RPM)	accelerometer (IPS)	Frequency (RPM)	level (IPS)
		290	0,04	300	0,04
Rotor RPM	403				
Rotor RPM x2	805	800	0,25	810	0,23
		1150	0,02	1140	0,02
Engine RPM	2682	2660	0,1	2700	0,1
Engine RPM/2	1341	1330	0,1	1350	0,11
Upper sheave	2087	2070	0,06	2100	0,1
Tail rotor	2396				
Tail rotor x2	4792	4780	0,04	4830	0,07
		3170	0,03	3210	0,02
		7980	0,08	8070	0,09

All the vibrations frequencies exist and are enough close with the two means of measurement.
We can explain some differences because the two acquisitions were not performed exactly at the same time.

Measures on a R44 Raven 2:

	RPM	Hz	vibration level (IPS)
NR	404	6,7	
NR x2	808	13,5	1,02
Engine	2691	44,9	0,06
Engine /2	1346	22,4	0,17
Engine x3/2	4037	67,3	0,05
Engine x3	8074	134,6	0,12
Upper sheave	2094	34,9	0,05
Tail rotor	2404	40,1	0,17
Tail rotor x2	4808	80,14	0,06

It is interesting to correlate measures with different helicopter frequencies.

6.4 STEP4: FLIGHT TRIALS RESULTS

The flight trials results are analyzed in this section. 102 hours of operating time of which 85 flight hours have been performed on R 44.

The difference between the operating time and the total flight time comes from the fact that the flight time only takes into account the time between the aircraft take off and landing. The recording starts when the engine starts up.
The on ground operating time is divided between:

- The power checks.
- The engine starting duration.

☑ Exceedances

All the on ground and in flight exceedances are notified when landed thanks to a recorder exceedance flashing light. The exceedances are detailed on the ground station.

Compared with the total flight hours recorded, the number of exceedances is not excessive. We note that the main exceedances refer to rotor and engine RPM due to the piston engine specificity.

The recorded data give an accurate aircraft configuration during the exceedance and an accurate value as shown on figure.15.
Appropriate mechanical check can be performed according to these data.

In the following example, the Ng min went down to 84, 98% and 81, 02%.
We could consider these values as normal values during an autorotation exercise.

10:13:53	10:13:54	NG min	84.98 %	not verified
10:13:57	10:14:01	NG min	81.02 %	not verified

Figure 14 – Exceedance Window

The recorded data give the possibility to analyse the flights afterwards.
The exceedance is notified on ground on the recorder box by lighting a red indicator and on the ground station by an appropriate icon.

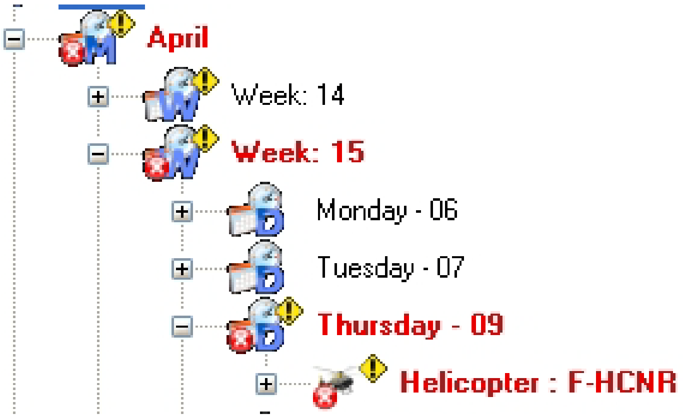


Figure 15 – Usage Window

☑ Data and curves

The aircraft parameters can be analysed thanks to data and curves. This allows having a better understanding of the circumstances of the exceedances and of the flight details.

After the analysis of the recorded data, we will highlight the curves which are representative of the different operating conditions.

- Start up

A start-up could be easily analyzed in order to detect abnormal behaviour.
On the following figure, we can analyze a good starting procedure.
On the blue curve (Fig.16-1), the battery is descending due to the power request in order to start the engine and just after, the generator supplies the battery which induces a steady curve.
The union between the Nr and Ng curves (Fig.16-2) shows us the good engage of the clutch in accordance with pilot's operating handbook time, temperature and pressure specifications.
The different temperature and pressure normally rise to their nominal functioning value.

Figure 16 – Start up

- Standard Navigation flight

The following curve had been recorded during an air navigation flight.
The purple curve (ZP) shows us the aircraft altitude during the flight.
The head cylinder temperature is normal (orange curve).
The Ng (white curve) and Nr (green curve) are stabilized during all the flight.
By analyzing this graph, all the different data are steady and we could easily check that the flight had been performed without any problem or exceedances.

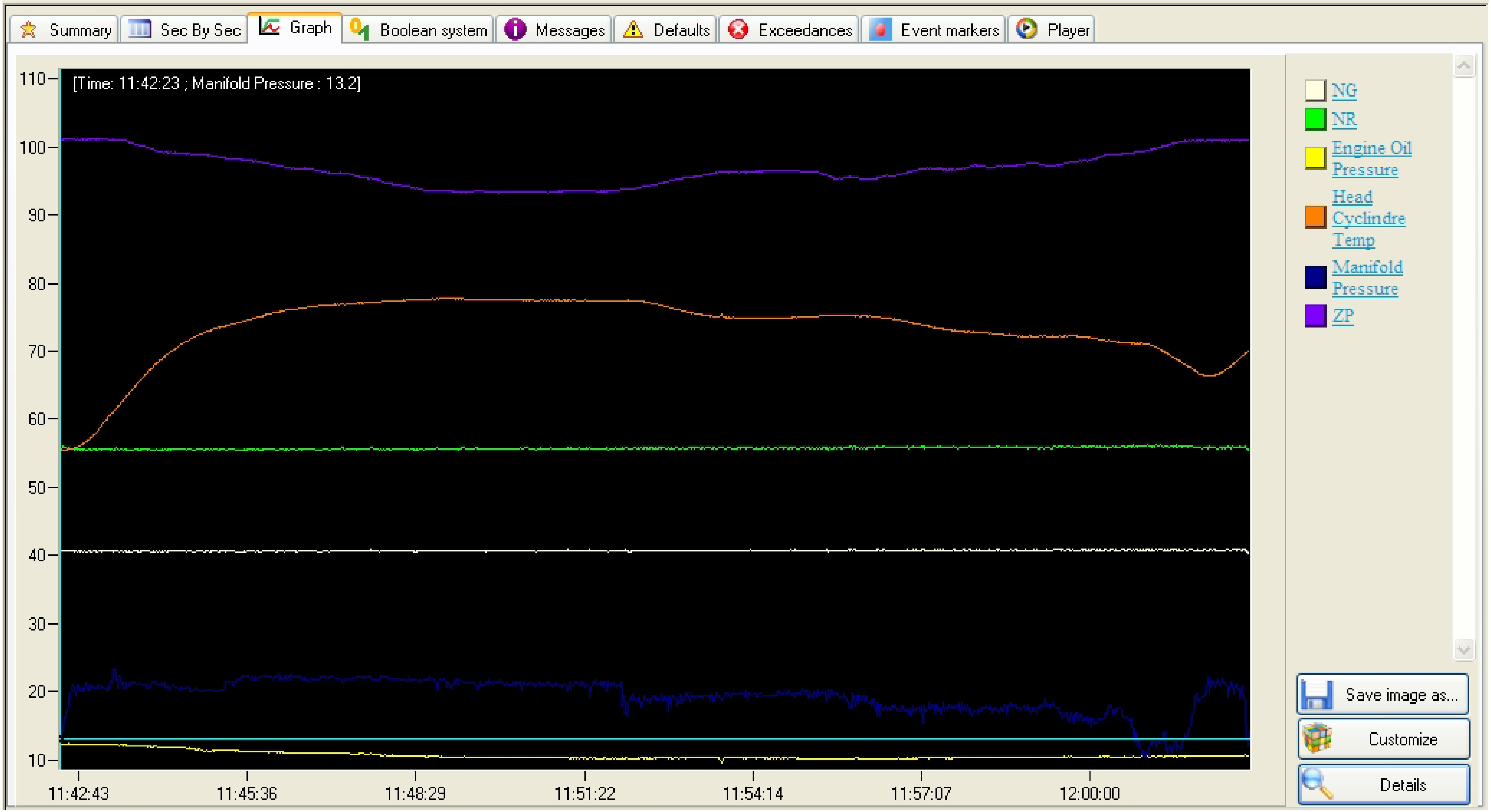


Figure 17 – Navigation flight

- Autorotation training

On the following figure, the pilot is performing some autorotation exercises. We could remark that the Ng (Fig.18-1) is passing the inferior limit. This is a normal exceedance due to a non powered flight during the autorotation final. The Ng recovers a normal value when the autorotation is completed.
The Boolean graph (Fig.19) confirms this exceedance.

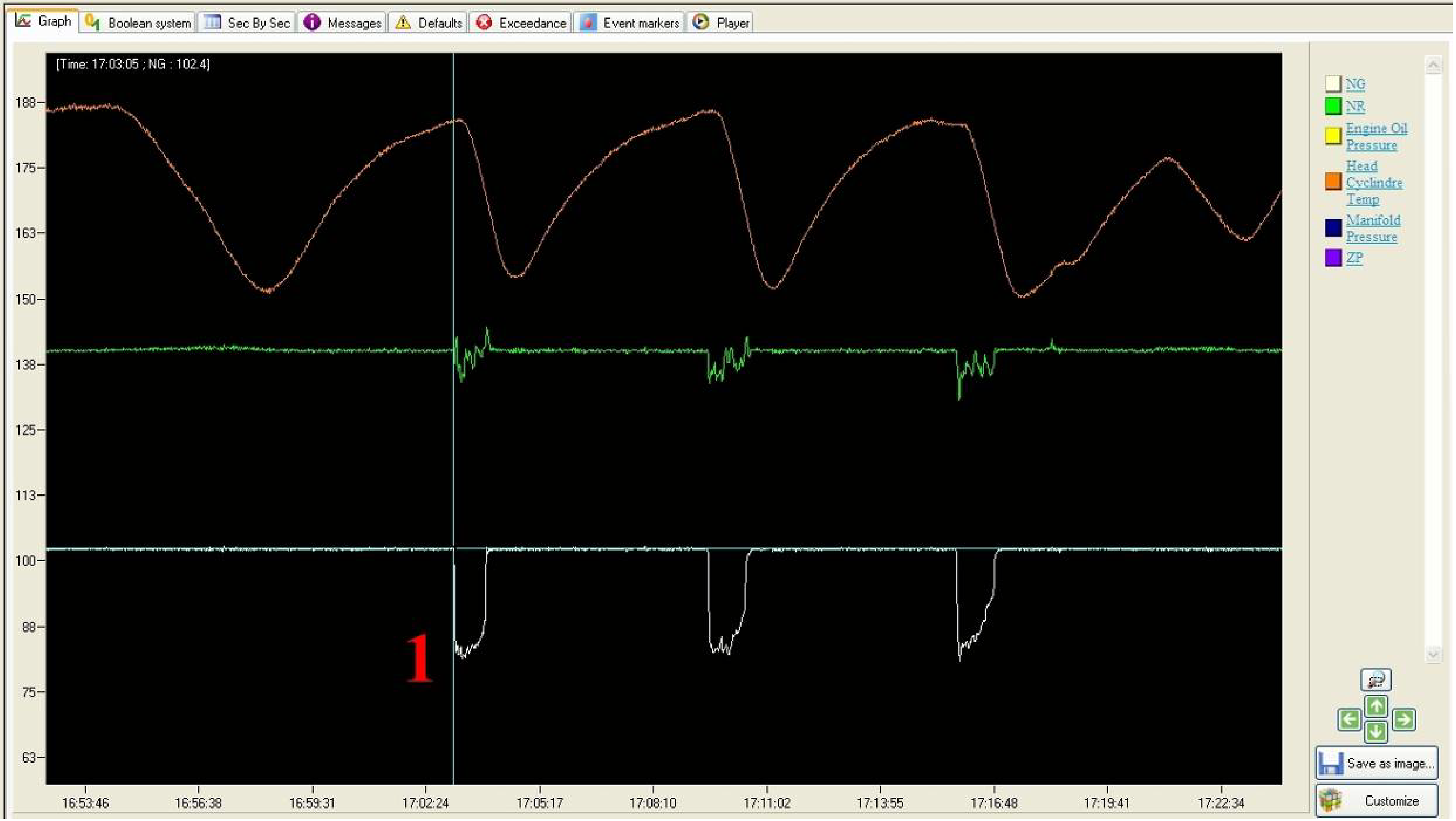


Figure 18 – Autorotation 1

Figure 19 – Boolean Autorotation 1

The following figure shows us an instruction flight.
During, this flight, the instructor is teaching autorotation with a motorized short final.
A series of three autorotation exercises is performed. They are materialized by the increasing Zp (Fig.20-1) on the upper purple curve which demonstrates that the aircraft was in a quick descent.
Moreover, the manifold pressure (blue curve, Fig.20-2) is decreasing. This indicates a reduction of the engine power. Accordingly, the head cylinder temperature (orange curve, Fig.20-3) decreases too.
If we pay attention to the green curve (Fig.20-4) which represents the Nr during the autorotation, we could easily remark that the Nr stabilization is very difficult to perform due to the aircraft specificity.

On the first exercise, indicated by the red circle, the Nr decreases under its lower limit. This analysis shows the difficulty of an autorotation exercise on these helicopters due to the small inertia of the blades. The blades of these aircrafts can be very light because the aircraft is very light. Therefore, the inertia is small.
This must alert the instructor.
A particular attention must absolutely be paid on the Nr during the autorotation.

