Results of the questionnaire: Engines in Sailplanes

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Date: October 14, 2008

Introduction

As a part of my thesis work in Aerospace Engineering at Delft University of Technology, I published a questionnaire titled *Use of engines in Sailplanes*. The purpose of this questionnaire is to investigate different rumours and assumptions about these engine systems.
The results of this questionnaire are used to form a more well-founded opinion about the actual customer satisfaction, and operation and reliability issues.
In the online introduction it was announced that the published results will be kept general in order not to harm manufacturers of sailplanes or engines. Therefore, not a single manufacturer or sailplane/engine type is mentioned in this report.

The first section describes how and where the information was gathered. Starting from the second section, the results will be discussed by means of comments and a graphical presentation of the answers given in the questionnaire. The results presented in this article will lead to conclusions towards the use of engines in sailplanes today and tomorrow.

In this introduction I also want to use the opportunity to thank all the participants in this small research. Also special thanks to the many proposals to post the questionnaire elsewhere. I hope the results presented below will contribute to a safer and more reliable operation of engines in sailplanes, and eventually to new developments that are even better than the present-day systems.

1 Gathering information

There is a lack of official information with respect to the reliability and customer satisfaction concerning the use of engines in sailplanes. A questionnaire was set up to gather information about customer satisfaction and propulsion system reliability.
To reach as much owners and users as possible the questionnaire was posted on the internet and people are made aware of it by announcing it on various glider portals.
The gliding sport is a very dynamic sport, and tactics, new developments, regulations, or just nice stories are distributed very frequently on these gliding forums. Therefore one can be sure that the intended audience for this questionnaire will be informed when announcing it there.
A selection of the used forums is given in Table 1.

Apart from these forums, some participants in the questionnaire sent proposals to post the questionnaire elsewhere to reach even more gliderpilots using motorised gliders.
The main goal of this questionnaire is to get more information on the following subjects:

- Engine reliability
- Frequency of the use of the engine
- Satisfaction of the end-user towards ease of operation, engine noise and engine vibrations.
- Wishes of the end users towards future systems and developments.

Table 1: Glider portals used to distribute the questionnaire

Country	Glider portal
The Netherlands	www.zweefportaal.nl
Belgium	www.lvzc.be
Great Britain	uras.gliderpilot.net
United States of America	rec.aviation.soaring
	www.gliderforum.com
Germany	www.segelflug.de
Austria	streckenflug.de
South Africa	www.sssa.org.za

The questionnaire and the accompanying letter are added at the end of this report, see Appendix A.

2 The results

At the moment of writing this report, a total of 132 participants have filled out the questionnaire. Although the saying *more is better* applies very well in this case, this is considered a sufficiently large group to obtain reliable results representative for the entire gliding community.
The results of the questionnaire are split up in two parts. The first part will show the results of the user's experience with his own aircraft. These results will mainly be given in the form of histograms, that will be commented along the way.
The second part is a summary of all the comments towards necessary modifications on future propulsion systems for sailplanes.
Both sections will have the same division as the questionnaire itself:

- Validity of the results
- Usage frequency
- Reliability/Failure related issues
- Ease of operation
- Noise related questions
- Vibration related questions

2.1 Validity of the results

The goal of this questionnaire is to get a realistic image of the use of engines in sailplanes. It is therefore important to determine the necessary sample size to achieve a certain confidence level. The calculations[1] of this sample size result in the following results for different confidence intervals and different margins of error:

[1]Source: Lenth, R.V. (2006). Java Applets for Power and Sample Size [Computer Software]. Retrieved from http://www.stat.uiowa.edu/ rlenth/Power.

Table 2: Estimated sample sizes for different values of *confidence interval* and *margin of error*

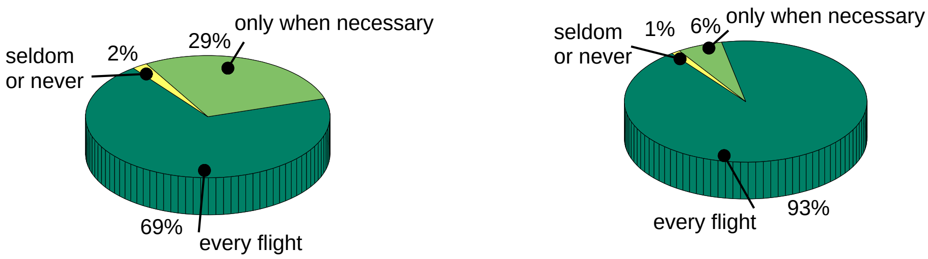
Confidence interval	Margin of error	Estimated sample size
99%	5%	664
95%	5%	385
90%	5%	271
99%	7.5%	295
95%	7.5%	171
90%	7.5%	120
99%	10%	166
95%	10%	96
90%	10%	68

Because the total population of sailplanes is not known, the calculations are executed for an infinite population. The computations are further based on the assumption that 50% of the gathered sample is true, thus the worst case scenario is selected.
From the introduction of the results section, it was learned that the gathered sample size is 132. This means that the gathered information is valid with a confidence of 90% and a margin of error below 7%.

2.2 Reliability and Customer satisfaction

2.2.1 Usage frequency

First, it is determined how often the engine is currently used by glider pilots. An overview of the usage frequency of both selflaunching gliders and sustainer equipped gliders can be seen Figure 1. Most of the pilots of a selflaunch capable glider use their engine every flight, 93 %. For the sustainer engine equipped aircraft that is 70 %. Only a negligible percentage of the pilots owning a selflaunch capable sailplane uses alternative take-off methods, and uses the engine to avoid an outlanding. For the sustainer engine equipped gliders, that is almost 30 % of the pilots. Closely related to the usage frequency is the fraction the running time of the engine amounts to, compared to the total flying hours of the aircraft. An estimate for this fraction is calculated using the numbers given in the questionnaire. For the selflaunching group the engine time is approximately 10 % of the flying time, for the sustainer equipped gliders this amounts to $2-5$ %. This difference can be explained by the fact that pilots of selflaunching gliders use their engine more for performing a take-off, while this is not possible with a sustainer equipped glider.



(a) Sustainer engine (b) Selflaunch engine

Figure 1: Usage frequency of the engines in percentage of total repondents per engine type

2.2.2 Reliability indication

As mentioned above, the ratio of engine time versus flying time is rather small, but the correct functioning of the engine in the most critical phases of flight is very important for the safety of the pilot and his aircraft.
As Figure 1 shows, most pilots use the engine every flight, the selflaunching pilots to make a take-off, and most pilots with a sustainer equipped aircraft make a test run before starting their cross-country flight. When the engine is needed at a later stage of the flight, the pilot expects the engine to start flawlessly. However, this is not always the fact. Therefore one of the questions was, *whether an engine failure has occurred after a successful testrun was performed at the beginning of the flight.*
The result is rather surprising. Both for the selflaunching and sustainer engines, 30 % of the pilots has had an engine failure after having performed a successful testrun at the beginning of the flight.
In a few cases the pilots could not find any cause of the malfunctioning of the engine. In all