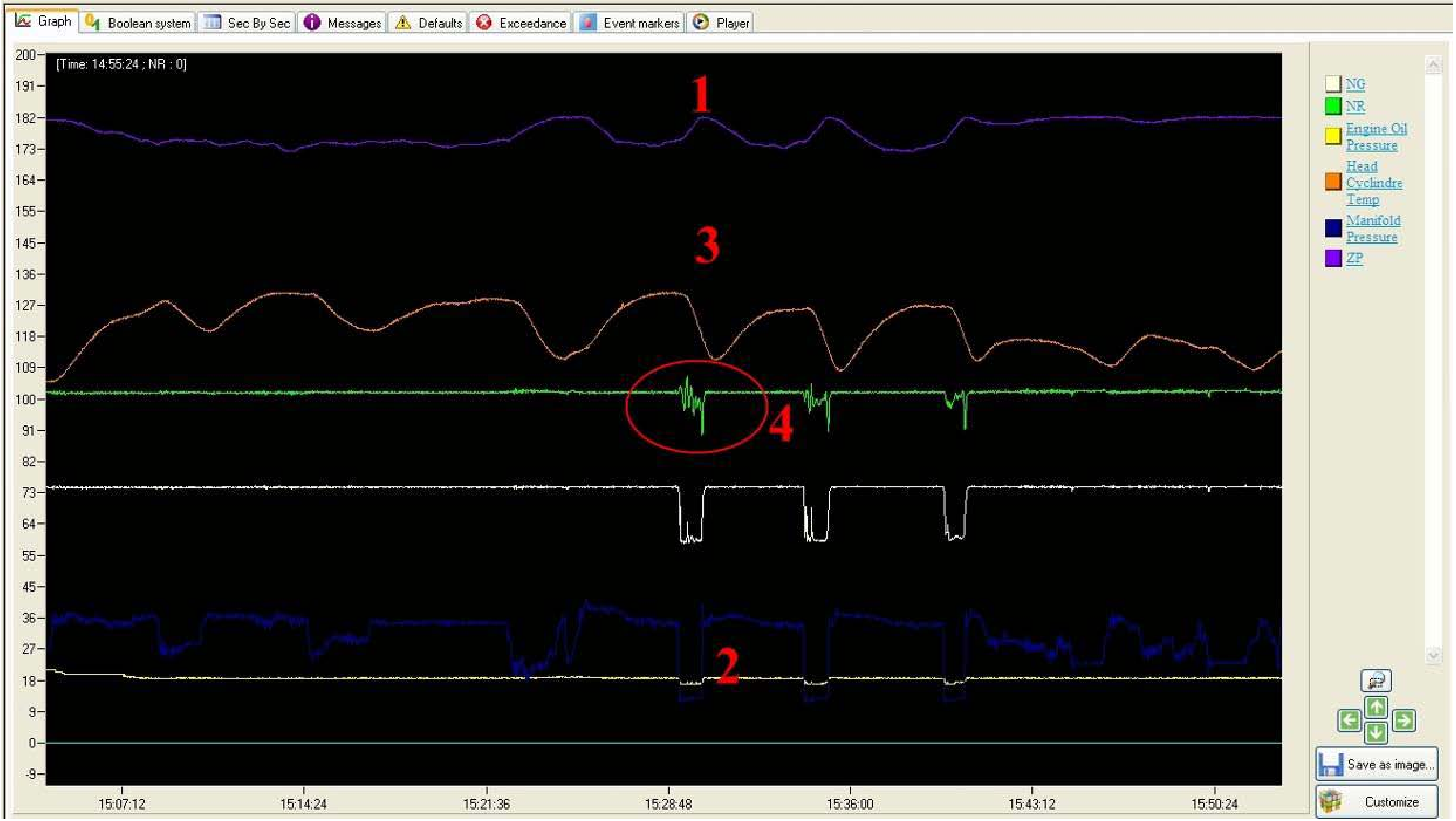


Figure 20 – Autorotation 2

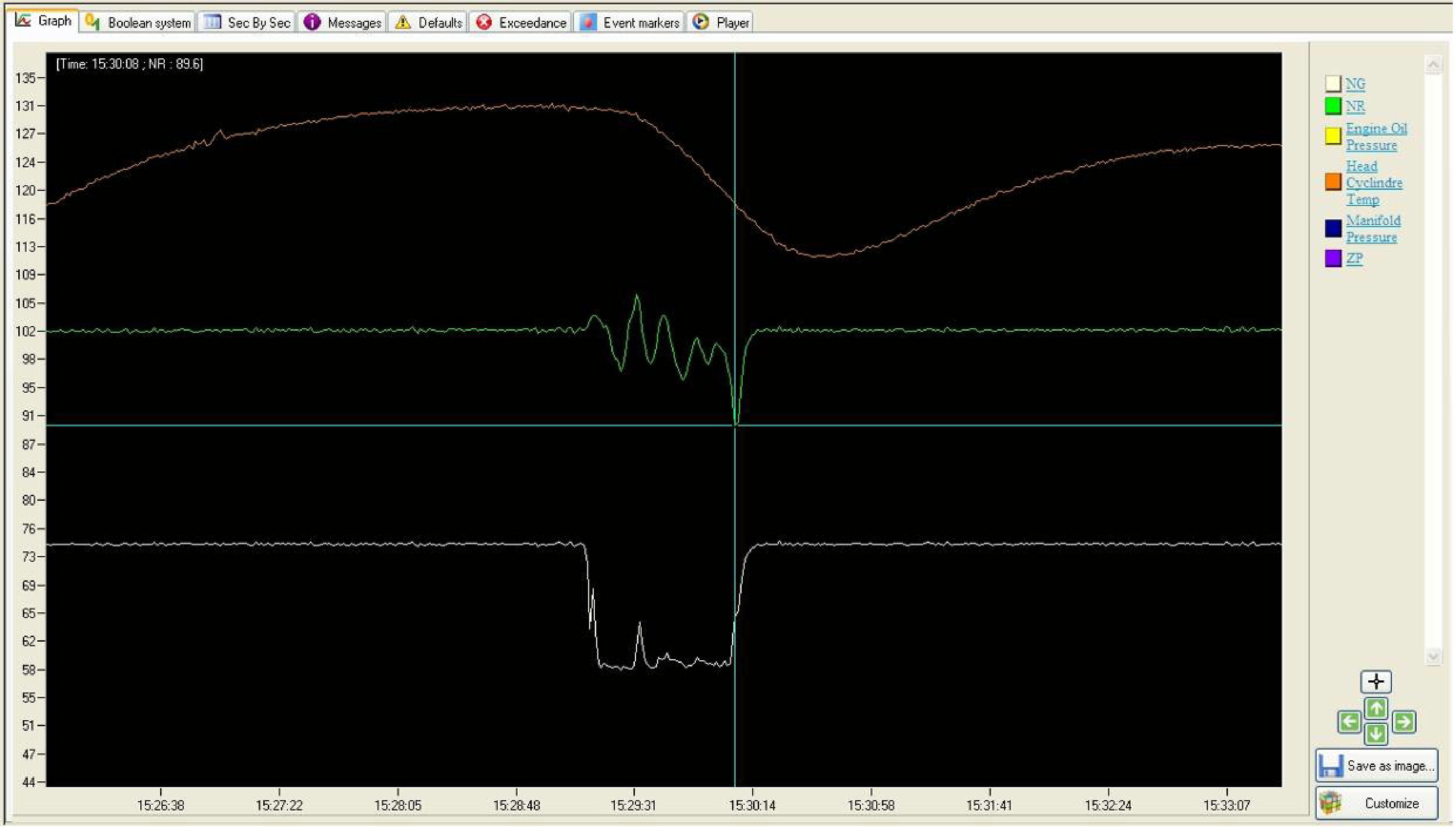


Figure 21 – Zoom of Figure 20

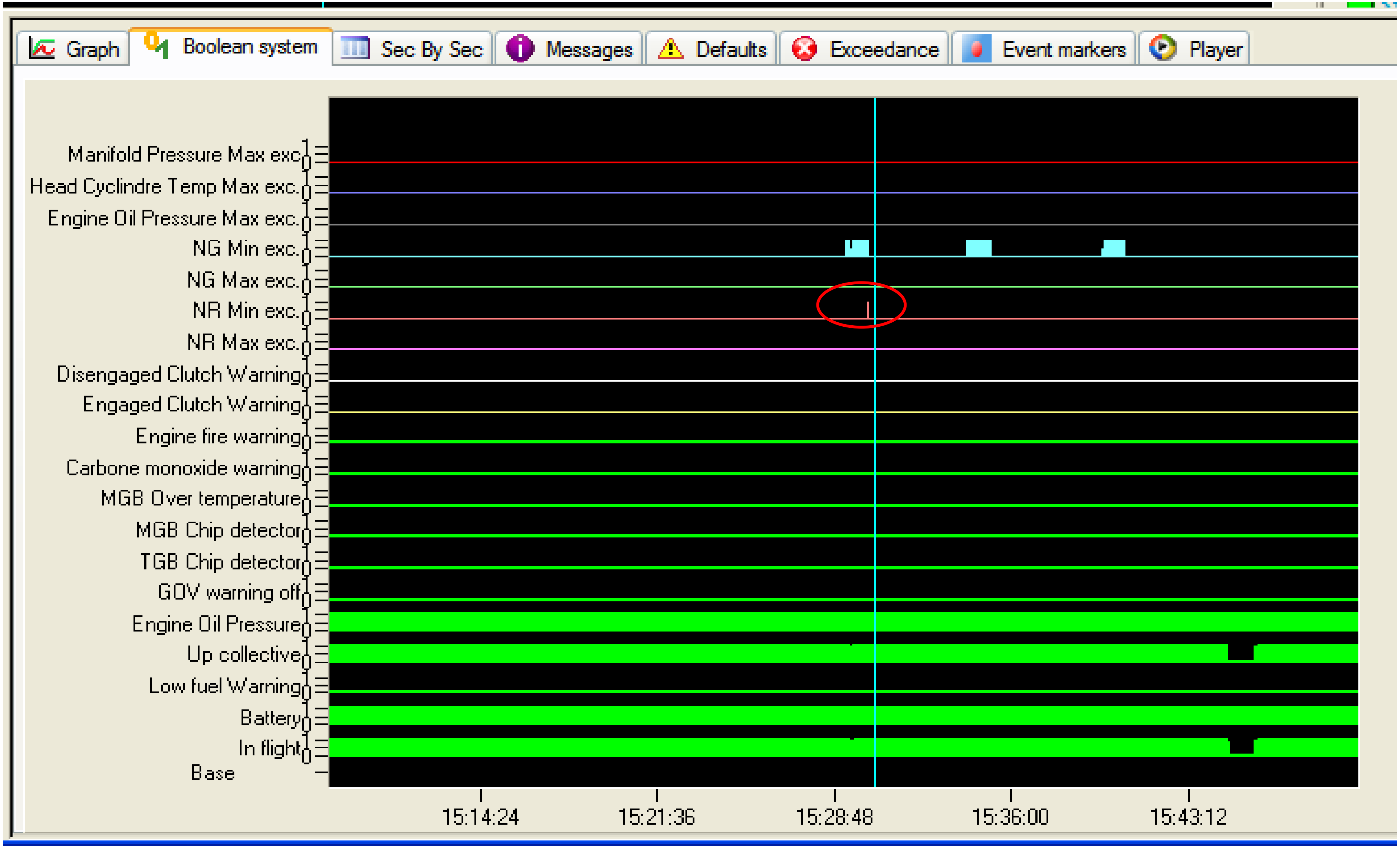


Figure 22 – Boolean Autorotation 2

- Final approach

On this graph, the pilot is performing a final approach which is materialized between the two red lines. The purple curve (Zp) slowly increases. This means that the aircraft is on a slight glide. The manifold pressure (blue curve) and the cylinder head temperature (orange curve) decrease because of the backoff.
We could remark that in very short final, the Nr (green curve) and the Ng (white curve) suddenly decrease and they pass beneath the minimal limit.
This is due to a quick action on the collective stick in short final near the ground effect. This is also shown by the sudden raise of the manifold pressure.
The governor cannot properly regulate and this leads to a Ng and consequently a Nr decreasing.

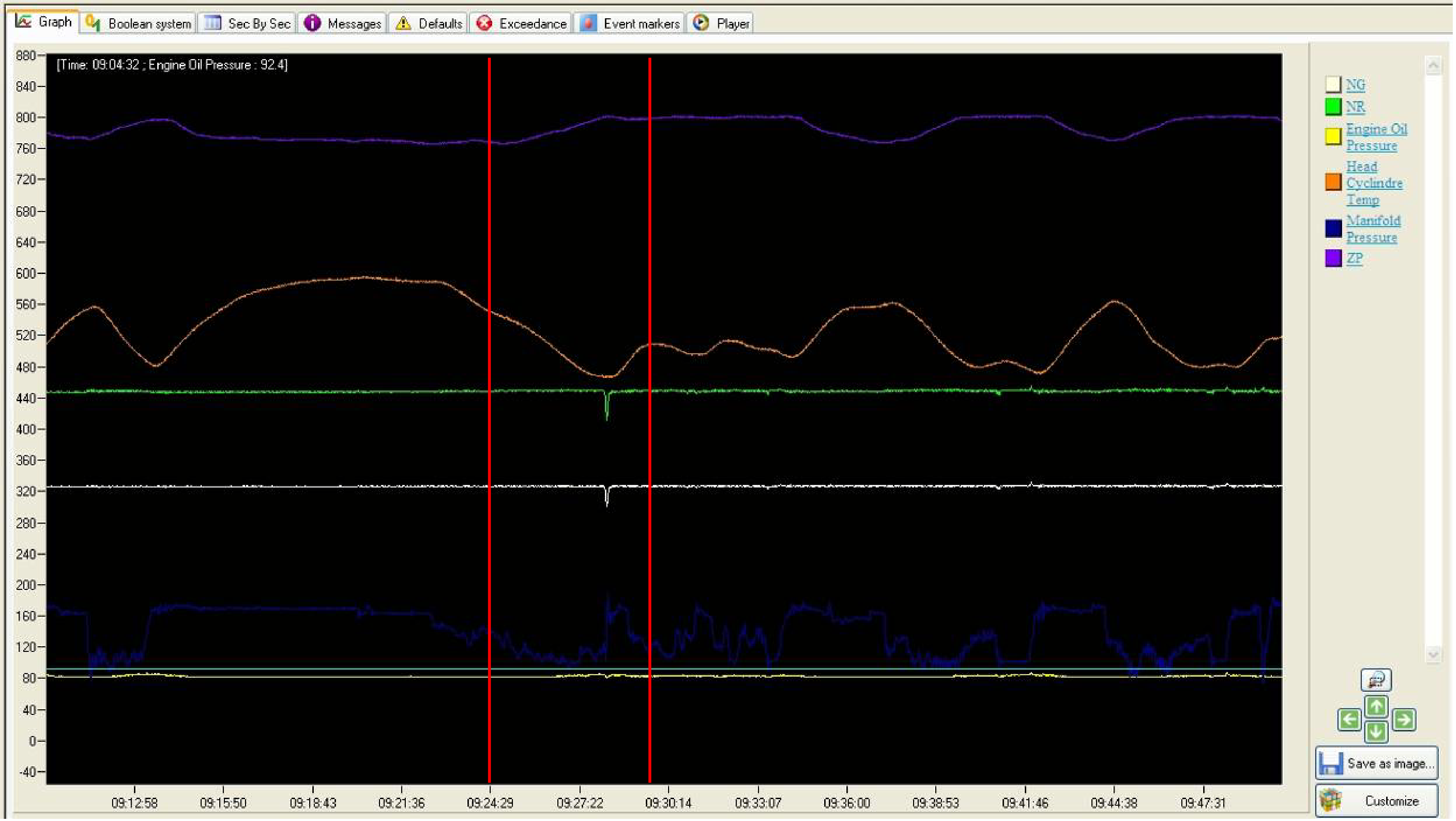


Figure 23 – Approach

Regarding to the seconds per seconds (fig.24), we could see that the different RPM are maintained under the limit during 6 seconds.
This allows warning the pilot on his actions in order to improve the further approaches. The interest for flight safety is indisputable.