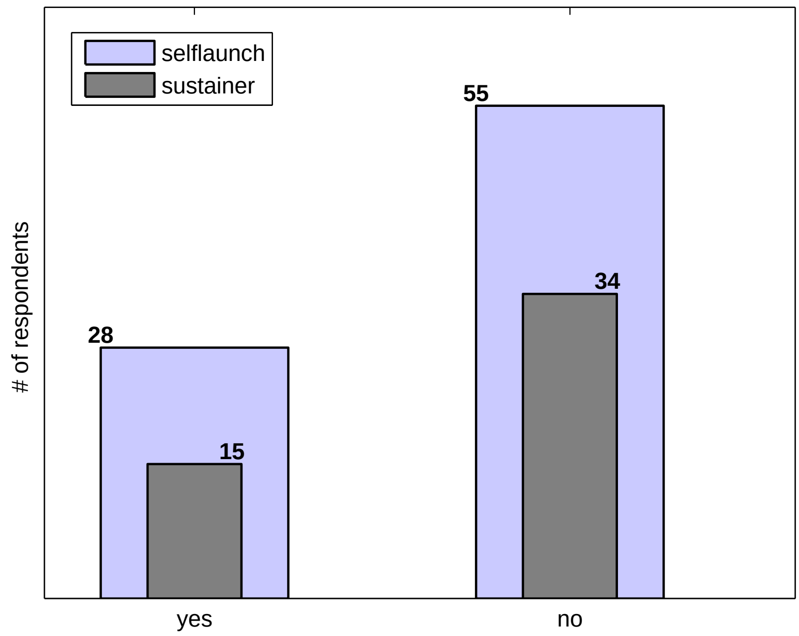


Figure 2: Number of respondents with an engine failure following a successful engine run at the beginning of a flight

other cases, failure of small components caused the entire system to fail. Some examples of these failures are given below:

- Broken fuel lines,
- Malfunctioning electronics,
- Fuel pump failure,
- Cracked engine pylon,
- Cracked exhaust, ...

Next to damage to the propulsion system, pilots also reported a decreased reliability of the entire glider due to the engine. 30 % of the pilots indicate that some kind of damage was done to the aircraft as a result of having and operating an engine. Some examples:

- Cracks in the fuselage at the place where the engine lies down in the engine bay,
- Damaged engine bay doors due to erroneous retraction of the engine,
- Shorter lifetime of instruments, ...

2.2.3 Ease of operation

Although many pilots indicate that the systems in general are rather easy to operate, a large number of extra comments show that extracting/retracting and starting/stopping the engine results in a very high pilot workload. Pilots flying two-seaters indicate that one pilot flies, while the other operates the engine.
One of the problems is that the levers for operating the engine are scattered around in the cockpit, which allows mistakes to happen easily.
A number of pilots report forgetting one or more steps in a critical phase of the flight, resulting in an unsuccessful engine start. This can be largely assigned to operating procedures which are too complex.
Although Figure 3 shows that the majority of the pilots think the system is *simple*, they still make a lot of mistakes operating it. This can be assigned to the fact that the increased workload at crucial phases of the flight, asks too much from the pilot causing him to forget some steps. Therefore an easier operating procedure and pilot interface could reduce this type of failure.

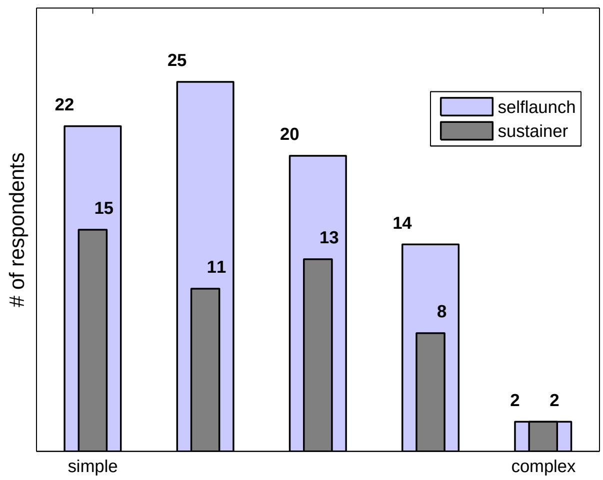


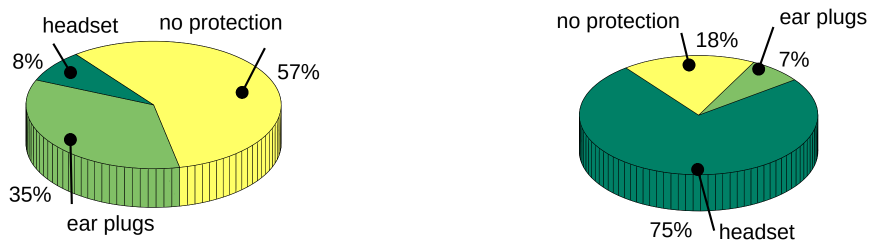
Figure 3: The ease of operation as it is experienced by the pilots, ranging from simple to complex

2.2.4 Noise related results

A running engine makes a considerable amount of noise, and because a sailplane is not built to isolate the pilot from this noise, this can be quite a burden to the pilot. The only limitations on the engine noise towards the environment is defined for selflaunch capable aircraft. For sustainer aircraft no official limits exist.

To protect the pilot from the noise in the cockpit, there are a few protection systems that can be used. A headset is the most obvious solution, because the radiocommunication can be continued whilst the engine is running. Ear plugs protect the pilot from the noise, but using them radio use becomes impossible.

Most of the Selflaunch equipped sailplanes have a headset on board, and very few pilots fly



(a) Sustainer - noise protection (b) Selflaunch - noise protection

Figure 4: Percentages of means of hearing protection used by the pilots

without any form of protection when having a selflaunching glider. Pilots owning a sustainer equipped glider however, are less concerned with protection. Most of them use no protection at all, some use earplugs and only a small percentage uses a headset. The main reason for the lack of protection with sustainer pilots is that they use the engine only for so little time that it does not pay off to use some kind of protection.

Unfortunately radio communication is then also indicated as *bad* by the sustainer pilots.

Noise related comfort issues do not seem to be a large problem for the selflaunch equipped glider pilots, as they take a neutral position. The sustainer equipped pilots tend to take a slightly more negative position. The short engine times play a significant role in these results. For the small amount of time the pilots need the sustainer engine, they accept the noise burden coming with it.

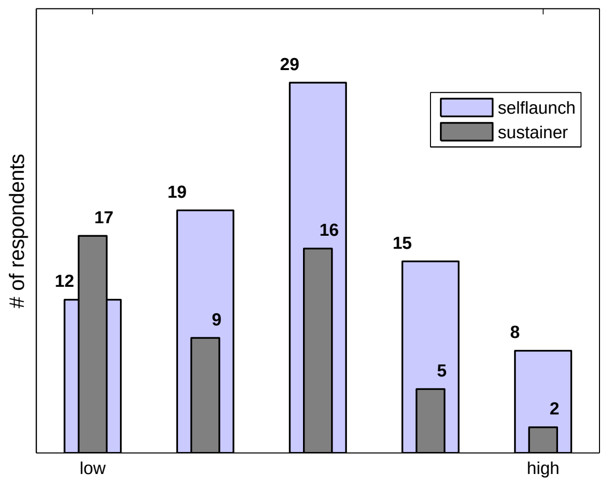
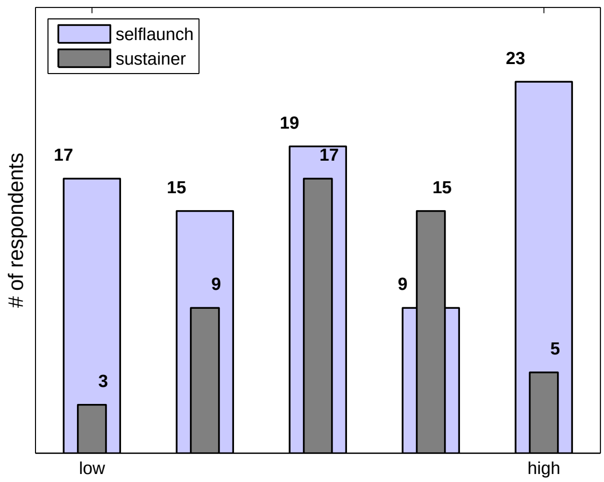