Summary | Sec By Sec | Graph | Boolean system | Messages | Defaults | Exceedances | Event markers | Player

AbsoluteTime	NG	NR	Engine Oil Pressure	Head Cyclindre Temp	Manifold Pressure	OAT	Tcomp	Carburetor air temp	ZP	Air speed	Engine Oil Temp	Internal Temp
09:28:05	102.2	102.1	84.7	293	14.3	18.5	23.5	0	1000	1	193	34
09:28:06	102.1	102	84.6	291	14.7	18.6	23.5	0	1000	1	193	34
09:28:07	102.2	102.1	84.8	292	14.5	18.6	23.5	0	1000	1	193	34
09:28:08	102.1	102	84.6	292	15	18.6	23.5	0	1001	1	192	34
09:28:09	102	101.9	84.7	292	15.8	18.6	23.5	0	1000	0	192	34
09:28:10	102	101.9	85	292	15.8	18.6	23.5	0	1001	0	193	34
09:28:11	99.9	99.9	82.8	292	12.8	18.6	23.5	0	1000	0	193	34
09:28:12	96.8	96.8	82.3	292	13.1	18.7	23.5	0	1001	0	193	34
09:28:13	95.2	95	82.7	292	16.7	18.7	23.6	0	1002	0	192	34
09:28:14	93.8	93.6	80.6	292	20.9	18.7	23.6	0	1001	0	193	34
09:28:15	96.1	95.6	82.3	292	22.7	18.7	23.6	0	1002	0	192	34
09:28:16	98.3	97.9	82.3	292	23.6	18.8	23.6	0	1001	1	192	34
09:28:17	100.6	100.3	82.5	292	21.6	18.9	23.6	0	1001	1	193	34
09:28:18	101.5	101.2	83.2	292	19.9	18.9	23.6	0	1001	1	194	34
09:28:19	101.5	101.3	84.1	292	18.7	18.9	23.6	0	1000	1	193	34
09:28:20	101.7	101.4	83.5	291	20.5	18.9	23.6	0	1001	1	193	34
09:28:21	101.7	101.3	83.9	293	20.6	18.9	23.6	0	1001	1	193	34
09:28:22	101.9	101.6	84.6	291	20.1	19	23.6	0	1002	1	193	34
09:28:23	102.1	101.8	84.5	292	20.3	19	23.6	0	1001	1	193	34
09:28:24	102.5	102.2	85	291	19	19.1	23.6	0	1000	1	193	34
09:28:25	101.7	101.4	84.6	292	19.7	19.1	23.6	0	1002	1	192	34
09:28:26	102.2	101.9	84.4	292	20.6	19.2	23.6	0	1002	1	192	34
09:28:27	102.1	101.9	84.7	293	19.9	19.3	23.7	0	1002	1	192	34
09:28:28	101.9	101.6	84.7	292	20.6	19.3	23.7	0	1000	2	192	34
09:28:29	102.2	101.9	84.2	293	20.3	19.3	23.7	0	1001	2	192	34
09:28:30	102.2	101.9	84.3	293	20.2	19.3	23.6	0	1000	2	192	34
09:28:31	101.9	101.5	84.2	293	20.7	19.3	23.7	0	1000	2	192	34
09:28:32	102.2	101.8	84.6	294	20.9	19.3	23.7	0	1000	2	192	34

In Flight   Air Ground Switch

Export to Excel...

Figure 24 – Approach sec by sec

- Landings

Thanks to the Boolean curves we could accurately enter in an account the total landings of the aircraft.
The landings are notified on each flight thanks to the “patin” line.
On the following figure, we can note four landings during the flight.
Based on the same method, we can immediately note an exceedance during the flight. In this case, any exceedance can be noted.

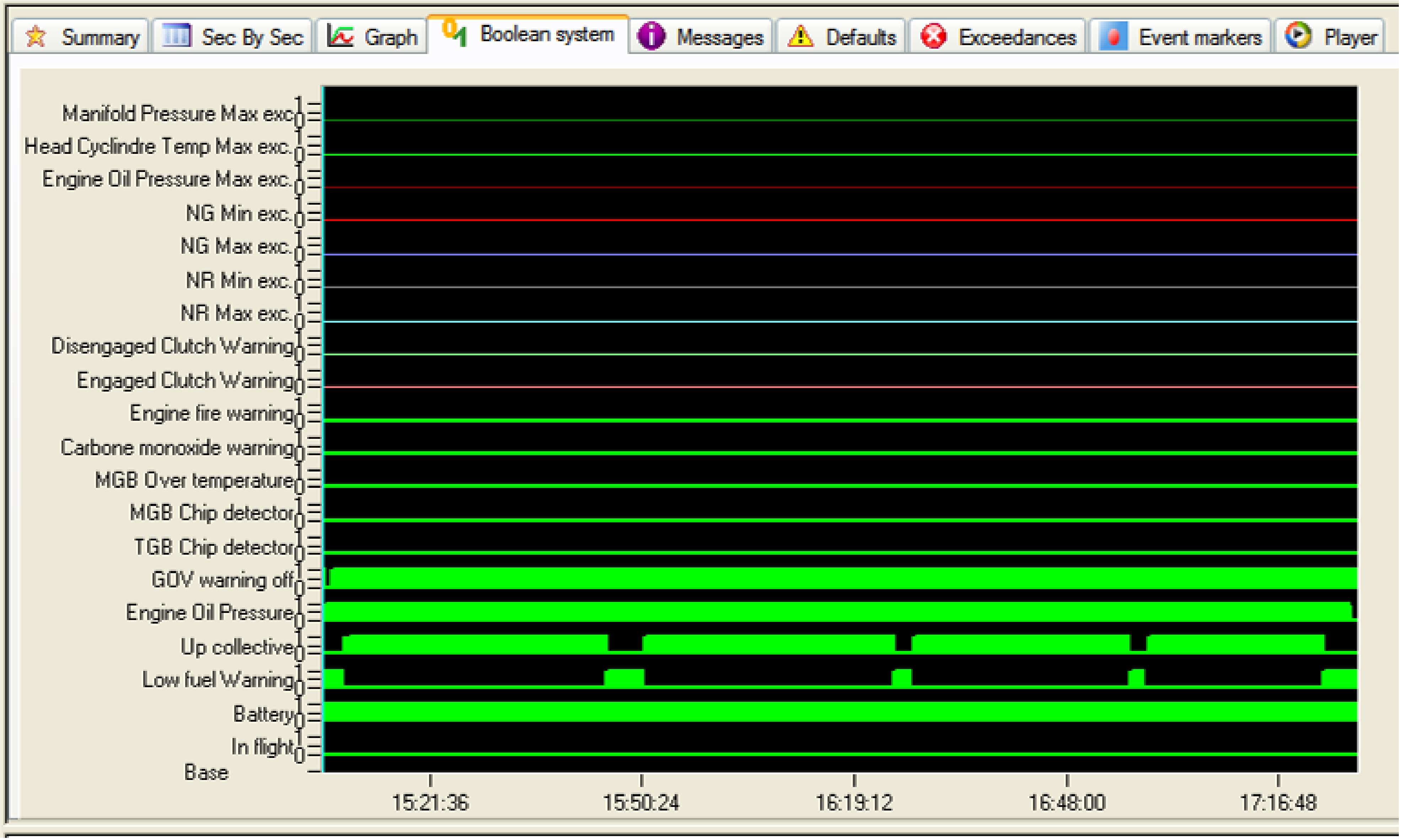


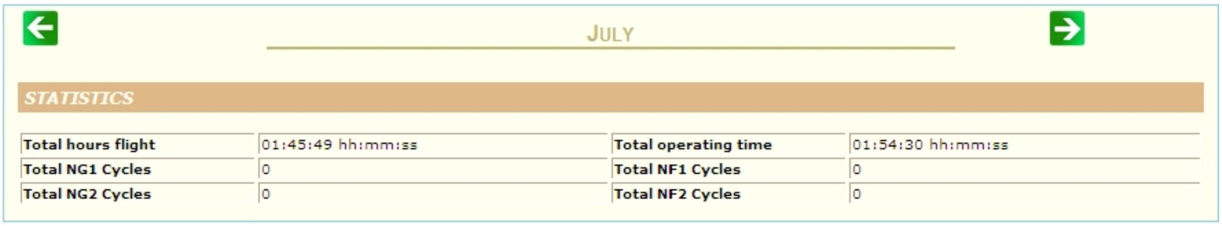
Figure 25 – Boolean-landings

☑ Flight and technical time

The following data are registered:

- Total flight time.
- Total aircraft flight hours.
- Total flight hours before an overhaul operation.
- Total flight hour of a fleet.

So, the flight time is accurate and the mechanical overhauls can be easily managed.


JULY

STATISTICS

Total hours flight	01:45:49 hh:mm:ss	Total operating time	01:54:30 hh:mm:ss
Total NG1 Cycles	0	Total NF1 Cycles	0
Total NG2 Cycles	0	Total NF2 Cycles	0

Figure 26 – Summary Window

☑ Vibration

The vibration record is manually actuated, when the pilot actuates the SYS pushbutton on the recorder. This allows checking the rotor settings, analyse the different frequencies. That can prevent a wear of the different mechanical parts.

Source	RPM	Frequency measure	Accelerometer Level (IPS)	Comments
upper sheave/6	352			
NG/7	388			
Tail Rotor/6	404	peak at 404	0,1 but disrupted by others peaks	Close peaks. Cannot be separated
NR	407			
upper sheave/5	422			
NG/6	452	450	0,08	
Tail Rotor/5	485	492	0,04	
upper sheave/4	528	527	0,04	
NG/5	543	544	0,05	
Tail Rotor/4	606	626	0,04	
NG/4	678	714	0,03	
upper sheave/3	703	703	0,03	
Tail Rotor/3	808	815	0,84	Close peaks. Cannot be separated
NR*2	815			
NG/3	904	943	0,05	
upper sheave/2	1055	1089	0,02	
Tail Rotor/2	1212	1227	0,07	Close peaks. Cannot be separated
NR*3	1222			
NG/2	1356	1361	0,35	
NR*4	1629	1630	0,23	
NR*5	2036	2045	0,05	
upper sheave	2110	2106	0,11	
Tail Rotor	2423	2448	0,38	Close peaks. Cannot be separated
NR*6	2444			
NG	2713	2720	0,36	
NR*7	2851	2854	0,02	
NR*8	3258	3261	0,57	
NR*9	3666	3656	0,09	
NR*10	4073	4078	1,3	
upper sheave*2	4221	4225	0,07	
NR*11	4480	4485	0,2	
Tail Rotor*2	4846	4850	0,36	
NR*12	4887	4890	0,25	
NR*13	5295	5298	0,05	
NG*2	5425	5443	0,24	
NR*14	5702	5705	0,15	
NR*15	6109	6109	0,06	
upper sheave*3	6331	6301	0,15	

Source	RPM	Frequency measure	Accelerometer Level (IPS)	Comments
NR*16	6517	6520	0,12	
NR*17	6924	6951	0,15	
TR*3	7269	7284	0,3	
NR*18	7331	7352	0,15	
NR*19	7738	7781	0,25	
NG*3	8138	8165	1,2	Close peaks. Cannot be separated
NR*20	8146			
upper sheave*4	8442	8426	0,03	
NR*21	8553	8569	0,05	
NR*22	8960	8978	0,16	
NR*23	9367	9355	0,03	
Tail Rotor*4	9692	9695	0,15	
NR*24	9775	9805	0,07	
NR*25	10182	10179	0,04	
upper sheave*5	10552	10555	0,05	Disrupting close peaks
NR*26	10589	10588	0,07	
NG*4	10851	10878	0,11	
NR*27	10997	10993	0,28	
NR*28	11404	11417	0,07	
NR*29	11811	11800	0,03	
TR*5	12116	12100	0,03	
NR*30	12218	12249	0,1	
upper sheave*6	12663	12670	0,04	
NG*5	13563	13610	0,03	

The tests were performed with Nr at 101,8% (407 rpm)

These vibration levels recorded are peak levels near the theoretical frequencies.
Levels under 0,05 IPS are weak and not representative.
It is possible to see frequencies coming from the different sources known: main rotor, tail rotor, upper sheave and engine.
These vibration level measures must be correlate with measures – tail rotor, engine fan – to verify that the vibration measures can be used to detect an helicopter degradation.
It will be necessary to find a condition to decide the bad or good health of the helicopter parts.
We can see other frequency peaks but their levels are low and we don't know the origin of these measures.

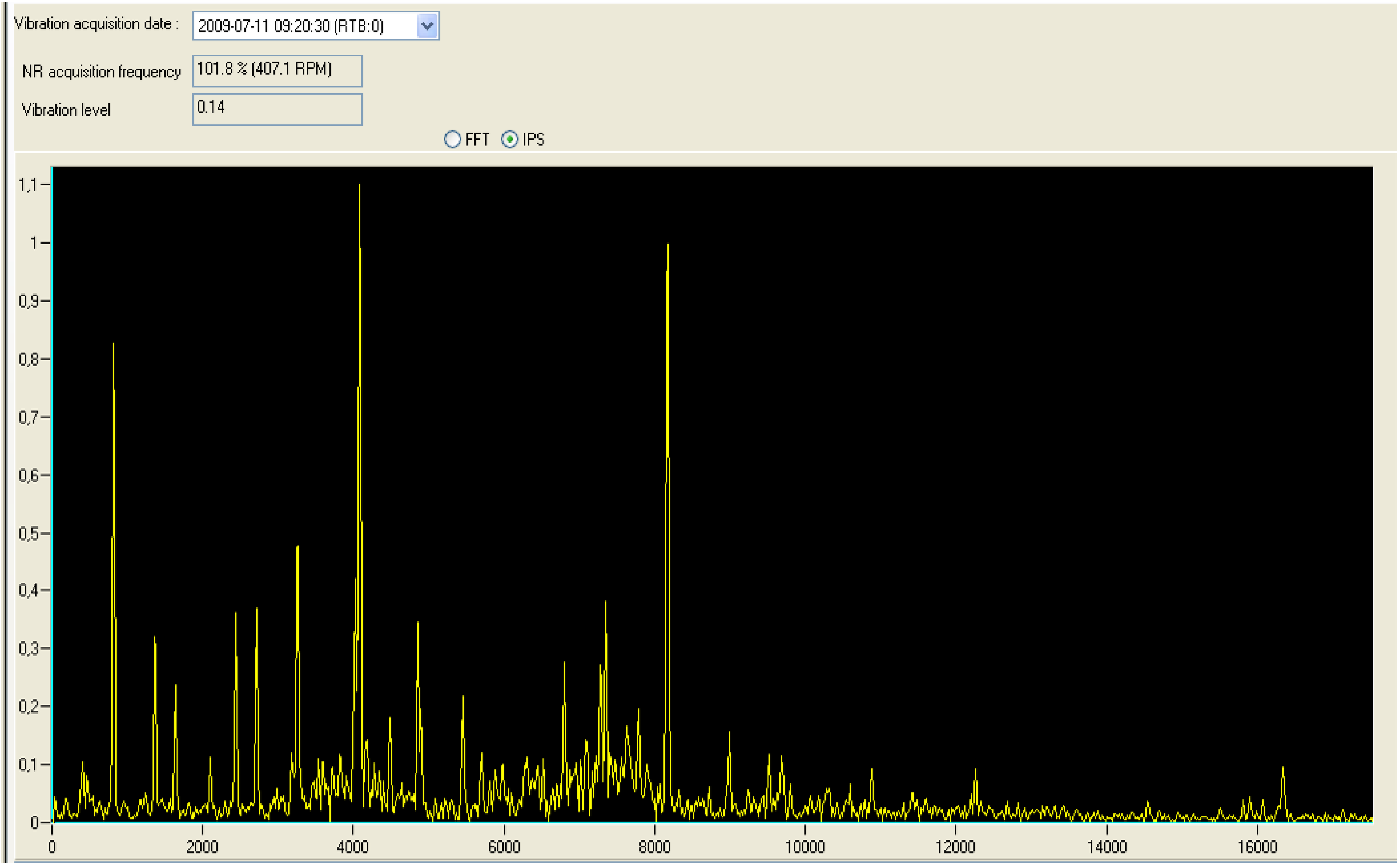


Figure 27 – Vibration Level Measure

- ☑ Replay a flight

A recorded flight could be replayed in the shape of the player window. It allows knowing what the aircraft parameters were during an exceedance.
We could easily analyze all the different data when the Ng is beneath the limit and follow the parameters evolution during all the flight time.

In this case, we note the NG value at 80,5 %, the Nr is normal, the manifold pressure is at a low value which indicates the pilot reduced the engine throttle. The engine oil pressure is normal.
We could exactly confirm the beginning and the Ng min exceedance duration by analysing the Boolean window (Fig.29).

If we pay attention to the curve window, and especially to the Zp curve, we note that the aircraft is descending.
Moreover, the Nr is not very well stabilized.
The pilot practices an autorotation exercise, all the parameters are normal and the low value of the Ng is a normal parameter during an autorotation exercise.

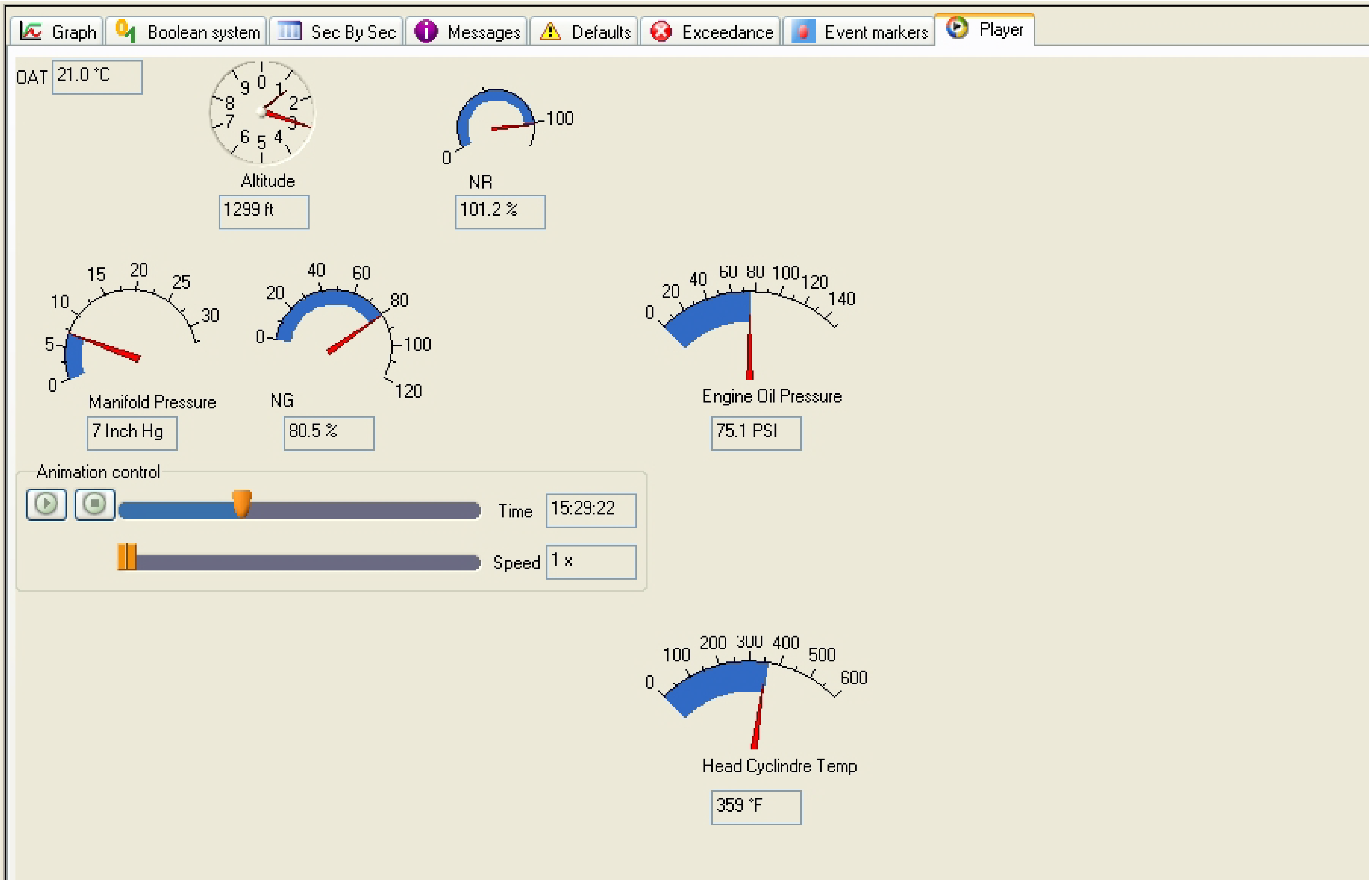


Figure 28 – Player Window

The possibility to switch from the player to the curve or the Boolean makes the analysis to be more easy and efficient. An accurate value can be analysed.

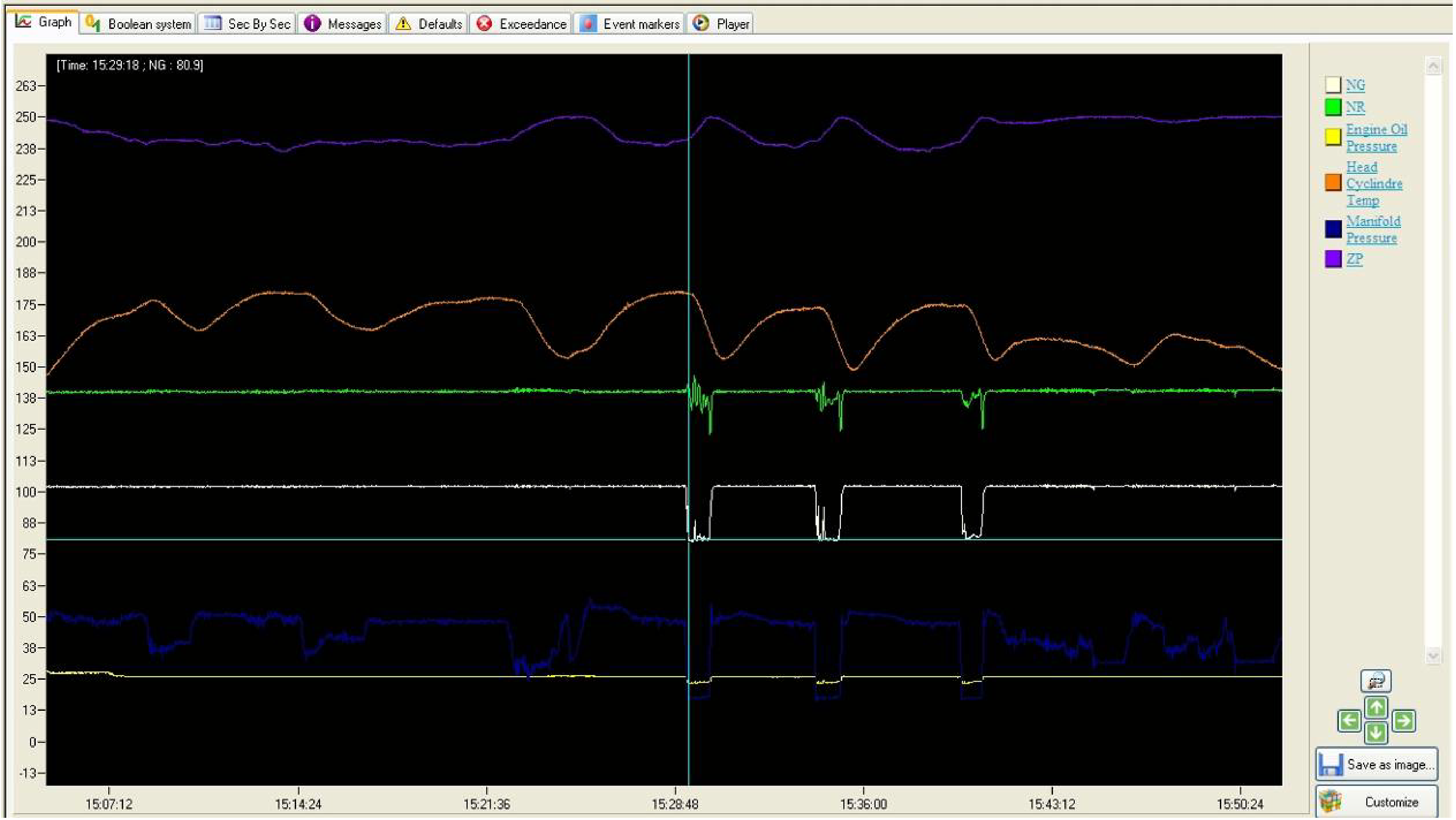


Figure 29 – Curve Window

Figure 30 – Boolean Window

SECTION 7 OUTCOMES

7.1 STUDY ACCHIEVEMENT AGAINST AIMS AND OBJECTIVES SET

Technical feasibility and flight safety benefits

- **Air/ground detection and engine operation detection**

  The air ground detection is provided by a switch mounted on the collective pitch. The engine operation detection is provided by the engine oil pressure signal. These two parameters are easy to record, easy to install, light and cheap.

  These parameters are necessary to measure operating and flight time: They are very useful for maintenance inspection schedule.

  <u>These parameters are monitored.</u>

- **Electrical instruments parameters (Rotor and engine RPM, Head Cylinder T°C, Engine T°C and pressure)**

  These parameters are technically easy to record, light and cheap: there are only wire connections to add.

  The record of these parameters is very to monitor exceedances and to perform maintenance operation.

  <u>These parameters are monitored.</u>

- **Zp, OAT, Airspeed, manifold pressure sensors**

  We have to add new sensors for these parameters. These sensors are light and cheap enough to respect the price quote.
  The airspped record is not really efficient in low speed due to pertubations induced by the rotor.
  The record of these parameters is used to monitor exceedances and to perform maintenance operation. They are very useful for pilot training.

  <u>These parameters are monitored.</u>

- **Warnings**

  These parameters are technically easy to record, light and cheap: there are only wire connections to add.

The major interest is for an historical recording and correlation with other parameters for maintenance.
Moreover, this allows detecting intermittent lighting of a warning.

These parameters are monitored.

- **Fuel flow.**

  It is technically feasible but a fuel flow meter is too expensive and the installation requires too much time.

  Moreover, the record of the fuel flow is not really useful for safety benefit because there is no limitation in the manuals.

  This parameter is not recorded.

- **GPS**

  If a GPS is already mounted, it is technically easy to record the data, light and cheap: there is only a wire connection to add. Otherwise, a GPS is too expensive for the price quote.

  One interest is to know the coordinates of the aircraft during the flight.
  It could be interesting for pilot training.

  This parameter could be monitored optionally. This option is still not developed.

- **Attitude**

  These parameters need gyroscopic sensors which are really expensive. These parameters could be very useful for pilot training.

  These parameters could be monitored optionally particularly for flying school. This option is still not developed.

- **Load factor**

  These parameters need 3 axes accelerometers which are relatively expensive. These parameters are very useful for maintenance operation ,hard landing analysis, and pilot training and could explain flight configuration.
  This allows analysing the fatigue of the aircraft.

  These parameters could be monitored optionally particularly for flying school. This option is still not developed.

- **Controls position**

These parameters need position sensors which could be mounted on the flight controls. The price remains expensive.

These parameters could be very useful regarding to the attitude and load factor conditions.

<u>These parameters are not recorded.</u>

- **Vibrations**

Vibrations record is first for main rotor, tail rotor and fan but could be also extended for gear boxes. We can only install the vibration accelerometer for main rotor as described in the maintenance manual. The other ones are forbidden in flight or not described in the manuals.

With the main rotor accelerometer, it is possible to check vibration ray for other rotating components.
The accelerometer could be expensive depending on the accuracy but the interest for helicopter heath is really important for safety benefit: in case of vibration detection, the operator could immediately solve the problem by setting the main rotor for example.

7.2 STUDY OUTCOMES AND THE IMPACT ON THE AVIATION COMMUNITIES

Following experience reports of Data Recorder users and Pilots/Instructors on piston engines, different points can be highlighted.

- First, the installation of a data recorder is mainly a means to increase the ***Flight Safety.***

  Indeed, the recorder allows controlling the flight parameters as soon as the flight is finished.

  - ✓ The recorder allows checking the properly use of the aircraft.
  - ✓ The installation of this device has a psychological impact on the pilot. By recording all the aircraft data, it involves the pilot's responsibility. It allows changing the pilot's behaviour.
  - ✓ In case of a rental company as Helitel in France, it permits to control the data after each flight in order to check every exceedance. Moreover, this system makes the customer to be more confident when renting an aircraft.
  - ✓ When the pilot has a doubt about an in flight data exceedance, the recorder allows confirming or invalidating the exceedance.
  - ✓ The recorded exceedance is very accurate. This allows performing the appropriate technical intervention without any doubt.
  - ✓ The recorder can also takes the main rotor vibration into account. This permits to check the rotor condition and settings. The vibration record could only be performed by actuating a pushbutton on the recorder. This action may easily be forgotten. (This recording could be automatic by modifying the recorder software)
  - ✓ In case of accident, it's easier to understand the circumstances by analyzing the flight parameters in order to avoid the same situation in the future.
  - ✓ The recorder also allows analyzing risky exercises on the piston engines as autorotation for example. In flight instruction, the analysis of these exercises permits to detect exceedances as explained on section 6.4 in order to warn the instructor in case of control actuation delay or flight close to the limits. This is a valued mean to alert and prevent accidents. However, according to the operators, it appears that the interest of a recorder during flight instruction is limited because the flight instructor takes place in the aircraft, pays attention to all the different flight

parameters and the student actions in order to prevent any problem or exceedance. This device is nevertheless very useful during solo flights.

- The installation of a recorder is also a **value for money**.

  - ✓ The recorder keeps in memory the data and can prove that no excess has been made. This demonstrates the aircraft safe condition for flight which is very important in case of aircraft resale. This device increases the venal value of an aircraft and, according to the operators, they prefer to buy a second-hand aircraft equipped with a recorder.

  - ✓ The aircraft flight hours are automatically cumulated and the overhaul operations could be easily managed.

  - ✓ In case of aircraft rental, the precision of the recorded data allows releasing an accurate invoice. Moreover, this also allows a better maintenance management.

According to the operators, the installation of a recorder doesn't induce any constraint both during the installation and in flight.

SECTION 8 CONCLUSIONS

The flight safety is a major stake. It's a permanent aim for all the aeronautical actors, mainly for the flying personnel and companies.

After more than 100 hours of functioning time, we could analyse different points as the exceedances which occurred in flight or on ground.
The curves allow following the aircraft parameters as Nr, Ng, altitude, etc, which shows a real interest in an aircraft use analysis.

That's the reason why the installation of a flight recorder could be very efficient on increasing the flight safety on piston engines as shown before and for many reasons.
The properly use of the aircraft is guaranteed.
By analyzing the pilots' behaviour, a lot of accidents could be prevented.
Moreover, the psychological impact of the recorder leads the pilots to be careful and prevent him to fly over the aircraft limits.
The recorded exccedances are very accurate preventing any doubt on the values.
The maintenance overhaul could be easily planed.

In order to have a good use of the recorder, it is necessary to configure the exceedance threshold in accordance with the pilot's operating book and the maintenance manual.

Regarding to the cost of the installation, and according to the benefits which could be obtained, the data recorder is an interested device for the operators.

However, some of them are absolutely not interested in such device if it could not allow them to extend their operational envelop by permitting them to overfly hostile areas during passenger transportation.

The addition of some optional functionalities as attitude recorder, GPS, load factors recorder, etc, could increase the flight safety by giving information as the way the aircraft had been used or the aircraft position, etc.
The addition of control position recorder shows a real interest in initial flight instruction in order to explain the basics of flight.
However, the cost of their installation could not be supported by the companies.

SECTION 9 IMPLICATIONS

9.1 GENERALITIES

The installation of a data recorder involves the companies to make a financial investment but it is not so important regarding to the flight safety benefit and the financial profit induced on a short period.

According to the operators who have installed a recorder on their aircraft, the technical operation is not a constraint. The installation can be made during an overhaul operation.

In order to increase a data base, it is necessary to continue the vibration analysis and mount other accelerometers if possible.
The pilots have to launch a vibration analysis on ground and at each hover
At track and balance operation, launch a vibration analysis at the same time that the Vibrex analysis.
These different procedures induce to create a procedure in the Rotorcraft Flight Manual Supplement or the Rotorcraft Maintenance Manual Supplement.

Replace telatemp stickers by recording temperature sensor is another mean to increase the precision of the recorded data.

9.2 LINK WITH WORKING GROUP WG77

The working group W77 aims to state recommendation regarding the minimum operational performance specification for light weight recording systems.
The system designed is compliant with all WG77 recommendations (dated end of February 2009) except the record of fuel flow (or pressure), and coolant temperature.

9.3 HOMP

The timeframe of the study was too short to implement HOMP analysis.
Therefore, the designed system may be used as a first step to HOMP. Indeed, as soon as flights are validated with the whole information concerning crew members, the type of mission (See Ground station Software), data are gathered in the GSS and may be used further.

SECTION 10 RECOMMENDATIONS

The installation of a data recorder on piston engines will increase the flight safety as shown before.

It is very important to explain this point of view to the operators. This is a real prevention device.

According to the operators, this only fact cannot be sufficient enough to encourage them to install data recorders.

They think it is also important to allow them to extend their operational envelop by permitting the piston engines when equipped with a recorder to overfly hostile areas during passenger transportation. This could allow them to perform new missions and for this reason, make their aircrafts to be more profitable.

Moreover, an effort could be made by insurance carriers to decrease the cost of their insurance when the aircraft is equipped with a data recorder. This is important to explain to the insurance carriers the safety benefit of the installation of such device on the aircraft, which could allow decreasing the number of accidents and therefore inducing them a financial benefit.

SECTION 11 REFERENCES

11.1 ABBREVIATIONS

The following abbreviations are used in this document:

AAIB	Air Accident investigation branch
AGL	At ground level
ANALOG	Continuously variable signal
APDOA	Alternative Procedure For Design Organization Approval
BEA	Bureau d’Enquête et d’Analyse
BRITE SAVER	Box Recorder Indicator of Trends Equipment - Signal Analysis Vibration and Events Recorder
BSPE	Brite Saver for Piston Engines
CO	Manifold pressure
CAT	Carburettor Air Temperature
CHT	Cylinder Head Temperature
DMC	Direct Maintenance Costs
DMS	Data Monitoring System
DO160E	DO160E and DO178
DO178	DO160E and DO178
DOC	Direct Operating Costs
DSP	Digital Signal Processor
DVMS	Data and Vibration Monitoring System
EASA	European aeronautical safety agency
EXC	Exceedance Light (On Man Machine Interface)
FPM	Feet per minute
GPS	Global positioning system
GSS	Ground Station Software
IN HG	Inch of Mercury
HOMP	Helicopter Operation Monitoring program
HUMS	Health and usage Monitoring System
KIAS	Knot indicated air speed
LED	Light Emitting Diode
LOC	Loss of control
LRU	Line Replaceable Unit
MMI	Man Machine Interface
MRGB	Main rotor gearbox
NR	Main Rotor Speed
NTSB	National Transport Safety Board
OAT	Outside Air Temperature
OGP	Oil and Gas Producers
PCB	Printed Circuit Board
PSAC	Plan for Software Aspect of Certification
PTU	U process landing
R22	R22 Robinson light helicopter
R44	R44 Robinson light helicopter

ROI	Return on investment
RPM	Revolution per minute
RTB	Rotor Track and Balance
SAS	Software Accomplishment Summary
SCI	Software Configuration Index
SD	Secure Data
SN	Safety notice
STC	Supplement Type Certificate (for civil aircrafts)
TBO	Time Between Overhaul
TOP	Top Event Marker (On Man Machine Interface)
TRGB	Tail rotor gearbox
UMS	Usage Monitoring System
VHM	Vibration Health Monitoring
WG77	Working Group 77
ZP	Altitude pressure

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SECTION 12 APPENDIXES

12.1 APPENDIXE 1: STC N° EASA R.S.01494 ON ROBINSON

European Aviation Safety Agency

SUPPLEMENTAL TYPE CERTIFICATE

EASA.R.S.01494

This Supplemental Type Certificate is issued by EASA, acting in accordance with Regulation (EC) No. 216/2008 on behalf of the European Community, its Member States and of the European third countries that participate in the activities of EASA under Article 66 of that Regulation and in accordance with Commission Regulation (EC) No. 1702/2003 to

Ect Industries

ZA La Plaine
07130
Soyons
France

and certifies that the change in the type design for the product listed below with the limitations and conditions specified meets the applicable Type Certification Basis and environmental protection requirements when operated within the conditions and limitations specified below:

Original Product Type Certificate Number:	FAA TC H11NM for R44 FAA TC H10WE for R22
Type Certificate Holder:	Robinson
Model:	R22, R22 Alpha, R22 Beta, R22 Mariner, R44, R44 II

Description of Design Change:
DMS R22 & R44 - Brite Saver PE Usage Monitoring System for Robinson R22 and R44 Series Helicopters

Associated Technical Documentation:

Installation, operation and maintenance of the DMS R22 & R44 Usage Monitoring System shall be in accordance with the following documentation;

- Definition Document - DD-0004-08BE58-EN Issue 3 or later revision
- Mounting Instructions - IM-KIT-PE-R22-R44-EN Issue 2 or later revision
- Maintenance Manual - MM1-0023-08BE58-EN Issue 0 or later revision
- Operator Manual - MUL-0022-08BE58-EN Issue 0 or later revision

Limitations and Conditions:

1. Prior to installation of this modification the installer must determine that the interrelationship between this modification and any other previously installed modification will introduce no adverse effect upon the airworthiness of the product.
2. The installation of this modification by third persons is subject to written permission of the approval holder and holding and disposal of the approved appropriate documentation.

This Certificate shall remain valid unless otherwise surrendered or revoked.

For the European Aviation Safety Agency,

Date of issue: 13 January 2009

Massimo MAZZOLETTI
Certification Manager

STC – EASA.R.S.01494 – Ect Industries

EASA Form 91, Issue 1

12.2 APPENDIXE 2: PISTON ENGINE HELICOPTERS' LIMITATIONS

12.2.1 R22

Parameters	Absolute min value	Absolute Max value	Other limitations
Airspeed indicator	NA	130knot	See the air speed placard
Rotor tachometer at power off	90%	110%	
Engine tachometer	97% or 101%	104%	According engine reference
Oil pressure on ground	25PSI	115PSI	
Oil pressure in flight	55PSI	95PSI	
Oil temperature	75°F	245°F	
Cylinder head temperature	200°F	500°F	
Manifold pressure	NA	24.1 to 25.9In Hg	According engine reference See the manifold pressure placard
Carburetor air temperature	5°C	NA	
Maximum altitude	NA	14000 ft	9000ft AGL
Oil quantity, min to takeoff	4 quarts	NA	

12.2.2 R44

Parameters	Absolute min value	Absolute Max value	Other limitations
Airspeed indicator	NA	130knot	See the air speed placard
Rotor tachometer	90%	108%	
Engine tachometer	101%	102%	
Oil pressure on ground	25PSI	115PSI	
Oil pressure in flight	55PSI	95PSI	
Oil temperature	75°F	245°F	
Cylinder head temperature	200°F	500°F	
Manifold pressure	NA	26.3In Hg	See the manifold pressure placard
Carburetor air temperature	5°FC	NA	
Maximum altitude	NA	14000 ft	9000ft AGL
Oil quantity, min to takeoff	7 quarts	NA	

12.2.3 R44-2

Parameters	Absolute min value	Absolute Max value	Other limitations

Airspeed indicator	NA	130knot	See the air speed placard
Rotor tachometer	90%	108%	
Engine tachometer	99 or 101%	102%	According serial number
Oil pressure on ground	25PSI	115PSI	
Oil pressure in flight	55PSI	95PSI	
Oil temperature	NA	245°F	
Cylinder head temperature	NA	500°F	
Manifold pressure	NA	26.3In Hg	See the manifold pressure placard
Maximum altitude	NA	14000 ft	9000ft AGL
Oil quantity, min to takeoff	7 quarts	NA	

12.2.4 SCHWEIZER 300CB

Parameters	Absolute min value	Absolute Max value	Other limitations
Airspeed indicator	NA	94knots	See the air speed placard
Rotor tachometer	Maintenance generalities	Maintenance generalities	
Engine tachometer	2530 RPM	2700 RPM	
Oil pressure on ground	25 PSI	95PSI	
Oil pressure in flight	NA	115 PSI	
Oil temperature	100 ° F	245°F	
Cylinder head temperature	230°F to 450 °F	500°F	
Manifold pressure		15 to 30	See the manifold pressure placard
Maximum altitude	NA	10000 ft	
Oil quantity, min to takeoff	NA	6 quarts	

12.3 APPENDIXE 3: GROUND STATION SOFTWARE

12.3.1 GROUND STATION DATA

The necessary functionalities mentioned in the tender specification were to provide a data set to the data interface to:

- Allow the pilot / maintenance personnel to access HOMP data
- Demonstrate if this is suitable for use by small helicopters operators and advise a pilot / maintenance personnel (on ground only) of any VHM indications.

The data and exceedance monitoring and the Ground Station Software fulfil the first request.
During flight trials, users will be interview to complete their opinion regarding the suitability of the system

Regarding VHM indication, the system only allows:

- A filtered measurement of the Main Rotor and a comparison to the thresholds of Robinson (Manual). A lamp might be lighted up to alert the crew.
- Record an overhaul measurement. This will have to be completed with spectrum analysis to check specific frequencies.

All records will be used to have a data bank for future and more accurate analysis
The Ground Station Software available is an application running on PC.
This application is designed around a database, and the technical team through a user friendly menu can store, compile and display recorded flight data.
When the data are downloaded to the ground station, an authorized member of technical team or a crew member acknowledges them.

The Ground Station Software can be adapted to the way the operator wants to use it.
It may be used to manage data from helicopter to fleet and from fleet to component. (Optional feature)

Users' rights management is used to restrict usage of some core functions and run software more safely and avoid possible damages.
The fingerprint login is the common way for a user to be logged on Ground Station Software.

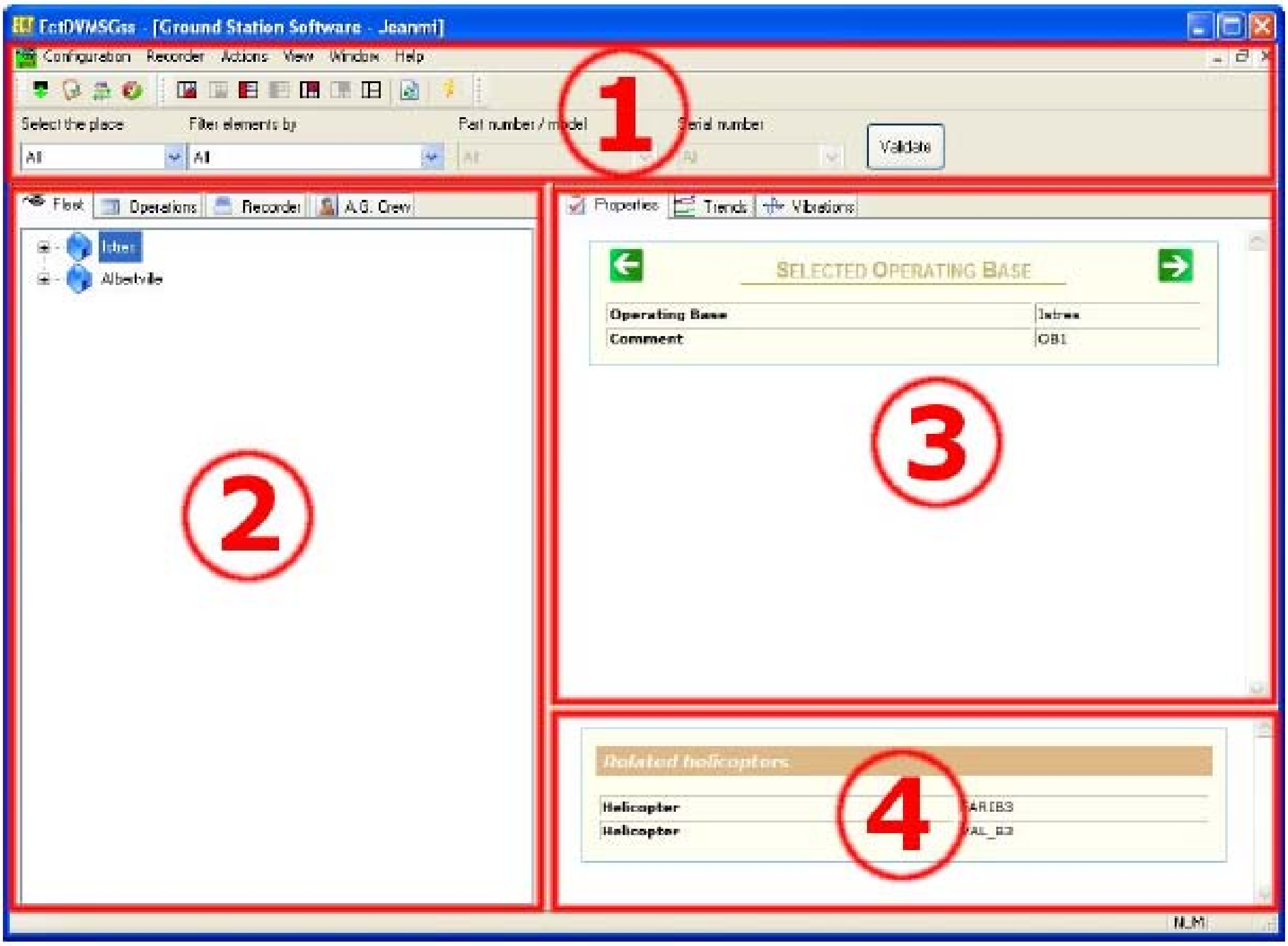


Figure 31 - Main window of Ground Station Software

12.3.1.1 THE MENUS, TOOLBAR AND FILTERS (1)

The menus, toolbar and filters allow users accessing to all features of the software:
Configurations (database, users, assemblies)
The actions with the system (Import data from SD card, lights validation, Maintenance operation, Acknowledge Exceedances)

Note: Filters are dynamically available according to Fleet or Operation tabs.

12.3.1.2 THE LEFT PANE (2)

The left pane is used to choose the working mode of the software.
Four working modes are available and allow the user to display associated information in the right pane:
Fleet: details about helicopters
Operations: details about flights
Recorders: recorders and their statistics
AG Crew: details of people’s activities (optional)

12.3.1.2.1 Fleet

The fleet tab display details about helicopters according to a fleet decomposition as per Figure 32.

The ground station is running properly with at least an operating base, a helicopter type, a recorder installed, and an engine installed. Information regarding from engine module to components and from rotary assemblies to component are not necessary to run the ground station.

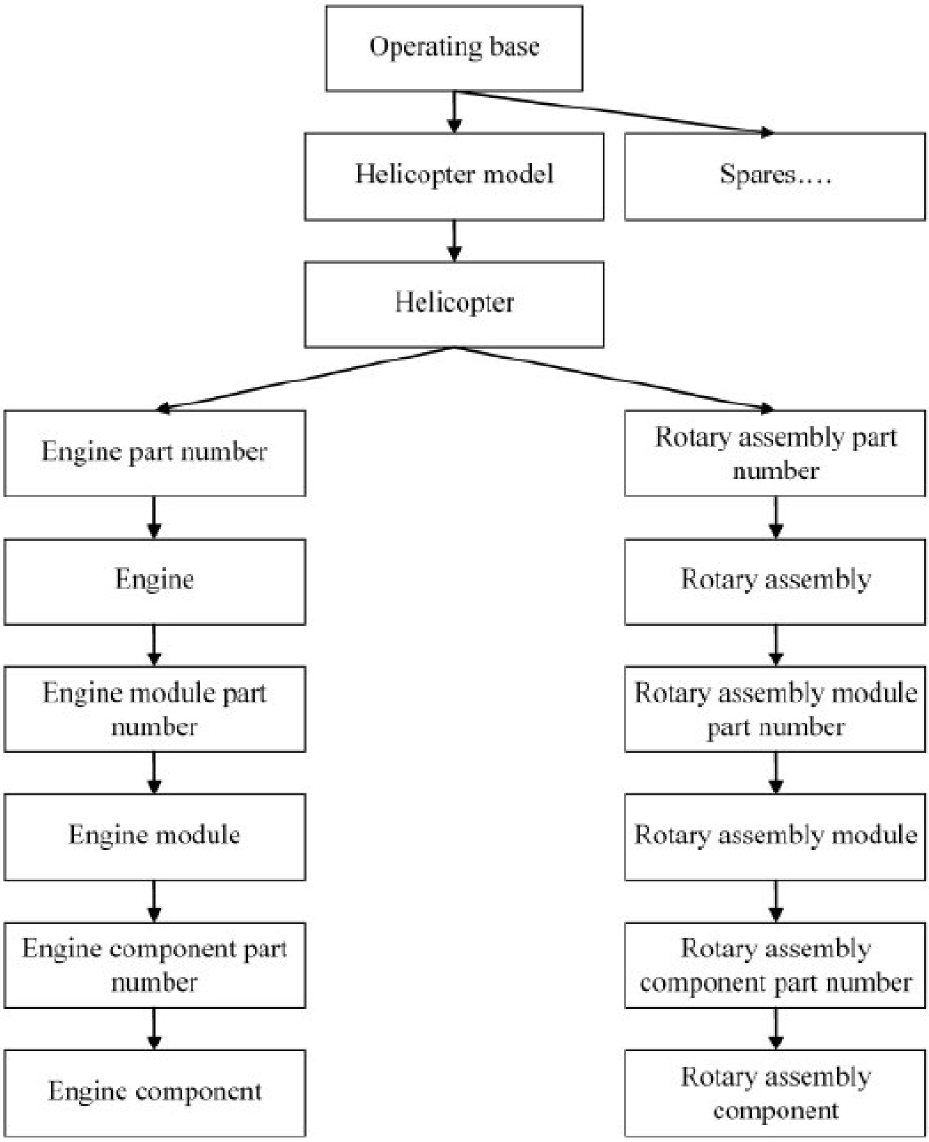


Figure 32 - Fleet decomposition

Status icons inform the user when a part is near overhaul (either TBO nearly elapsed or number of cycles). A warning icon is in that case superposed to the normal one:

12.3.1.2.2 Operations

This Operation tab shows all flights which have been previously downloaded and classify them by operating base, by date and by helicopter.

12.3.1.2.2.1 FLIGHT STATES

The use of each helicopter defines three states:

- Helicopter is only powered on.
- Helicopter is operating : the engine is running
- Helicopter is in flight

These states may be represented by Figure 33.

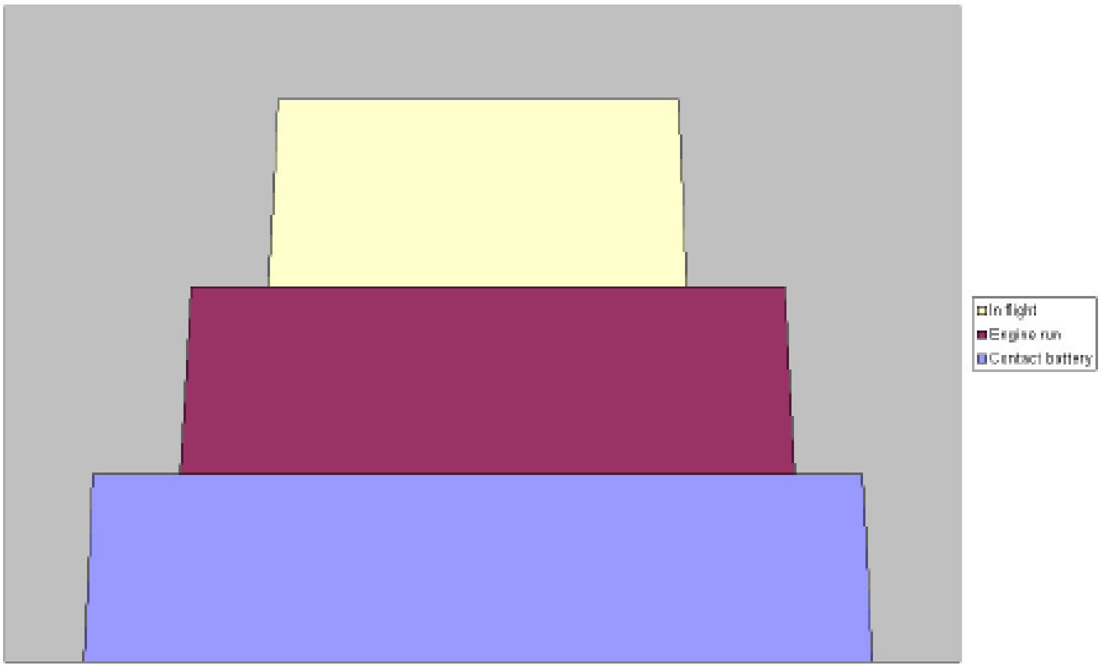


Figure 33 - Flight states of one helicopter

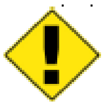
12.3.1.2.2.2 OPERATION TREE

An operation tree able to display data corresponding to:

- An operating base
- A year of flight
- A month of flight
- A week of flight
- A day of flight,
- A Helicopter,
- Each Power on/off
- Each operating phase
- Each flight of the helicopter

Figure 34 - Operations associated icon

Status icons may be superposed to these ones to inform about the validation of the flight:


Flight that have not been validated


Flights in which exceedances have not been acknowledged


Flights in which exceedances have been acknowledged

Figure 35 - Flight status icons

12.3.1.2.2.3 OPERATIONS TABS IN THE RIGHT PANE

Summary Tab

The “Summary” tab shows the main features of the item selected in the left tree. It shows the selection properties and evaluates some basics statistics.

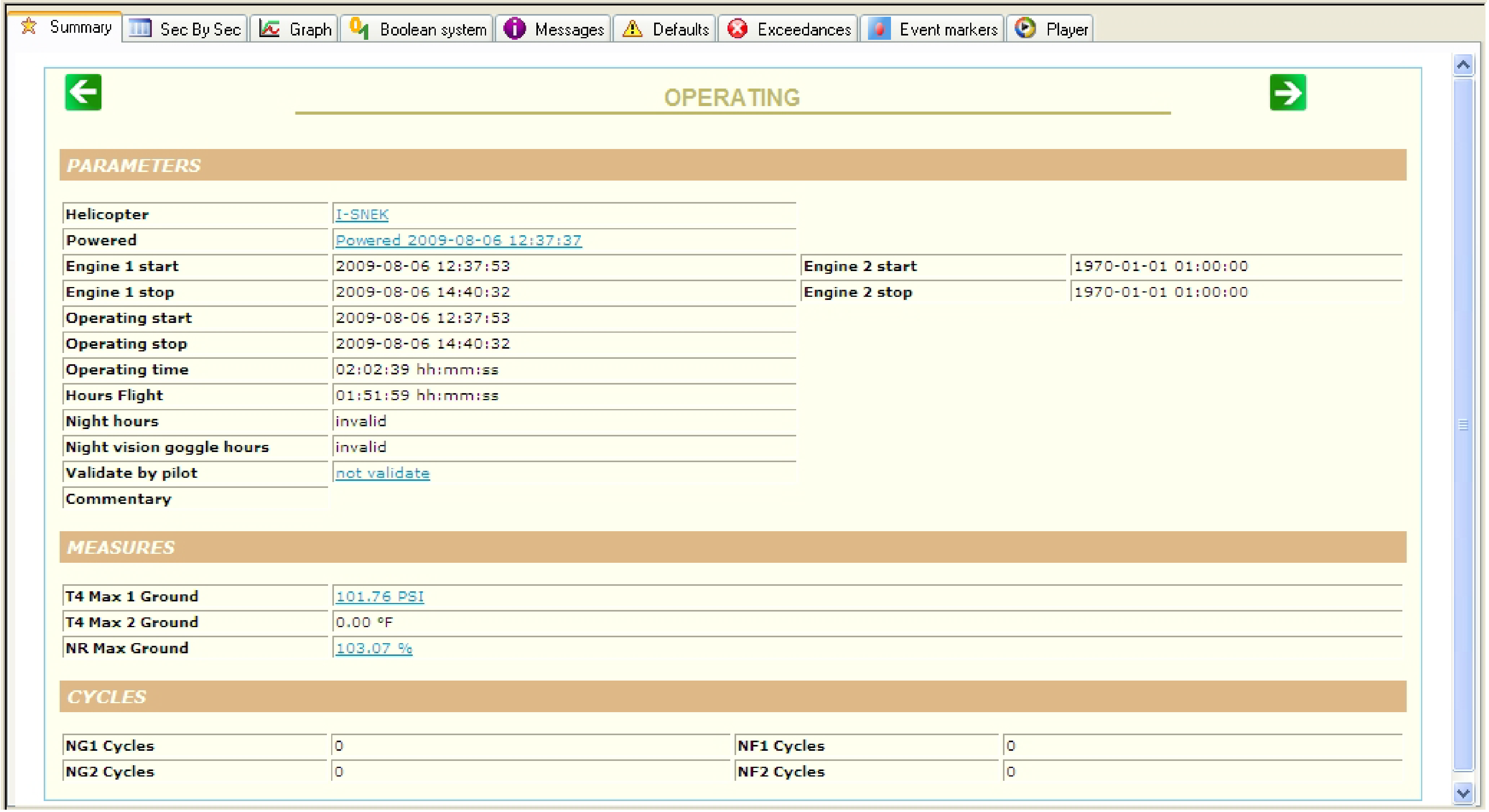


Figure 36 - Example of data displayed if "Operating" is selected

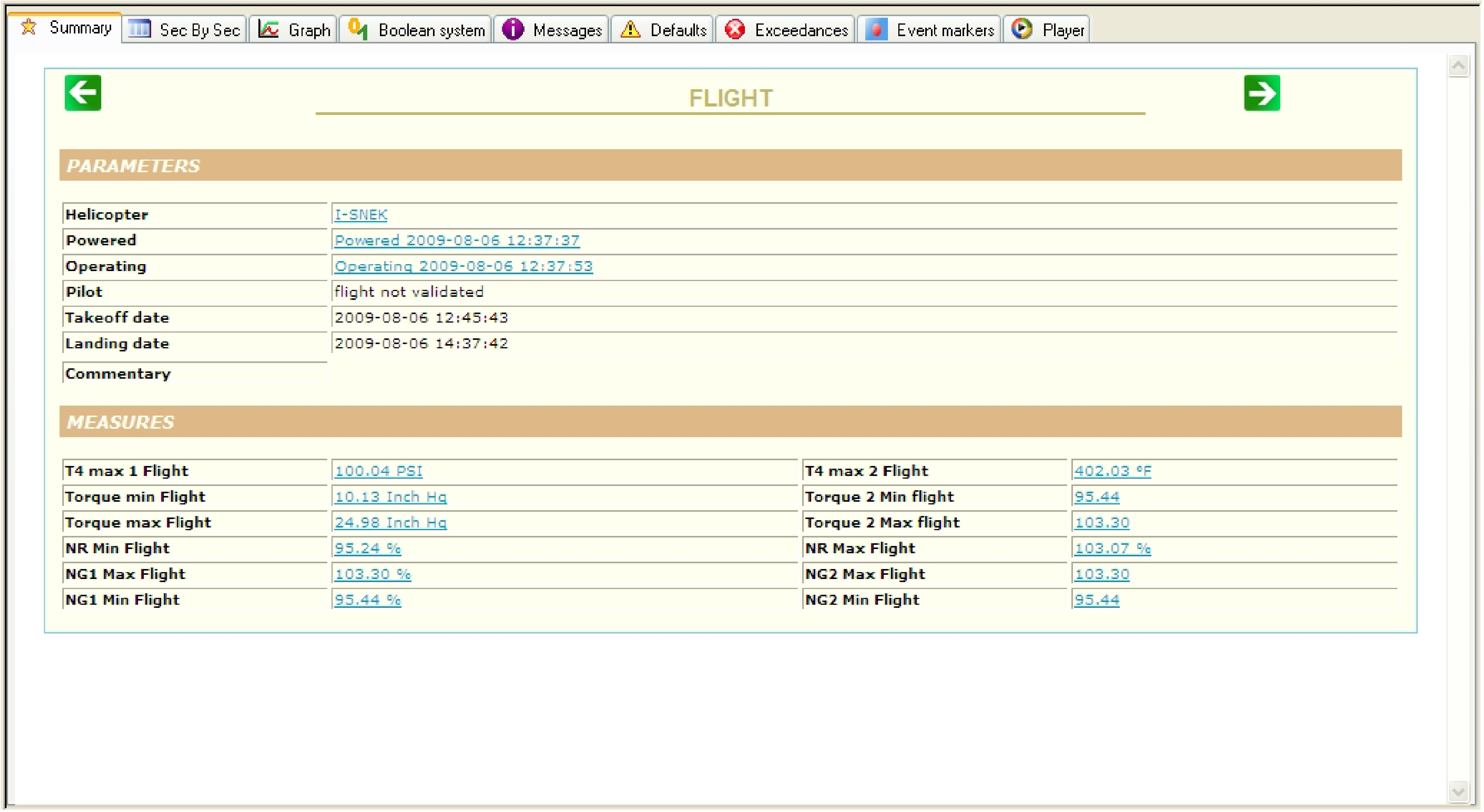
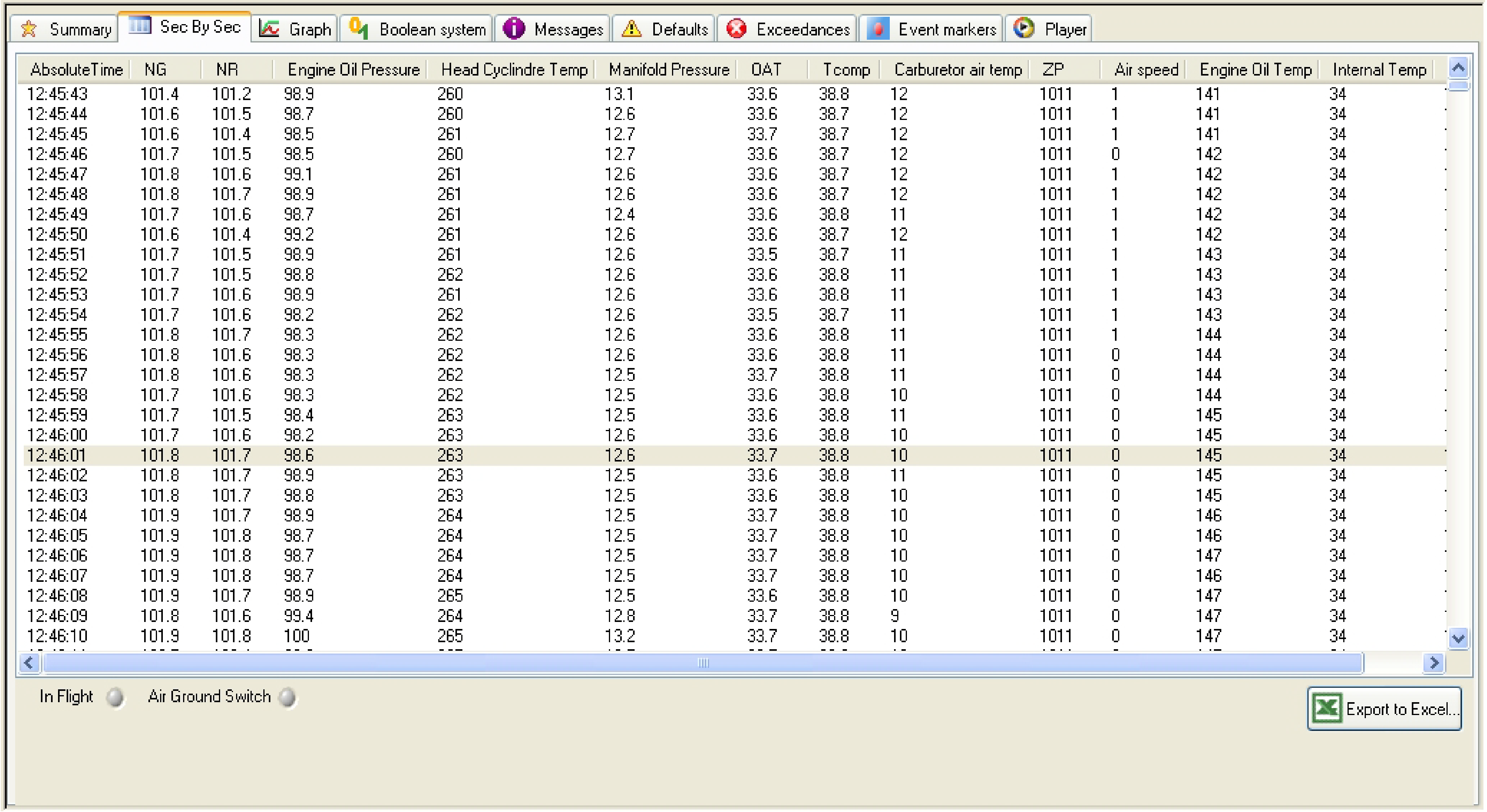


Figure 37 - Example of data displayed if "Flight" is selected

Second By Second data Tab
For each powered, operating or flight period, all values of each parameters are displayed in a table, second per second.



Summary | Sec By Sec | Graph | Boolean system | Messages | Defaults | Exceedances | Event markers | Player

AbsoluteTime	NG	NR	Engine Oil Pressure	Head Cyclindre Temp	Manifold Pressure	OAT	Tcomp	Carburetor air temp	ZP	Air speed	Engine Oil Temp	Internal Temp
12:45:43	101.4	101.2	98.9	260	13.1	33.6	38.8	12	1011	1	141	34
12:45:44	101.6	101.5	98.7	260	12.6	33.6	38.7	12	1011	1	141	34
12:45:45	101.6	101.4	98.5	261	12.7	33.7	38.7	12	1011	1	141	34
12:45:46	101.7	101.5	98.5	260	12.7	33.6	38.7	12	1011	0	142	34
12:45:47	101.8	101.6	99.1	261	12.6	33.6	38.7	12	1011	1	142	34
12:45:48	101.8	101.7	98.9	261	12.6	33.6	38.7	12	1011	1	142	34
12:45:49	101.7	101.6	98.7	261	12.4	33.6	38.8	11	1011	1	142	34
12:45:50	101.6	101.4	99.2	261	12.6	33.6	38.7	12	1011	1	142	34
12:45:51	101.7	101.5	98.9	261	12.6	33.5	38.7	11	1011	1	143	34
12:45:52	101.7	101.5	98.8	262	12.6	33.6	38.8	11	1011	1	143	34
12:45:53	101.7	101.6	98.9	261	12.6	33.6	38.8	11	1011	1	143	34
12:45:54	101.7	101.6	98.2	262	12.6	33.5	38.7	11	1011	1	143	34
12:45:55	101.8	101.7	98.3	262	12.6	33.6	38.8	11	1011	1	144	34
12:45:56	101.8	101.6	98.3	262	12.6	33.6	38.8	11	1011	0	144	34
12:45:57	101.8	101.6	98.3	262	12.5	33.7	38.8	11	1011	0	144	34
12:45:58	101.7	101.6	98.3	262	12.5	33.6	38.8	10	1011	0	144	34
12:45:59	101.7	101.5	98.4	263	12.5	33.6	38.8	11	1011	0	145	34
12:46:00	101.7	101.6	98.2	263	12.6	33.6	38.8	10	1011	0	145	34
12:46:01	101.8	101.7	98.6	263	12.6	33.7	38.8	10	1011	0	145	34
12:46:02	101.8	101.7	98.9	263	12.5	33.6	38.8	11	1011	0	145	34
12:46:03	101.8	101.7	98.8	263	12.5	33.6	38.8	10	1011	0	145	34
12:46:04	101.9	101.7	98.9	264	12.5	33.7	38.8	10	1011	0	146	34
12:46:05	101.9	101.8	98.7	264	12.5	33.7	38.8	10	1011	0	146	34
12:46:06	101.9	101.8	98.7	264	12.5	33.7	38.8	10	1011	0	147	34
12:46:07	101.9	101.8	98.7	264	12.5	33.7	38.8	10	1011	0	146	34
12:46:08	101.9	101.7	98.9	265	12.5	33.6	38.8	10	1011	0	147	34
12:46:09	101.8	101.6	99.4	264	12.8	33.7	38.8	9	1011	0	147	34
12:46:10	101.9	101.8	100	265	13.2	33.7	38.8	10	1011	0	147	34

In Flight   Air Ground Switch   Export to Excel...

Figure 38 - Second per Second tab

Each flight may be checked second per second by selecting each line of the flight.
In case an exceedance occurred during the selected time (line), associated indicators at the bottom of the table will be lighted (green for Boolean information and red for analogue ones).

Graph Tab
For each powered, operating or flight period, all analogue data may be displayed in a graph. The display of the data may be customized by the user (data selection, scales…)

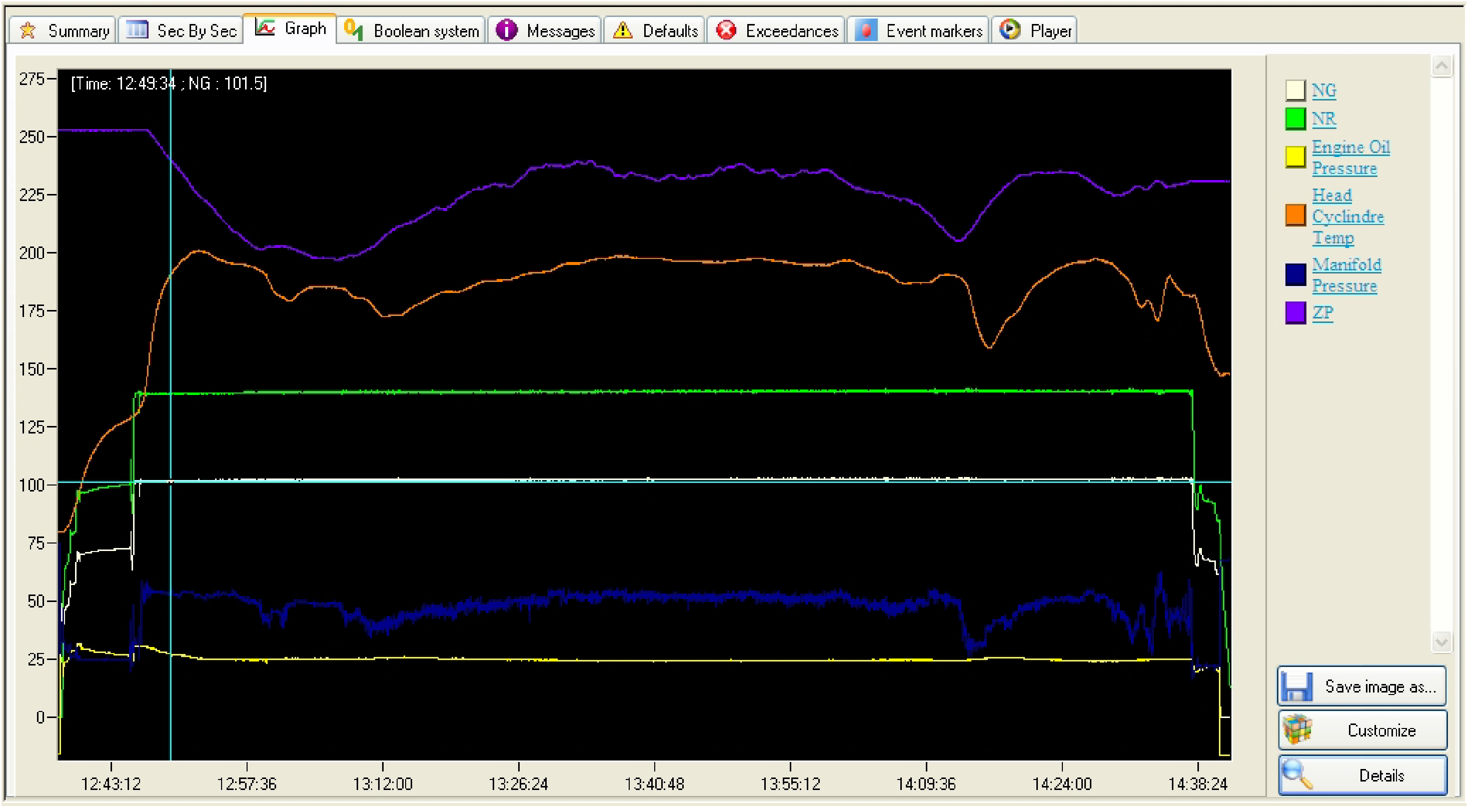


Figure 39 - Graph display

Boolean data Tab

For each powered, operating or flight period, all boolean data may also be displayed in a graph.

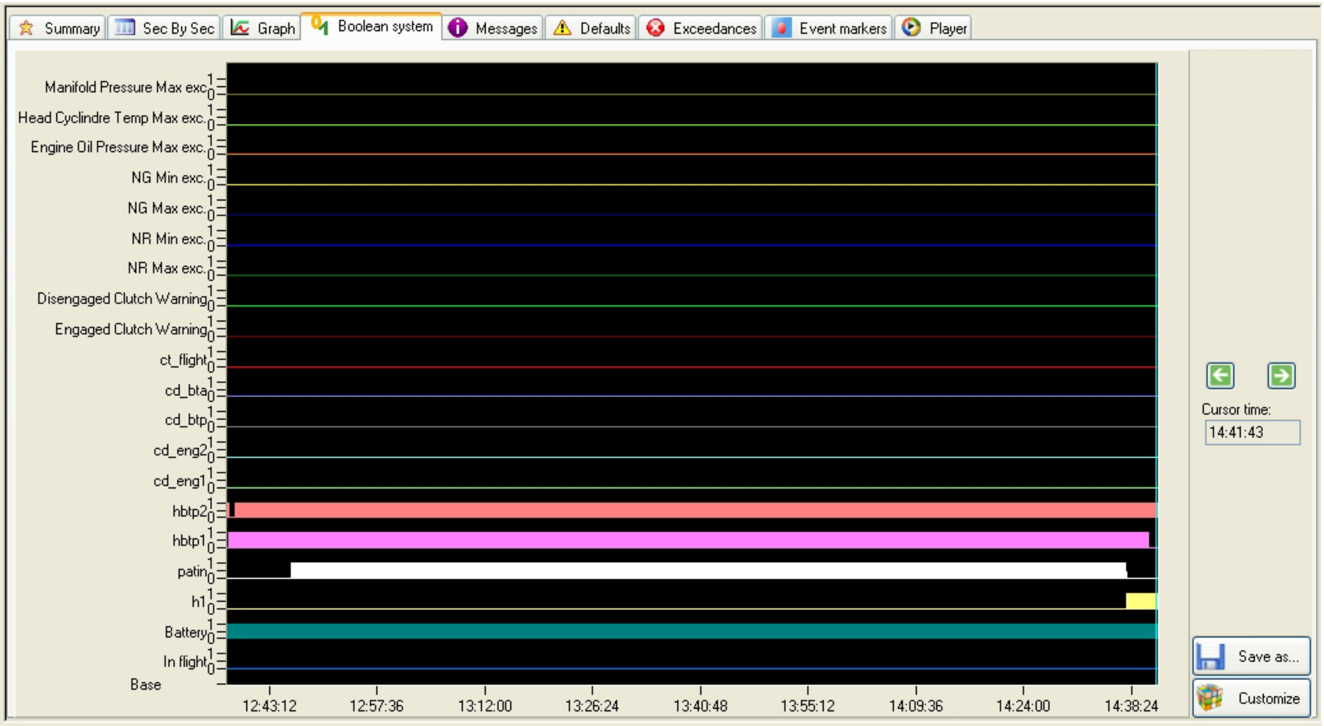


Figure 40 - Boolean data

Messages Tab

For each powered, operating or flight period, all recorder messages are displayed: information regarding flight states and major events (flight events or recorder events).

Start date	Message Text
12:37:37	Power on
12:37:37	Configuration - State0 start
12:37:37	Configuration - State1 start
12:37:37	Configuration - State2 start
12:37:37	Configuration - XML version
12:37:37	SD card in place
12:37:45	Power off
12:37:48	Power on
12:37:48	Return from micro-cut
12:37:48	Configuration - State0 start
12:37:48	Configuration - State1 start
12:37:48	Configuration - State2 start
12:37:48	Configuration - XML version
12:37:48	SD card in place
12:37:53	Turbine 1 start
12:45:43	Take off
14:37:42	Landing
14:40:32	Turbine 1 stop
14:41:49	Power off

Figure 41 - Message display

Defaults Tab
For each powered, operating or flight period, all recorder defaults are displayed in this tab. These defaults correspond to malfunctions and error that occurred during the flight.
Each default is associated to a corrective action that must be applied according to the maintenance manual of the system

Start	Message Text	Corrective action
16:04:16	Analogical input 1 fault	Check the wiring (refer to Maintenance Manual for details)

Figure 42 - Default display

Exceedances Tab
All exceedances that occurred during powered, operating and flight period are displayed in Exceedance tab.
All details regarding each exceedance are mentioned:

- When it started
- When it stopped
- The kind of exceedance (which parameter has been exceeded).
- The value of the parameter when the exceedance started
- The acknowledge status of the exceedance
- The identification of the user who acknowledged the exceedance
- The date of the acknowledgement

The comments entered when acknowledging the exceedance

Event Markers Tab
Data regarding top events made during flights are given in this tab.

Player Tab
For each powered, operating or flight period, flights may be played again thanks to this tab to show values of the parameters on a simulated front panel

12.3.1.2.3 Recorders

When the recorder tab is selected on the left pane, the right one shows the statistics of the use of the recorder.

12.3.1.2.4 AG Crew (optional)

The AG crew tab allows listing all activities of each team member (optional).
For each member, a tree structure allows to show statistics on the right pane.

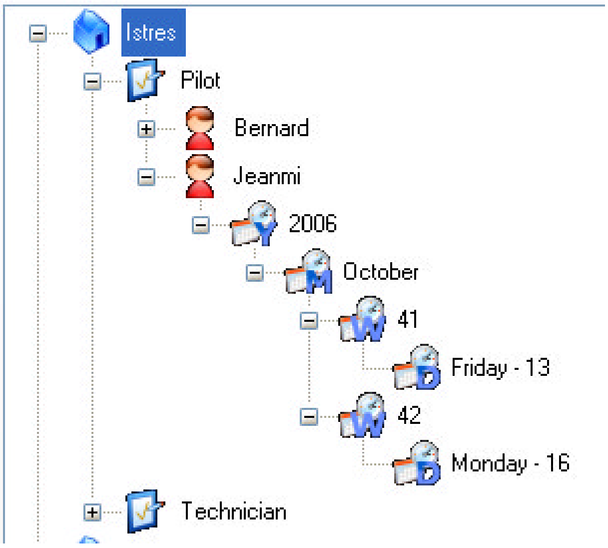


Figure 43 - Crew list

Related data tab is used to sum up the team member history as follows:
For a pilot:

- · All his flights

For a technician:

- · All his maintenance operations
- · All acknowledged exceedances

FLIGHTS LIST

	Takeoff	Landing	Helicopter	Recorder	Powered	Operating
	2006-10-02 16:49:20	2006-10-02 17:11:46	FARIB3	01	Powered	Operating

Operations list

Date	Description	Category	Item immat	Parent Before	Parent After
2006-12-18 09:37:11	engine component check	Engine Component	ds-1	m2-a	m2-a

ACKNOWLEDGED EXCEEDANCES

Ack date	Ack comments	Powered	Start time	Stop time	Value
2006-12-18 09:38:35	Abnormal temparature exceedance. Must check turbine components.	Powered	2006-10-17 14:17:24	2006-10-17 14:17:34	13696

Figure 44 - Related data of AG Crew

The Properties tab is used to display pilot statistics:

- General statistics
  - o the total flight time
  - o the total night hours
  - o the total night vision goggle
- Statistics by helicopter model
  - o display the total time spent on each helicopter model
- Statistics by flight type
  - o · display the total time spent depending on the flight type

All these information may after this be used as a first step for HOMP purposes.

12.3.1.3 THE RIGHT PANE (3)

The right pane (3) is used to show specific data related to left tree selection (left pane).
For example, if a helicopter is selected on the fleet tree, the right pane shows three tabs: properties, trends (optional) and vibration (optional):

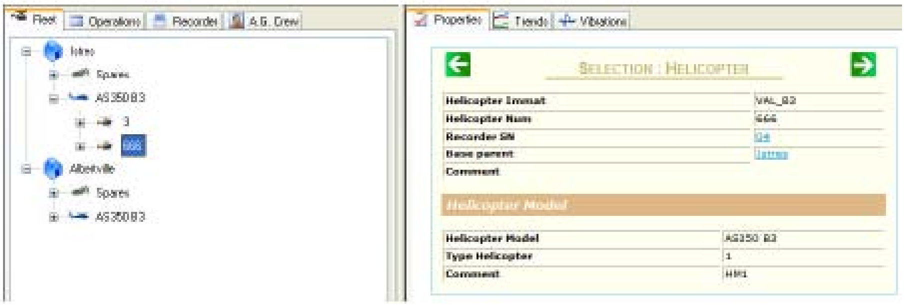


Figure 45 - Example of right pane display

If Operations tab is selected in the left tree, the right pane shows Graph, Messages, Defaults, Top events, Exceedances, Player).

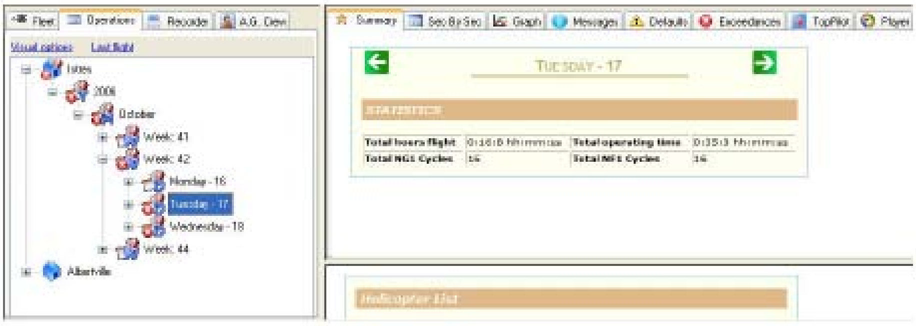


Figure 46 - Example of right panel display

12.3.1.4 THE LOWER PANE (4)

The lower pane (4) is used as a status bar, and displays specific information related to item which is selected in the left pane. It usually gives details on the sub-elements of this item.
For example, if a helicopter is selected in Fleet tree, the lower pane displays references to Engines and Rotary Assemblies part numbers.

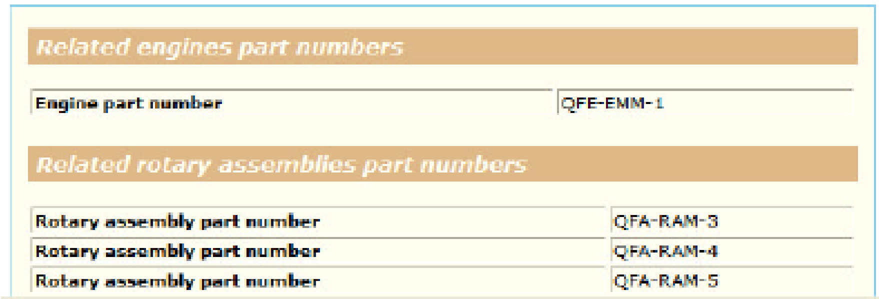


Figure 47 - Example of lower display