Figure 5: Comfortlevel due to engine noise - Selflaunch and Sustainer

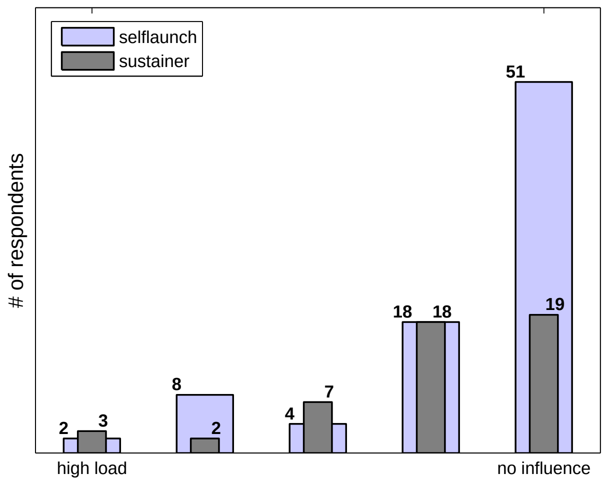
2.2.5 Vibration related results

To keep simplicity high and weight low, the engines used in sailplane propulsion systems are mostly small engines with rather bad vibration characteristics. The layout of the aircraft does not allow extensive mounting options, and the majority of the engine vibrations are communicated through to the airframe and pilot. Lots of small damages to the propulsion system and the airframe are caused by these engine vibrations.

Although many pilots complain about the vibrations in the comments, the results of the questions do not reflect these complaints, see Figure 6. Figure 6(a) shows a neutral position for the pilots owning a selflaunch capable glider. For the sustainer equipped glider this position even tends more to the comfortable side. The instrument readings do not seem to pose any problems for the majority of the pilots, nor do the loads on their flying skills.



(a) Comfort level due to vibrations



(b) Load on flying skills due to vibrations

Figure 6: Results related to the vibration level of the engine

3 Additional comments

This section gives an overview of the comments given by the participants in the questionnaire. At the end of the questionnaire the participants were asked for their ideas and wishes towards the development of new systems. These ideas for better new systems also emphasise the problems with the current systems.
Most of the comments given by the pilots are closely related to the subjects given earlier in this report. The answers are grouped in the following sections:

- Start-up sequence
- Structure related comments
- Performance related comments

3.1 Start-up sequence

Although the results in Section 2 show that most of the participants to the questionnaire do not experience the start-up sequence of the engine as a complex operation, many reactions ask for an easier start-up sequence that is less prone to making mistakes or forgetting necessary steps. Most of the pilots refer to the need for a one-lever operation for starting the engine. The extra comments given by the participants clearly confirm the findings as described in Section 2.2.3.

Related to the start-up sequence is also the height loss due to extending the engine, making a dive to speed up the propeller through windmilling. The whole process takes time, and the increased drag of the extended engine causes an increased rate of descent. Many pilots want less loss of height during the starting of the engine.
In this area, both a more efficient propeller and a faster extending of the engine can reduce the height loss considerably.
The biggest disadvantage of a large height loss during engine start, is that the pilot needs to initiate the engine start at a higher altitude. This makes him loose the opportunity to find the saving thermal he needs to continue his/her cross-country or competition gliding flight.

3.2 Structure related comments

Different types of damage were reported, some examples are given below, followed by a short analysis of the possible causes of these damages.

- Small cracks in the fuselage on the rest points of the retracted engine,
- Broken engine pylon,
- Electronic system failure made engine retract while still running,
- Loosening decompression valves and different bolts and screws,
- Cracking exhausts,
- Opening canopy locking mechanism while engine runs.

These are the most important types of damage given by the participants in the questionnaire. The source for most of the above mentioned damages can be traced to the engine's vibrations. It is clear that the engine is not isolated well enough from the rest of the aircraft. The impact of the vibrations on the comfort of the pilot is rather limited, but the system itself suffers considerably from the engine vibrations.

3.3 Performance related comments

A number of pilots indicate the need for more performance. Especially the sustainer systems lack performance. The selflaunch gliders have sufficient power because they have been designed to obtain sufficient acceleration and climb performance to make a safe take-off.
According to the manufacturers specifications sustainer system generally generate a rate of climb of approximately 1 m/s (1.9 kts), although a large number of participants report lower actual values. Instead of 1 m/s (1.9 kts), 2 m/s (3.9 kts) would increase the possibilities of the sustainer system. In addition to this, the pilot will feel more secure when climbing away with 2 m/s (3.9 kts) instead of 0.5 m/s (1 kts).
Another advantage of an increased rate of climb is the possibility of using sustainer systems at higher density altitudes, and in mountainous areas.
Flying in high density altitudes creates a false feeling of safety with an engine that produces small rates of climb. When the engine finally is needed, it cannot provide the necessary power to climb away. Therefore when flying in high density altitudes one always needs to keep in mind that the engine might not do what one would like it to do.

3.4 Future concept comments

In addition to the comment summary given above, some of the participants also mentioned the potential of new concepts in the propulsion systems for gliders.

First and foremost it must be noted that the engines currently used are not purpose-built for gliders, at the most they are modified before integration. A first new concept might be to continue using *combustion engines*, but instead of using existing models, developing an engine that fits the design of a sailplane perfectly.
Unfortunately the sailplane industry is rather a small-scale business and the costs of designing a new engine can be regained by selling enough aircraft.

Besides the traditional combustion engines new concepts are being investigated.
First there is the *electric engine*, a concept that becomes more and more attractive considering the point of view towards sustainable engineering. For the selflaunching gliders this concept has already been proven, for the sustainer equipped gliders, prototypes have been developed, but a series product has not been announced yet. Anyhow, this concept will gain potential as long as the specific energy density of the batteries keeps increasing.

Very recently the first series solutions of a *jet propelled glider* have been announced. Although the system is not certified yet, this might also be a solution for the future. Integration of a jet engine is easy because of its small size, but it has also some drawbacks; for instance, high fuel consumption and high noise levels.

There are many opportunities to make the propulsion systems in gliders more powerful, efficient and better to build. The future will tell which systems will remain, and prove their value.

4 Concluding remarks and recommendations

At the end of this report it can be concluded that the rumours and assumptions stated in the introduction are at least partially confirmed. There are clearly a number of problems with the current propulsion systems in gliders, both selflaunchers and sustainer equipped gliders. There is still room for improvement towards a perfect system.

Chances on failures after a successful test-run are too high in proportion to the operating frequency of the engine versus the flying time. The main causes for a failed engine start are mechanical problems or pilot error.
Reducing the chances on pilot error can be done by introducing a simple *one-lever* control mechanism. The mechanical problems can probably be diminished by optimizing the engine setup and engine mounting, but for that further analysis is required.

Additional comments learned that the sustainer equipped engines are not powerful enough to give the pilot the comforting climb performance he needs. Therefore it can be concluded that the performance of future systems needs to be increased. And next to the performance, the height loss during start-up is too high. This is caused by the increased drag of the extended engine, and the increased airspeed necessary to speed up the propeller. To increase the margins in this phase, this height loss must be reduced in future systems.

Lately some alternative designs for the propulsion system in a glider have turned up.
The two important and promising propulsion systems for gliders in the future are *the electrical propulsion* and *the jet propulsion*. Both systems have a lot of potential, but on the other hand there are some issues to resolve before arriving at a competitive design.

An indication of the important problems is known, and the wishes of the users are known as well. The only thing that remains is more research towards better systems. This can be achieved both by optimising existing systems, or by designing a completely new propulsion system.

A Appendix A

A.1 Introductory letter

As an introduction to my final thesis project at Delft University of Technology, I am conducting a small research to the use of engines in the sailplane industry. In this research both selflaunching and self-sustaining sailplanes will be considered.

Very often one hears gliderpilots say that the engines used in sailplanes are generally unreliable. Unfortunately, there are no official records that confirm these opinions. For that reason I use this questionnaire to get a right impression of the performances and the reliability of these propulsion systems.

The only purpose of this questionnaire is to get a real image of the functionality of these engines. This questionnaire has no intention of criticising the manufacturers of engines and sailplanes. On the contrary, the results of this research will be used to determine what the necessary changes will be for the future systems.

The data that will be retrieved through this questionnaire will not be published in detail. Only a broad summary will be made available on the internet. This will be done to avoid that these data will still be used to criticise the existing systems.

With this short introduction I want to ask you kindly to participate in this research. The more experienced users offer their participation, the better the results of this research will be. I tried to keep this questionnaire as short as possible, it will take only 5 to 10 minutes of your time. This questionnaire is made up in English and Dutch, and will be spread among the majority of the glider forums throughout the world, in order to reach as much glider pilots as possible.

A.2 The online questionnaire

The next three pages show the questionnaire exactly as it has been published online.

QUESTIONNAIRE: ENGINE USE IN SAILPLANES

General information

Sailplane type:		◯ **Self-launch** ◯ **Turbo**
Engine type:		
Year of construction:		
Flight hours:		
Engine hours:		
Country (registered):		

Use and Reliability

1. How often do you use the engine?

◯ Each flight; an engine run at the beginning and if necessary to avoid an outlanding.
◯ Only if really necessary (to avoid an outlanding).
◯ Seldom or never.

If you use the engine *seldom or never* on purpose, can you give a reason for that?

2. Has is occured before that the engine did not function when needed after a succesful engine run at the beginning of the flight?

◯ Yes
◯ No

If *yes*, was the reason known? And if so, can you shortly describe the reason of malfunction?

Further questions related to the engine use

3. Operation of the engine.

Imagine yourself being in the situation that you should perform an outlanding if you don't have an engine. Is the time needed to extract and start up the engine sufficient?

- ◯ Yes
- ◯ No

If *no*, can you give an indication about how much time or how many actions are needed to extract the engine and start it? Or can you give an indication of the altitude needed to extract the engine and start it?

	1	2	3	4	5
How do you experience the ease of operation of the engine? (1 = simple - 5 = complex)	◯	◯	◯	◯	◯
How does operating the engine affect your flightperformance? (1 = high - 5 = no significant change)	◯	◯	◯	◯	◯

Remarks:

4. Engine noise level

Do you use one of the following measures to attentuate the noise level towards yourself?

- ☐ Headset
- ☐ Ear plugs
- ☐ None

	1	2	3	4	5
How do you experience the comfort level due to the engines noise level?(1 = low - 5 = high)	◯	◯	◯	◯	◯
How does the noise level affect your flight performance? (1 = high - 5 = no significant change)	◯	◯	◯	◯	◯
How is the radio communication at running engine? (1 = bad - 5 = good)	◯	◯	◯	◯	◯

Remarks:

5. Vibration level

	1	2	3	4	5
How do you experience the comfort level due to the vibrations of the engine? (1 = low - 5 = high)	○	○	○	○	○
How do the vibrations affect your flight performances? (1 = high - 5 = no significant change)	○	○	○	○	○
How is the readability of the instruments at running engine? (1 = bad - 5 = good)	○	○	○	○	○

Remarks:

6. Did you already have some damage to your aircraft that was related to the use of an engine?
damage to the engine framework, structural damage to the aircraft, damage to instruments, ...

○ Yes
○ No

If so, can you give a short description of these damages?

What about future systems?

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7. In which areas should the current systems be improved according to you?

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-
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8. Further remarks related to this subject and/or questionnaire: