Bachelor Theses in Aeronautical Engineering
15 Credits, Basic Level 300

Project Solaris

Evaluation of EASA-regulations applied to a solar powered UAV

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ABSTRACT

This report is a part of the first phase of the Solaris project, where a solar-powered UAS (Unmanned Aerial System) will be developed. This part of the project concerns laws and regulations, both internationally and nationally. The report is largely adapted and targeted on the Solaris project but is also relevant for other UAS applications.

In Europe, all UAS - activities of aircrafts with a weight over 150 kg is regulated by EASA (European Aviation Safety Agency). For UAS with a weight below 150 kg, the responsibility has been delegated to a national level. The SBT (Swedish Board of Transportation) is currently working to develop a new regulatory framework affecting UAS - activities.

What has been done

- Evaluation of international and national UAS- regulations.
- Consultation with the SBT and other Swedish operators.

Conclusions

- Neither the development of the project nor the forthcoming flights are threatened by regulations. The new regulations are encouraging future UAS activities.
- Solaris is regulated at a national level by the SBT.
- UAS-aircrafts in Sweden are cathegorized into 3 categories where category 3 has the most demanding requirements on the aircraft and organisation.
- Solaris is a research project and will be issued an adapted permit from the SBT, hence it will be easier for the project to be able to perform flights without strictly having comply with regulations eg. category 3.
- A dialogue with the SBT should be cept during the development of the project to make sure Solaris is developed and constructed in a way to be able to receive a permit.
- As for now, Solaris can only be flown in segregated areas. In the future, UAS in civil air traffic will become reality.
SAMMANFATTNING


I Europa är det EASA som reglerar all UAS -verksamhet med flygfarkoster med en vikt över 150 kg. Reglerna för verksamhet med UAS:er under 150 kg har EASA lagt på nationell nivå där Transportstyrelsens luftfartsavdelning står för regelverket samt tillståndsgivning. Transportstyrelsen arbetar just nu med att ta fram ett nytt regelverk som berör verksamhet med UAS:er.

Vad har gjorts

- Utvärdering av nationella och internationella lagar och bestämmelser rörande UAS aktiviteter.
- Kontakt med Transportstyrelsen och Svenska operatörer för samråd rörande regler och drifterfarenhet.

Slutsatser

- **Lagarna kommer inte sätta stopp för projektet eller kommande flygningar.** De nya lagarna som är under utveckling kommer underlätta UAS verksamheten i framtiden.
- Solaris projektet regleras nationellt av Transportstyrelsen.
- Regelverket delar in UAS:er i 3 kategorier där kategori 3 ställer högst krav på flygplanet och organisationen.
- Eftersom det är ett forskningsprojekt kommer Solaris troligtvis inte betungas av alla de krav som ställs på en UAS organisation utan ett individuellt anpassat tillstånd ska kunna tas fram som gäller för Solaris och den verksamhet som är tänkt.
- Transportstyrelsen bör hållas uppdaterade under projektets gång för att lättare få ett individuellt anpassat tillstånd.
- I nuläget kan Solaris enbart flygas i avskilda luftrum. I framtiden kommer dock UAS intergreras med övrig luftfart.
## Abbreviations

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<th>Abbreviation</th>
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<tr>
<td>ACAS</td>
<td>Aircraft Collision Avoidance System</td>
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<td>AIP</td>
<td>Aeronautical Information Package</td>
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<td>AMC</td>
<td>Applicable Means of Compliance</td>
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<td>BCL</td>
<td>Civil Aviation Regulations.</td>
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<td>CAA</td>
<td>Civil Aviation Authority</td>
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<td>CPL</td>
<td>Commercial Pilot License</td>
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<td>CS</td>
<td>Certification Specifications</td>
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<td>DOA</td>
<td>Design Organization Approval</td>
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<td>EAA</td>
<td>Experimental Aircraft Association</td>
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<td>EASA</td>
<td>European Aviation Safety Agency</td>
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<td>GM</td>
<td>Guidance Material</td>
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<td>ICAO</td>
<td>International Civil aviation Organisation</td>
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<td>IFR</td>
<td>Instrument Flight Rules</td>
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<td>ITU</td>
<td>International Telecommunication Union</td>
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<td>JAA</td>
<td>Joint Aviation Authorities</td>
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<td>Joint Aviation Regulations- Flight Crew Licensing</td>
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<td>LFS xxx</td>
<td>Swedish Aviation Regulations</td>
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<td>NATO</td>
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<td>NOTAM</td>
<td>Notice To Air Men</td>
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<td>NPA</td>
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<td>PPL</td>
<td>Private Pilot Licenses</td>
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<td>PTS</td>
<td>Post and Communication Board</td>
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<td>SDRs</td>
<td>Special Drawing Rights</td>
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<td>SBT</td>
<td>Swedish Board of Transportation</td>
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<tr>
<td>UAS</td>
<td>Unmanned Aerial System</td>
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<td>UAV</td>
<td>Unmanned Aerial Vehicle</td>
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<td>VFR</td>
<td>Visual Flight Rules</td>
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<td>VLA</td>
<td>Very Light Aircraft</td>
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<td>WG-73</td>
<td>Work Group</td>
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<td>WM</td>
<td>Workshop Manual</td>
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**APPENDIX A. Application**

**APPENDIX B. Responsibilities**

**APPENDIX C. Operations Manual**

**APPENDIX D. Project Approval**

**APPENDIX E. Manufacture Approval**

**APPENDIX F. Workshop Manual**

**APPENDIX G. Kinetic energy**

**APPENDIX H. Project data**
1. Introduction

1.1. Preface

In 2009 Mälardalen University started a project called Project Solaris, lead by Gustaf Enebog. The project is intended to progress for approximately two years. The project consists of four phases:

- Feasability and conceptual design
- Detailed design
- Construction and initial flight testing
- Further development

This particular study is a part of phase one and is one of seven feasibility studies conducted by other students in various areas such as aerodynamic, and avionics etc. This project although a student and a research project is thought to hold a potential as a product for a market.

Västerås, May 2009
Erik Nordén and Jonas Malmquist
1.2. **Objective**

The purpose of this study is to investigate regulations and to evaluate the projects feasibility from a legal point of view. This study evaluates how laws and regulations apply to UAS today and what may be of relevance for Solaris. Thus this report can be considered as a guide for those who wish to work with UAS projects in Sweden.

1.3. **Problem formulation**

The challenge of this study is to find out which rules and regulations that applies to UAV’s today. There are many documents released from various organizations and because new regulations are under development there is a need to clear up what rules apply and which could be of relevance for the Solaris project. Questions that are to be answered are:

- Could solaris (from a legal point of view) be turned into a commercial product
- Will Solaris eventually be legally feasible
- What is needed to know for the development of Solaris

1.4. **Limitations**

This thesis will serve as a basis for further development of the project. The report covers as much as possible that may be of relevance to the Solars project within the time of 10 weeks and 15 ECTS credits. However it does not go any deeper into communication or the design aspects. It focuses on the Swedish CAA regulations for UAS since Solaris is planned for a weight far below 150 kg.
2. **Methods**

The first thing to do was to identify the problem, what was the purpose of this report and what was needed to find the answers? After establishing the problem formulation the preparation began. The preparations for this report consisted of reading and understanding publications and other materials available online and try to see it’s implications for our project as well as more generally how similar UAS-activities look like today, both nationally and internationally. Furthermore, contact with the SBT and other Swedish operators were established in order to via direct conversation with the authorities to achieve a clear picture of how the regulations works in Sweden and to take advantage of operators' experience. All the information and our conclusions have been summarized in this report.
3. Background

What is a UAV?

In order to better understand the content of this report and the work it deals with, a presentation of what a UAV is and stands for is prepared. UAV stands for Unmanned Aerial Vehicle, which is exactly as it says, an unmanned aerial vehicle. The aircraft is usually remote-controlled from the ground or flown without receiving input from the ground in an autonomous manner by pre-programmed flight plans and GPS navigation. UAV's can be found in a variety of configurations and types which are adapted to a flora of applications.

The earliest documented flights of UAV's are from the mid-1800s when Australia attacked the Italian city of Venice with balloons loaded with explosives. Although the balloons are not comparable with the current definition of UAV's, the concept was strong enough that as the airplane was invented, immediately military uses of unmanned aircrafts were found. As early as during the First World War, the first unmanned aircrafts were radio controlled from the ground, more like today's model aircrafts, which by the way also falls within the Group of UAV. During the Vietnam War the U.S military used UAV's equipped with cameras that recorded on film. These UAV's were not possible to control from the ground, but were sent up to fly in a straight line or in circles until they ran out of fuel, since the technology for radio control was limited and had poor range. After landing the UAV was recovered and the recorded material was analyzed. These UAV's were often called drones because of their function.

Development continued steadily in pace with the aerospace industry development and as computers evolved and became sufficiently powerful, the first programmable and autonomous systems evolved. The UAV could be programmed to a task which it then performed without the control of a pilot from the ground. Today's UAV's are often combining radio control with computerized automation to carry out their missions. Today military uses the technology for different applications: For remote sensing through the use of different types of sensors and cameras; for transport with cargo often embedded in the body of the aircraft but also as suspended load using helicopters as a launch platform. Search and Rescue is another type of application.
Although the development has been mostly done by the military, more and more civilian applications where UAV’s are of great value have been found. Forest companies use the technology in the inventory of natural resources. Other uses are fire fighting, traffic control, aerial photography, urban planning, coast guard and observations in dangerous environments, where you do not want to risk human health. In scientific purposes UAV’s may act as an instrument for collecting data such as weather, natural deposits and archaeological sites.

A name that is increasingly used when talking about UAV’s and mainly used in this project is UAS (Unmanned Aircraft Systems). The term UAS refers not only to the aircraft but also all the equipment needed to start, operate, carry and maintain aircraft and is hence referred as a system, as can be seen in the figure below. UAS has in recent years widely started to replace UAV both internationally and nationally in Sweden. The rules for UAV’s in Sweden and Europe are written to apply to UAS.

Figure 2. Sharc and filur two UAV’s developed by SAAB Aerosystems. Copyright SAAB AB. Ref 5

Figure 3. The different parts of the UAS. Ref. 16
4. Regulations

4.1. Authorities and organisations

The following authorities and organizations are working with the development of a regulatory framework surrounding UAS.

4.1.1. EASA - European Aviation Safety Agency

EASA is an EU authority and a single aviation safety authority operating under EC Regulation 216/2008, which recently replaced the 1592/2002 regulation. These regulations act as a framework of responsibilities to be fulfilled, after which the EASA implements more technical and detailed rules to achieve these so-called implementing rules. The implementing rules are followed by Guidance Materials and Acceptable Means of Compliance. Since EASA is a joint authority, the national authorities acts like an extended arm to EASA. National authorities must therefore comply with the EASA's rules as a minimum. EASA is responsible for development of rules, executing tasks such as certification, inspections and training. Rule proposals prepared by EASA or by working groups such as Eurocae are presented in a document known as the NPA (Notice of Proposed Amendments) and will be submitted to interested parts for comments. Sweden participates in the development of new rules in the EASA by participating in the Advisory Group of National Authorities which is a group that provides rule proposals to EASA. EASA is today only regulating UAS with a weight over 150 kilos. The A-NPA 216 is based on the JAA/EUROCONTROL joint taskforce report and brings up proposals about UAS certification procedures.

4.1.2. Eurocontrol

The organization was formed with the mission to make air traffic management more effective with preserved safety. Eurocontrol runs part of the European airspace and the goal is to create a border-free airspace over Europe. The original proposal came from ICAO which recommended a “single European sky”. Since the traffic is expected to grow over the forthcoming ten years the safety must be improved and this is one of Eurocontrols missions. In the document “Eurocontrol specifications for the use of military unmanned aerial vehicles as operational air traffic outside segregated airspace 25/04/06” are guidelines for military UAS that also apply civil UAS. These are guidelines for how to integrate UAS into air traffic.
4.1.3. Eurocae – European Organisation for Civil Aviation Equipment

Eurocae is a nonprofit organization formed in 1963 and consists of authorities, manufactures and operators from all over the world. The organization is from the beginning a forum that worked with avionics similar to the RTCA. Eurocae consists of a number of working groups that treats different areas. WG-73 is an expert group on UAS and gives regulation proposals to EASA. WG-73 was established in April 2006 and continues the work after Eurocontrol, NATO and the JAA. WG-73 consists of four subgroups where subgroup one treats “operation & sense and avoid”. Subgroup two treats “airworthiness and the continued airworthiness”. Subgroup three treats “command and control, communication and spectrum security” and subgroup four treats UAS below 150 kg. The goals of WG-73 are:

- *A framework of requirements that will support civilian UAS airworthiness certification and operational approvals.*
- *Safe operation within non-segregated airspace in a manner compatible with other airspace users.*
- *Compatibility with the existing ATM regulatory framework, existing ATM infrastructures, existing procedures, and without degrading ATM efficiency*  

4.1.4. ICAO – International Civil Aviation Organisation

ICAO is an international organ that governs the development of the flight safety over the entire world. ICAO consists of 18 annexes which treats different areas. ICAO standards are regulations that must be followed by the member states, but the recommended practices are only recommending actions. The 18 annexes consist of both standards and practices.

The unmanned Aircraft Systems Study group (UASSG) consists of representatives from organizations like Eurocae, Eurocontrol, EASA and the Swedish CAA. The UASSG will assist the secretariat with SARPS (standards and recommended practices) in order to eventually be able to integrate UAS into non-segregated areas.

4.1.5. Swedish Board Of Transportation

The SBT is a Swedish governmental administrative authority which has the main tasks of regulation, authorization and supervision in the field of transport. The SBT is a joint organization consisting of the authorities of air, rail, sea and road. The part of the SBT that concerns Solaris is the Civil Aviation Authority, situated in Norrköping.
The Civil Aviation authority is working to develop rules, perform audits, issue licenses, and reviews the civil aviation with focus on safety. It also has a section which specifically affects issues and permission to operate UAS systems. The SBT is responsible for the regulation for UAS below the weight of 150 kg, weights above 150 kg is handled by EASA.

Figure 4, Illustration of authorities and organisations controlling UAS.
4.2. Documents

When the SBT reviews an application to operate a UAS in Sweden, following documents are used as a basis. It might be useful to look into these documents during the development of a UAS.

4.2.1. UAS TASK-FORCE

JAA-Eurocontrol UAV Task Force is a group that has worked with developing a concept of rules for the UAV in civil aviation. The report includes safety, airworthiness, continuing airworthiness, maintenance, approval and licensing. The Task force was established after an initiative by the JAA and Eurocontrol. Many other countries participated in the development of this report that does not focus upon UAS below 150kg, but can be of use since cat.3. is quite similar to UAS above 150kg.

4.2.2. CAP722

CAA is the aviation authority in the United Kingdom. CAP 722 is a document prepared by the CAA and acts as a guide of how to operate with UAS in the UK. Many parts of this document are useful not only for UK but also for other nations. The document will provide a guidance for how to meet the requirements in safety during the phase of development in order to ultimately be able to certify an UAS.

4.2.3. BCL-T

The SBT releases constitutions called BCL:s. BCL-T stands for civil aviation regulation – Airtraffic.
4.2.4. Other documents of relevance to the project

“Eurocontrol specifications for the use of military unmanned aerial vehicles as operational air traffic outside segregated airspace”
The document written by Eurocontrol is made for military UAS but is applicable on civil UAS as well. The document concerns integration of UAS’s in civil air traffic

“Advance – Notice of proposed amendment NPA No 16/2005 Policy for Unmanned Aerial Vehicle certification”
NPA-16 is a document from EASA and the first step to a more extensive constitution and policy for UAS certification.

” Information needed for UAV flight-Authorization”
A document written by Lars Sundin at the SBT and updated by Erik Bergdahl. The document serves as a template for an application. It specifies in paragraphs what information the SBT needs in an application.

” Flying with unmanned aircraft (UAVs) in airspace involving civil aviation activity. Air safety and the approvals procedure”
A document from the SBT written by Eskil Wiklund. It describes procedures of construction and in part also the operations.
4.3 Swedish operators

There are a number of Swedish operators who have been approved by STB to operate with UAS’s. These are:

**Linköping University**

Linköpings University operates autonomously with two RMAX helicopters(Figure 3) developed by the Yamaha Motor Co.

**Smartplanes**

The company manufactures and sells complete UAS systems and education. The applications are mainly for aerial photography in various forest and agricultural applications. Can be flown with autopilot.

**HW Postcards**

The company uses a German surveillance helicopter, MD 4-200, equipped with a digital camera for aerial photography.

**Cybaero**

Cybaero has developed a helicopter which flies autonomously with military applications. It can be configured in to many options, depending on the customer’s demands.
**SAAB Barracuda**

SAAB Barracuda works with military camouflage. In order to perform visual tests from the air they use a UAV with camera in order to save costs on a full-scale helicopter or airplane.

**Flyingoptics**

The company flies a helicopter with four rotor blades when photographing in similar way as HW Postcards.

**Helicopter View**

Helicopter view flies to take photographs and record video with helicopter and a Zeppelin aircraft.

**Airghost**

Airghost uses a relatively large RC helicopter, PN 512, equipped with camera for aerial photography and surveillance.

**Videobolaget, Helifoto och Reidevalls flygfoto**

The companies flies different types of RC-helicopters equipped with a video camera for photographing/video recording.
4.4. The Swedish Board Of Transportation regulations and general advice on the operation of unmanned aircraft

This is an analysis of the SBT’s rules and guidelines applicable on unmanned aircraft. A review of the arrangements will be made and parts concerning the Solaris project will be explained in more detail. To some extent also the technical documents and applications for the Solaris project will be created (Placed in APPENDIX).

4.4.1. Applications

The regulatory framework is developed to support the civilian operators who operate with unmanned aircraft in Sweden. The regulatory includes rules for design, manufacturing, modification and maintenance of unmanned aircraft with take-off weight below 150 kg, and those that are designed and constructed for experimental, research or scientific use whatever the start weight. These regulations shall apply to the unmanned aircraft which are designed or used for:

1. Testing, research
2. Commercial purposes, which charge for their services
3. Occupation
4. Flown out of sight to the pilot

The Solaris project will primarily fall under category 1, but towards the end of the project, it is also possible that category 4 will be relevant.
4.4.2. Classifications of UAS

As mentioned earlier, UAS’s can be designed very differently, towards many different fields of applications. This means that it would be unreasonable to impose the same requirements for all UAS’s and their operating organizations. Some UAS’s are more like small model airplanes and are controlled from the ground with eye contact by the pilot. Others are much heavier and designed to navigate and carry out their duties out of sight of the pilot. With this in mind, three different categories have been developed, in which the requirements for UAS systems and their operators differ widely:

Category

- **1A** - UAV with a maximum take off weight equal or less than 1.5 kg, which develops a maximum kinetic energy of 150 J and is flown within sight of the pilot. For 1.5 kg this corresponds to a maximum speed of about 14 m/s.

- **1B** - UAV with a maximum take off weight between 1.5 kg, and 7 kg, which develops a maximum kinetic energy of up to 350 J and is flown within sight of the pilot. For 7 kg this corresponds to a maximum speed of approximately 10 m/s.

- **2** - UAV with a maximum take off weight between 7 kg, and 150 kg flying within sight of the pilot. No direct requirement for kinetic energy.

- **3** - UAV that is equipped to be flown out of sight from the pilot, with a maximum weight of 150 kg.

- UAV’s with weights over 150 kg is placed in a class of its own that is governed by EASA.

APPENDIX G shows the kinetic energy for different weightclasses of UAS’s.

Without knowing the exact weight of Solaris when fully developed, a very early estimate of 5 kg has been made leading Solaris weight in category 1B. However, there is also a goal to be able to fly out of sight from the pilot, which means that Solaris still fall into category 3, which is the class with the greatest demands on the organizations and aircrafts. One possible way to reduce this work is to first categorize Solaris in category 1B while carrying out flight testings, and then if these are successful, move on towards the more demanding category 3.
4.4.2.1. UAS above 150 kg

The EASA rules applies only for UAS with a weight of 150 kg and over. This joint authority is where you should turn with a UAS within this category. In principle, the same safety standards applies for this type of UAS’s as for manned flights. This means that it certifies after CS-25, 23 or VLA depending on the size of the aircraft. A new CS (Certification Specifications) is under development (CS-UAS) and will be adapted for UAS. Part 21 is applicable, which means a DOA (Design Organization Approval) will be needed by the company and a Certificate of airworthiness. For the continuing airworthiness Part-M with subparts C, D, E, H, I and F applies. The maintenance must be performed by an approved 145 workshop and Form 1 must be issued on components. Along the airworthiness of an UAS the system itself must also be thought as worthy as the whole system needs to be approved. If you fly in remote areas, a limited TC (Type Certificate) and Certificate of Airworthiness can be issued. This makes it easier to certify more UAS’s and boost the development of regulations and UAS.

As mentioned earlier, UAS’s below 150 kg are governed on a national level and a DOA is not required. Thus, alternative procedures can be used for certification. The Swedish authorities have chosen to follow the international rules as much as possible and today, Sweden is at the forefront of rule development of UAS less than 150 kg. When applying for certification in Sweden, each case is individually reviewed and a permit based on the type of UAS and what type of operations will be issued.

Figure 13. Describes the similarity between a manned flight and a UAS over 150 kg or Category 3. Ref 20.
4.4.3. Permission

In order to operate a UAS in Sweden it is necessary to seek permission for the operation from the SBT. The permit is sought for the class or category the UAS fall below. Solaris would by weight be classified as 1B but to be able to operate out of sight from the pilot it must later be classified up to category 3, because not all the requirements for category 1B are being fulfilled.

Category 1 only requires the operator to turn in a notification of the activities to the SBT. This review will provide a simplified permit that is valid indefinitely. The following information shall be included in the notification for Category 1:

- **Operator data**: name and company name, address, telephone number, e-mail and corporate identity.
- **UAS system**: a description of the aircraft with data for the type, manufacture, weight, performance, propulsion and control systems. Photo or exploded view of the craft must be attached. If the UAS is of category 1B also the failsafe system must be described.

Permission for category 2-3 obtains in a similar way but is valid for one year. The renewal of the permit may be extended to a maximum of 2 years at a time. The following information shall be included in the notification for Category 2:

- **General information**: The operator's contact details, description of organization and management of the proposed activities and curriculum vitae of accountable manager, flight manager, technical manager and the pilot. Birth certificate or registration number, depending on business type. Description of the proposed activity, description of the UAS system for category 1 and how to meet the other requirements for category 2 and a copy of insurances.
- **Operation and Maintenance Manual**: Operation and maintenance manual shall be designed as described in chapter 4.6.3 operation and maintenance manual.

The application for permission of category 3 is conforming to the largest part of category 2. In the new regulatory proposal for UAS from the SBT, a template for category 3 had not been included as the most common categories will be 1-2 and that notification of category 3 will be similar to category 2. A preliminary notification for category 3 and Solaris has been created and can be found in APPENDIX A. Since all the info needed to create the application is not yet available some assumptions and guesses about the aircraft and organization have been made, but with some updates the notification can function as a model to the final application.
4.4.4. Safety analysis
While developing a UAS it is needed to prove that the SBT overall safety goals are met by performing an analysis on the system. This kind of system analysis must be shown to the SBT and be approved before an approval can be issued.

The overall safety objectives are:

- *It should be very unlikely that any deaths occur on the ground in the case of an accident, a maximum of one person over a period of 50 years may be permitted.*

- *The individual risks for people on the ground should be 100 times lower than for road traffic*

- *UAS may not cause more air incidents than the manned flight suffered from the last decade.*

Depending on the size of the operation and the complexity of the UAS itself the extent of the analysis can vary. For example, a "Preliminary Hazard Analysis" can be enough for a UAS that flies in sight of the pilot. If the aircraft is to be flown out of sight of the pilot, a more extensive analysis will be required, including a probability that an accident would occur. If the UAS is intended for airspace shared with other aircrafts additional requirements will be added and one must calculate the probability to collide with other aircrafts, must be calculated for.

4.4.5. Preliminary hazard analysis
A preliminary risk analysis should be preformed at an early stage so designers can avoid these potential failure modes. Examples of possible failure modes can be:

- Loss, degradation or incorrect data between the operator and the aircraft
- Loss or degradation of the contact with air traffic management
- Difficulties of controlling the aircraft or decreased ability to fly autonomously
- Problems resulting in stopping the safety systems from working, or with limited functionality
- Mistakes made by the operator or air traffic as a result of misleading data
- Link interferences disrupting the connection between the UAS and the operator
- Structural failure of the aircraft leading to breakdown

The analysis must show that the applicant has reviewed the risks that can be found and how these risks are to be eliminated. All types of error should be considered, both in hardware and software. The human factor must also be taken into account, wrong decisions can be made and wrong buttons may be switched by accident. Therefore this
analyses should be included, giving room for making mistakes when operating the UAS and to be able to build safety nets in the system design.

How these analyses are made can be found in EASA CS-23 or CS-25 under section 1309 "System Design and Analysis" and in the AMC (Applicable Means Of Compliance). According to the SBT, these standards can initially serve as an approach and not as requirements. Information of the system development analysis can also be read about in the "Civil Avionics Systems by Ian Moir and Allan Seabridge G 2006 Ref 14" which describes these different methods of analysis.

In the document “flight with unmanned aircraft (UAV) in airspace with civil aircraft operations” by Eskil Wiklund describes how to calculate the probability of an accident using a given formula. This probability must agree with the SBT’s guidelines.

4.4.6. COTS– Commercial Off The Shelf

COTS are products that are commercial available. These products are not custom made and are used in their current conditions. This includes both hardware and software. The advantages of these types of products are that they are easily accessible, there are many possibilities of choices and that they are cheaper. It is likely that Solaris widely or solely will consist of COTS-parts. The main disadvantage of COTS is that the quality of these products can not be verified in a good way. It must therefore be assumed that non-predictable failure modes may occur, leading to risks with such frequency that the air safety goals are not met.

If COTS products are to be used in safety critical systems the applicant must be able to demonstrate that air safety can be maintained even if errors in hardware or software of COTS-products would occur. Alarm features that makes the staff aware in the event of an error will be required and methods describing how to proceed in the event of failure must exist. If this is not possible and if the quality verification can not demonstrate, COTS products can not be used in safety-critical aviation systems.
4.4.7. Insurance

It is required for a UAS operator to be insured in accordance with the European Parliament and Council Regulation (EC) No 758/2004 (insurance for air carriers). This is a set of rules that apply to all air operators and not only UAS operators. The parts that apply to a UAS operator states that the operator must have an insurance policy to cover third part, covering death, personal injury or damage to property caused by an accident. A craft under 500 kg requires an insurance policy that covers at least 0.75 million SDRs (Special Drawing Rights). SDRs are a type of international currency or shares created by a number of countries' currencies in order not to be affected by individual countries' crises. 0.75 Million SDRs (Special Drawing Rights) are equivalent to approximately 9 million Swedish SEK.

Contact with some of the Swedish UAS operators revealed that they all have insurance for third parts, however, it seemed difficult to find an insurance company for damage to the UAV at a reasonable price, and most respond that they had no such insurance.

One possible insurance company for the Solaris project could be "Inter Hanover", an insurance company which at least one of the Swedish UAS operators use but which also is common among other flight clubs. Swedish EAA (Experimental Aircraft Association), which is an association for experiment class and home-built aircrafts, has a contract with Inter Hanover with very favorable prices for their members.
4.5. Requirements for UAS Category 1

In order to get a permit for category 1 a range of criteria must be fulfilled and followed. These rules govern how you may fly, the operator's responsibility, pilot responsibility and handling of the aircraft. Below is a list of the rules from the SBT regulations:

- The aircraft must be operated well within sight of the pilot without aids (binoculars) and the within the operational range of the aircraft.
- Before a considered flight, it should be planned and prepared on a flight map to see in which type of airspace the flight will be implemented. Operation in controlled airspace may only happen with the permission of and with the conditions provided by ATM (Air Traffic Management).
- Operation in restricted areas is only allowed if the field is not enabled or permission given from the ATM or the appropriate authority.
- The flight must not be carried out at night.
- The pilot should be familiar with the aircraft’s performance and control, and must have ascertained that the flight can be done in a safe manner.
- For each flight a pilot will be designated as the commander, with ultimate responsibility.
- The operator must ensure that the UAS is maintained according to the manufacturer's instructions and that the system is being checked before flight.
- The operator must ensure that the system is kept intact during the entire flight, e.g. falling objects can constitute a danger to the public.
- The aircraft must be labeled with the operators name and phone number and the aircrafts registration number+ allocated by the SBT.
- Accidents or incidents which have caused damage to animals, people or property on the ground or in the air must be reported to the SBT.
In addition to the above paragraphs, each category must also fulfil the following:

4.5.1. Specifically for Category 1A:

- A flightzone and a safety zone must be established before the flight. The area should have a sufficient safety distance (50m) to humans, animals, vehicles and other property not involved in the activity, in such fashion that nothing or no body can come to harm during the flight.
- The flight must be performed on such altidude that the craft is easily visible to the pilot and the air space must be monitored so the flight can be terminated if another aircraft is approaching the area.

4.5.2. Specifically for Category 1B:

- A flightzone and a safety zone must be established before the flight. The area should have a sufficient safety distance (50m) to humans, animals, vehicles and other property not involved in the activity, in such fashion that nothing or no body can come to harm during the flight.
- The flight must be performed on such altidude that the craft is easily visible to the pilot and the air space must be monitored so the flight can be terminated if another aircraft is approaching the area.
- The UAS must be equipped with a built in failsafe system, which can terminate the flight if, for example, radio connection is lost.
4.6. Category 2

4.6.1. The organization
Every UAS organization must have an accountable manager, approved by the SBT. The accountable manager shall ensure that all activities are conducted in accordance with the restrictions issued by the SBT and applicable laws.
Every organization must have a person responsible for the flight operations and a person responsible for maintenance activities. If the operations are small like the Solaris project the same person can have both responsibilities.
The responsibilities of the technical and flight managers can be found in APPENDIX B.
UAS operations must always have a person serving as flight and technical managers. Any changes must immediately be reported to the SBT. Operations without these positions are not allowed.

4.6.2. Technical regulations
An UAS-aircraft which fall under category 2 must be equipped with a failsafe system that terminates the flight if contact with the UAS is lost.
If the UAS is able to fly on a preprogrammed route the operator must be able at all times to take over control and fly it manually.
Manuals for the system and for its management should be easily available.
Maintenance should be done according to checklists included in operating and maintenance manuals.
Parts may only be replaced by original parts or parts that are completely equivalent.
The UAS must as far as possible be designed in such manner that if an accident occurs, no harm to other persons or properties will occur.
The UAS must be labeled with the operators name, contact information and the aircraft’s registration number.
4.6.3. Operations and maintenance manual
An organization within the limits of category 2 must establish an operating and maintenance manual. This handbook should serve as guidance for the staff, describing how operations are to be conducted. It is the organization’s responsibility to ensure that the manual is lawful and to notify any changes to the correct authorities. This manual is part of the SBTs decision for issuing permission. The manual shall contain the following points:

- The organization illustrated by a chart and all the responsibilities of the positions.
- Description of the operations and operational restrictions
- Instructions and checklists for the preparation and execution of missions
- Maintenance instructions with checklists
- A fail safe analysis where possible errors are analyzed with the corrective action

4.6.4. Limitations
SBT grants permission on a case by case basis, depending on how the UAS vehicle is constructed. The following restrictions can apply.

- Flight is not permitted in areas where the aircraft imposes a threat to harm people, animals or properties in a case of uncontrolled flight.
- A safety zone must be set up with least 50 meters.
- Flight with the UAS when it is out of sight for the pilot is not permitted for category 2 aircrafts. The operator must also take the topography into account and other obstacles that may obstruct the radiolink.
- Maximum altitude is 150 meters above sea or ground level.
- Operation in controlled airspace is only allowed after authorization.

4.6.5. Before flight
Before flight, the proposed airspace must be examined using an aerial map. It must be made sure that no obstacles such as powerlines, are nearby. The provincial government, police and the municipality should be contacted so the flight can be performed as safe as possible.
4.6.6. In flight
While establishing the frequency spectrum for a UAS operation, frequencies approved must be used allowed by the PTS (Post and communication board).

- The weather must allow for that the pilot to have visual contact with the UAS at all time and the maneuvers to be performed in a safe way. If the weather deteriorates the flight shall be aborted.

- UAS must sidestep for all manned aircrafts.

- If someone enters the flight safety zone the flight must be aborted.

- For night operations the UAS-aircraft must be equipped with anti collision beacons on the sides and the pilot must meet the requirements for the dark flight theory according to JAR-FCL 1125.

- Minimum age for a UAS category 2 pilots is 18 years.

4.6.7. Reporting
Any accidents or incidents on the ground or in the air must be reported to the SBT. Any deviation from the operating instructions or the issued permit must also be reported if a risk of harming anything or anyone was present. The reporting is important in order to be able to spread knowledge to other UAS operators, thus learning from others mistakes and preventing more incidents.
4.7. UAS category 3

Aircrafts flying out of sight of the pilot falls into category 3, regardless which the weight. If the UAS falls within category 3, more requirements apply, which are similar to the requirements for manned flight. For example, the pilot will be required to have a theoretical CPL (Commercial Pilot License). This category is for UAS that will fly in all kind of airspaces on a routine basis.

Below is listed some points of importance for flying out of sight.

- The aircraft must be equipped with a Sense and avoid system.
- Communication with the ATM must be established at all time and not give the ATM more work load than other traffic.
- Frequency spectrum (what applies here is expected to be completed in 2011 by the organization ITU).
- Airworthiness (requirements for the design refers to “CS-23/VLA”).
- Training and Certificates required for category 3 personnel.

To be able to fly with UAS, permission from the Swedish CAA must be obtained, issued for the area intended to fly in. If the flight intended in a non-segregated area it must be demonstrated to the Swedish CAA that it does not pose a threat for the safety of other aircrafts or third parts on the ground, and that the system has a safety level which is equivalent or exceeds the civil aviation safety standards.

4.7.1. The organization

The organization for category 3 is equal to the organization for category 2, see 4.6.1. The responsibilities for the flight commander and the flight operations manager responsibility are listed in APPENDIX B.
4.7.2. Reporting
Any accidents or incidents on the ground or in the air must be reported to the SBT. Any deviation from the operating instructions or the issued permit must also be reported if a risk of harming anything or anyone was present. The reporting is important in order to be able to spread knowledge to other UAS operators, by learning from others mistakes in order to prevent more incidents.

4.7.3. Operations manual
Any operations which falls within category 3, must establish an operating manual. This manual shall describe how the operations are carried out and how the preparation, operation and maintenance is conducted. It is important to describe “how to” and not “what to” do according to Erik Bergdahl at the SBT. This is because the manual is supposed to be used as a handbook for the personnel. The handbook must be continuously updated and the staff and the Aviation Board must be notified every time it is updated. When the authorities issue a permit or perform an audit the Operating manual is used as part of their review. The handbook can also be used as a checklist for staff, since all procedures can be found there. A template for an operation manual can be found in APPENDIX C.

4.7.4. Airworthiness certification
When a UAS system is developed, a project approval must be obtained according to BCL-M 1.6, subsection 4.1. Flight test permission is sought under the BCL-M 1.6, subsection 4.2.3. Since there is no design standard for Solaris, an adapted design standard for manned flight should be used and approved by the SBT under BCL-M 2.1. Since Solaris is an experimental aircraft with a unique design, a continuous dialogue with the SBT should be held during the entire development of Solaris. If the SBT is continuously updated on the project they can provide advice and guidance to keep the project on the right track. A contact with the SBT has been established and informed of the project existence. The SBT have also been provided a "back of envelope" sketch of Solaris. Solaris will in the beginning be a category 1b or category 2 aircraft and will initially not be required for having a certificate of airworthiness, as is for category 3 and aircrafts above 150 kg.
4.7.5. Maintenance

The requirements of the maintenance organization are assessed in each case with respect to the extent of the operations so the system is kept air worthy and system worthy. Contracted maintenance is possible but less likely for the Solaris project since it is a research project. The case of contracted maintenance, primary responsibility for maintenance lies either with the operator or the contracted maintenance organization.

The SBT may grant permission for the UAS operator to manufacture replacement components such as hoses or rudder cables. If the UAS organization acquires material from an outside company (e.g. raw materials and spare parts) the UAS operator is responsible for the quality and origin of the material and that it complies with the BCL-M 3.2 (regulations of materials), which includes maintenance and modification of maintenance. Only a government department or a government-approved company is allowed to perform material testing and calibration of measuring equipment. If a private company is hired as a subcontractor for this purpose, it must be a well-known actor on the market.
4.7.6. Technical staff
The technical manager is responsible for ensuring that all staff possess the knowledge required for their assignments and that sufficient staff is available. This also applies if the activity is carried out at a place other than the home base (provided that maintenance is not subcontracted). Delegation of responsibilities is allowed, but only after the procedures established by the UAS organizations. The technical manager must ensure that the staff has access to documents, training methods and tools so that work is performed properly and reliable. The Technical manager is also responsible for that the stated instructions are followed.

4.7.7. Facilities and equipment
Premises for UAS maintenance should be adapted after type of UAS. Workshop facilities and maintenance facilities must be heated, have an appropriate humidity and be protected against dust and dirt. Material that is "unserviceable" and awaiting maintenance must be kept separate from airworthy material. See BCL-3.3 Aircraft workshop.

4.7.8. Work orders
For maintenance operations work orders must exist.

The work orders must contain at least the following:

- A description of the aircraft type
- Requirements for maintenance of the aircraft type, such as daily, periodic, special inspections and overhauls of aircraft and components. Also intervals, time and storage time should be provided in these documents
- Procedures for how maintenance is carried out. Maintenance procedures from material manufacturers should also be included, such as for instance the solar voltaics manufactures. Maintenance procedures that the UAS organization carried out itself is to be included.
- Lists of different overhauls should be included in the WM.
4.7.9. Work methods

Below follows a list of procedures that the UAS organization must establish:

- Working methods for manufacturing, generally standardized production methods like riveting, heat treatment, bonding and finishing
- Working methods for welding, brazing and soft soldering of aviation products which comply with the regulations stated in BCL-M 3.3.
- Procedures for the storage of raw materials and consumables
- Protective measures and procedures for storage, transports, labeling, storage time and how to distinguish between airworthy materials and other materials
- Procedures for audits and the follow up of aircraft documents. (This is described in the BCL-M 1.1)
- All maintenance should, if possible, be conducted at the home base. If it becomes necessary to conduct maintenance at another location the UAS operator must have established procedures for how this is to be done. It is the technical manager’s responsibility to ensure that the personnel has the right education and that the documentation, the tools and equipment, proper facilities and spare parts are available.

In order to carry out an overhaul flight evidence of competence must exist inform of a certificate. This certificate is issued by the technical manager and contains the name of the operator, certificate number and the name of the holder, type of overhaul and the validity of the certificate. It must show that the technical manager issued the certificate and that it only applies when the staff is serving as an employee at the organization where the certificate is issued. The technical manager shall establish training plans and manage the examination, he also establishes instructions and overhaul lists. It is important that staff have access to overhaul lists when the aircraft is in flight. The technical manager must compile all issued certificates in a document, with names and certificate numbers and make sure the document is kept up to date.
4.7.10. Audits
In order to keep a good standard of the maintenance a control system of the production and the quality should be available.

Production control includes all inspections that are described in the WM, overhauls not conducted by a licensed staff, overhauls stated in the WM and repairs and modifications should be included.

In order to maintain an acceptable maintenance standard following should be reviewed:

- Qualification of maintenance technicians
- Workshop facilities and equipment
- Working methods and processes
- The standard of maintenance both on external stations and on home bases
- Aircraft materials and raw materials from suppliers in terms of acceptability
- The standard of storage and transportation
- The reliability of measuring equipment
- Documents

4.7.11. Technical records
All maintenance performed and the technical status of the aircraft must be documented through technical records. Technical records exist to make sure that all staff are informed of the system and the maintenance status of the UAS system.

Technical records contain the following points:

- Standard forms for propeller or engine, time periods, performed maintenance, modifications and calendar times.
- Instructions for how these forms should be used and treated.

The SBT uses the workshop manual as a part of their review when the first certificate is to be issued. It is also important to inform the SBT when changes are made to the WM. See APPENDIX F for the content of the WM.
4.7.13. Operational staff
Before each flight, a commander must be appointed. If the flight lasts for longer periods at a time a duty-roster must be established to make sure that a commander always is present throughout the flight. To not jeopardize flight safety, the periods of service for the commander and pilot should be defined. Account must also be taken for how much the pilot or the commander has flown previously without resting and how they have served in other contexts. Records of flight time and duty periods must be kept, and these must be saved for 12 months. The commander’s responsibilities are to be found in APPENDIX B.

4.7.14. The Pilot
A UAS pilot must undergo UAS-training approved by the SBT or undergo theoretical training for a CPL. He or she with a minimum age of 21 years must also have training in the system of the UAS and meet the medical requirements for air traffic controllers. IFR training is required for IFR (Instrument Flight Rules).

4.7.15. Requirements for access to energy
No special rules that treat the access to energy for solar powered UAS exist today. The problem with solar power is that there is no guarantee that there will be sun throughout the flight. According to the SBT there must be a backup solution of some kind approved by the SBT, when flying over non-segregated areas. One possible solution could be backup power batteries which supplies the emergency systems, control surfaces and possible, powering the propulsions for a short period of time. When consulting the SBT in this matter at the time of writing, it is not yet clear what rules apply. This is one reason of why the SBT should be consulted during the development phase. When it is decided how Solaris is supposed to be used it will be easier for the SBT to issue a permit. A demand on backup power is however not required when flying in remote segregated areas and in sight of the pilot.

According to the proposed rules for UAS flying in non-segregated areas, flights may not take place if there are any doubts that the energy supply will not be sufficient for the mission. Account must be taken on the weather and how reliable the weather forecast is. Also any changes in the mission as for example air traffic control directives and the possibility of diverting to alternative airports that may cause higher energy consumption than expected.
## 4.7.16. Equipment requirements for special conditions

The following equipment is required for each type of flight condition.

<table>
<thead>
<tr>
<th>Visual flight rules (VFR)</th>
<th>Instrument flight rules (IFR)</th>
<th>Flying in dark conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Airspeed indicator</td>
<td>- VFR equipment</td>
<td>- Navlights (see EASA:s CS)</td>
</tr>
<tr>
<td>- Altitude indicator</td>
<td>- Preassure altitude indicator</td>
<td>- Landinglights</td>
</tr>
<tr>
<td>- Position/course indicator</td>
<td>- Clock</td>
<td></td>
</tr>
<tr>
<td>- Energy indicator</td>
<td>- Attitude indicator</td>
<td></td>
</tr>
<tr>
<td>- Fault indicator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- System that detect weather conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Ground proximity warning system</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Icing conditions

- The aircraft must be protected against icing and the pilot must have the appropriate training

### Airspace with special requirements

- See Swedish CAA (LFS 2007:25) for areas with reduced vertical space
- See BCL-D 1.21 for R-NAV
4.7.17. Other equipment

To fly in airspace with air traffic, all UAS’s must be equipped with a transponder according to (LFS 2007:26) and an ACAS (Aircraft Collision Avoidance System), a sense and avoid system. If an ACAS is missing, another system can be used if it is possible to prove that the system is safe. This is a critical part for the integration of UAS in civil aviation. Systems of sense and avoid, communication and navigation are large areas under development and are not specifically addressed in this report. Even small UAS that flies out of sight needs this system. It might be thought that an object of 1-2 kg can not inflict any larger damage. The figure on the right demonstrates a birdstrike with devastating consequences. Solaris with its weight of about 5 kg would inflict great damage if it would collide with another aircraft. Before the integration of UAS in civil aviation clear rules must exist. The EASA report from February 2009 "Inception Report of the Preliminary Impact Assessment on the Safety of Communications for Unmanned Aerial Systems (UAS)" is one document that addresses this matter.

Equal to flight data recorder on a manned aircraft, an unmanned aircraft must be able to record all in- and outputs in order to reconstruct a flight.

4.7.18. Com/nav

Rules for frequencies are today being developed at an international level by the ITU (International Telecommunication Union). To find out what frequencies apply to UAS the PTS must be contacted. The UAS navigation equipment must be able to show its exact location and be approved by the SBT and must also be compatible with the ATM system, meaning that the UAS must not put any more workload to the ATM then other aviation. The crew of the UAS must at all time make sure that contact with ATM is established and also have the possibility to have a two-way communication with the air traffic controller.

4.7.19. Safety systems

The SBT requires from issued permits that a security system can abort the flight, for instance if the datalink is lost. One example of an emergency systems used today is a so-called "go home system ". In an event of a failure the aircraft will return to its base. Another system will put the control surfaces in a certain position so the aircraft rather floats down to the ground than crashes. The option of having an emergency parachute installed on Solaris has been discussed within the project. The SBT’s response is that it may be a good idea to minimize the damage to both the aircraft and whatever might be on the ground.
3.7.1.20. Fees

The SBTs fees for inspections and approvals are compiled in LFV2008:54. Below is a table of the various UAS categories and fees. The SBT estimates the cost for permits to a few thousand SEK.

Table 1. Fees for different UAS categories. Ref 18.

<table>
<thead>
<tr>
<th>Category</th>
<th>UAS weight (kg)</th>
<th>Application Fee (SEK)</th>
<th>Annual Fee (SEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>≤ 1.5 kg</td>
<td>1800</td>
<td>1500</td>
</tr>
<tr>
<td>1B</td>
<td>1.5 kg ≤ UAS ≤ 7 kg</td>
<td>1800</td>
<td>1500</td>
</tr>
<tr>
<td>2</td>
<td>7 kg ≤ UAS and beyond</td>
<td>Mom 1</td>
<td>2 700</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>Mom 1</td>
<td>18 750</td>
</tr>
</tbody>
</table>
5. Results and conclusion

Since there currently are no special regulations for UAS, a custom permit would be issued by the SBT. All systems, procedures and responsibilities must be presented to the SBT who then makes an assessment of the total system. The operator must also be able to demonstrate in practical terms how the system works and that it works, also the competence to operate the aircraft must be ascertained. This report serves as a general guide of how to proceed to obtain an authorization to operate a UAS.

Even though there are no clear regulations considering UAS, this report will most probably match the final proposition taken into action in a near future. This because the report is made in consultation with the SBT and their proposition for UAS and documents released by EASA and other organizations.

One of the most important conclusions made from the study was that nothing seems to prevent the development of the Solaris project. To ensure that the project is developing in the direction for an approval, it is highly recommended to consult the SBT during the entire period of developing. Flights should initially only be flown in isolated areas.

Since Solaris is a research project, it will be easier to get permission to fly from the SBT, than it would be if intended for production or commercial purposes. It is possible to receive a special permit e.g. allowing Solaris to fly at higher altitudes than allowed in its category. This may result in additional requirements e.g. a transponder.
5.1. Certification
Since there are no special "certification specifications" for UAS developed today, a custom permission of each UAS will be issued. Requirements from manned flights will be assumed. Certification categories CS-VLA, 23 or 25, depending on the size of aircraft used. CS-VLA or 23 is most likely to be applicable on Solaris and can be used as guidance.

5.2. Categories
Without knowing the exact weight of Solaris when fully developed, an estimate weight of 5 kg has been made, which puts Solaris into Category 1B. However, there is a goal of flying out of sight. This means that Solaris would fall into category 3, with higher demands on the organization and aircraft. One possible way to reduce the workload in the beginning is to fly “in sight” and thereby put Solaris in Category 1B while carrying out test flights. After successful flight tests the project can move on towards the more demanding category 3.

Subjects of importance for category 1.

- Maximum weight for category 1a: 1.5 kg and maximum developed kinetic energy is 150 joules
- Maximum weight for category 1b: 7 kg, maximum developed kinetic energy is 350 joules and maximum altitude is 150 m
- Flight is only allowed with the aircraft in sight of the pilot
- Application for a simplified permit
- Insurance
- Safety system for category. 1b
Subjects of importance for category 3

- Requirements for the UAS organization similar to the civil aviation. Flight manager, technical manager and operations manager is required.
- Flying out of sight of the pilot.
- Frequency spectrum (what applies here is expected to be completed in 2011 by the Organization ITU)
- Airworthiness (requirements for the design refers to CS-VLA/23). In long term VLA-UAS
- Education and Certificate.
- Transponder, flight data recorder, communications equipment, Sense and Avoid system.
- Permission for category 3.
- Airworthiness Certification. Project Approval, flight testing permission, and manufacturing permission.
- Insurance

5.3. Insurance
For all UAS operations an insurance covering the damage to a third party after an accident is required. An insurance company which is widely used in aviation and UAS operators is “Inter Hanover”.

5.4. System requirements
The developer of the UAS must demonstrate to the SBT how the different system operates. As a guidance see “certification specifications” on EASA’s website under the regulation 1702/2003.

This report is not getting any deeper into these demands but refers to EASAs website. For example under "control system" in CS-VLA : "Each element of the flight control system must have design features, or must be distinctively and permanently marked, to Minimize the possibility of incorrect assembly that could result in malfunctioning of the control system" and" No cable smaller than 3 mm in diameter may be used in primary control systems." Ref 9. System developers should look up the relevant GM(Guidance Materials) and AMC(Applicable Means Of Compliance) for their particular system to be sure that the system is constructed to be airworthy.
6. Future Work

Things left to do.

- System developers should study EASA CS’s for each system
- Fault analysis
- Do a follow up on the development of UAS regulations
- Establish the Operating manual and workshop manual
- Apply for approvals. Project approval, operation approval and if needed production approval
- Purchase of an insurance
- Appoint persons to be responsible within the organization
- Sense and avoid system for flying out of sight of the pilot
- Maintain contact with the SBT
7. Thanks to

- Erik Bergdahl, UAV-inspector at the SBT.
  Erik welcomed us for a visit 3/27/2009 and gave us a review of the rules and publications available about UAS activity. After the meeting we began having a constant dialogue with Erik and he answered all the questions we had about the Solaris project.

- Ola Fristrom Smartplanes and Hans Wallstedt, HW-Vykort.
  We have consulted Hans and Ola with regard to insurances.

- Simon Bengtsson, Airghost
  Simon has sent pictures and shared his experience as a UAS operator.

- Tommy Nygren, supervisor at Mälardalens University.

- Gustaf Enebog, project leader and examiner at Mälardalens University.
8. References

Via Homepages:


Publications:

9. EASA CS-VLA (decision_ED 2003_18_RM. CS-VLA Control systems details 685), 14/11/03.
10. Erik Bergdahl, Transportstyrelsens externremiss, Luftfartsstyrelsen föreskrifter och allmänna råd om verksamhet med obemanannde luftfartyg. xx/xx/09
11. EASA, A-NPA-16-2005,
13. BCL-M kapitel 1.6, 3.1 och 4.
18. Maria Melchersson Tell, Luftfartsstyrelsen föreskrifter am avgift för Luftfartsstyrelsens verksamhet och om avgifter för Luftfartsstyrelsens tjänster, 18/12/08, S 22.
20. The Joint JAA/Eurocontrol inititative on UAVs. UAV TASK-FORCE FINAL REPORT 11/05/04. S19.
APPENDIX A. Application

Ansökan skall sändas till:
Transportstyrelsen (dessa tre rader bör tas bort senare)
601 73 Norrköping

Application for approval of UAS Category 3 activities
**Organization and management**

The organization for project Solaris consists mainly of 4 people. Accountable manager Gustaf Enebog, flight manager xxx, technical manager xxx and pilot xxx. The division of responsibility between these persons is clearly described in the Operations Manual. Here shall also be provided a CV of the people in the organization on the following posts: Accountable manager, flight manager, technical manager and pilot.

**Activities**

Activities will mainly consist of experimental flights, attempts to break altitude records and flight time records. Solaris can be equipped with camera and sensors to be used as a flying weatherstation or aerial photography.

**Insurances**

Copies of the insurances subscribed to the project must be attached.
The UAS system Solaris
Solaris is an UAS developed and built by a project at Mälardalens University.

The aircraft is designed with a number of wing elements and pods which can be assembled into various configurations depending on type of mission.

Similar parts are designed identical making repairs and overhaul faster and simpler and for smoothen manufacturing progress. The pods that connect the wing elements contain all the electronics required for steering and propulsion.
**Technical specifications**

Examples. (probably many more points)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wing span</strong></td>
<td>4-8m depending on configuration</td>
</tr>
<tr>
<td><strong>Cord</strong></td>
<td>0.8 m</td>
</tr>
<tr>
<td><strong>AR</strong></td>
<td>5-10 depending on configuration</td>
</tr>
<tr>
<td><strong>Wing area</strong></td>
<td>3.2-6.4 m$^2$ depending on configuration</td>
</tr>
<tr>
<td><strong>Height</strong></td>
<td>0.6 m</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>3-5 kg depending on configuration</td>
</tr>
<tr>
<td><strong>Propulsion</strong></td>
<td>2-4 20 w electric motors depending on configuration</td>
</tr>
<tr>
<td><strong>Batteries</strong></td>
<td>Lithium-Ion 7.2 V 3 Ah</td>
</tr>
<tr>
<td><strong>Solar cells</strong></td>
<td>Maximum effekt 10-40 W depending on configuration</td>
</tr>
<tr>
<td><strong>Controlling</strong></td>
<td>RC-control and programmable GPS-oriented control computer.</td>
</tr>
<tr>
<td><strong>Maximum speed</strong></td>
<td>70 km/h</td>
</tr>
<tr>
<td><strong>Stall speed</strong></td>
<td>25 km/h</td>
</tr>
<tr>
<td><strong>Rate of climb</strong></td>
<td>1 m/s</td>
</tr>
</tbody>
</table>

Descriptions of how to meet the technical requirements for category 3 should also be presented here. These requirements consider, for instance, battery capacity, flight instruments, ground proximity warning system, transponder equipment, flight data recorder, communication and navigation equipment and fail safe system. All requirements can be found in chapter 4.7 of the report.

**Operation and maintenance manual**

The operating and maintenance manual for the UAS and the organization shall be presented here. They are probably best added as attachments to the application.

Signature of Accountable manager: Place: Date:

................................................................. ........................................... ...........................................
APPENDIX B. Responsibilities

The commander’s responsibility

The commander has the responsibility for the UAS-aircraft and all the procedures from the moment the first engine is started to the point when the last engine is stopped.

The commander is responsible for:

- That the UAS is used according to the operations-handbook containing the routines and checklists
- Establishing a flightplan before a flight
- Notifying the ATM in the event of an emergency eg. (in the case of loss of control or if the energy are insufficient to land safely)
- To log the flightdata

The Flightmanager’s responsibility

- Managing the operations and responsible for obtaining all required permissions
- Establishing the instructions and safety procedures
- Assessing the skills required by operational staff, clearing of staff and establishing training and documentation
- That the staff has the necessary skills and the necessary training to maintain the skills
- Ensureing that there is sufficient material for the operational staff to complete mission.
- Establishing documentation and reporting system for maintenance operations
- Notifying the authorities of any changes in the organisation.
The Technical manager’s responsibilities

- Maintenance operations and monitoring of any contracted maintenance
- That the necessary documentation required for the maintenance staff is established and followed
- Assessing the skills needed by maintenance personnel and the implementation of the training required
- Acquisition of equipment and materials required for maintenance activities
- Establish documentation and reporting system for maintenance operations
- To notify the authorities of any changes of the organisation
APPENDIX C. Operations Manual

The following are the minimum requirements for the content of operations manual:

- Description of the company’s organization, illustrated by an organizational chart
- Responsibilities of flight manager and all other operational staff
- Description of the company's activities
- Copy of authorization documents and special conditions
- Description of the company's administrative procedures
- Programs for training of company’s staff
- Equipment requirements for UAS, pilots and operational staff
- Operational restrictions, safety procedures and instructions for each activity performed by the company.
- Established procedures and restrictions regarding flight under special environmental conditions
- Instructions and checklists for the preparations of flight, including in particular the instructions for calculations of fuel and oil reserves including refueling
- Instructions and checklists for the flight mission
- Instructions for determining the minimum flight altitude in IFR flight
- A route guide for IFR flight information for each planned route on the radio frequencies, navigation aids, air traffic control, rescue, airport and approach instructions
- A risk analysis of activities in which every fault is analyzed and treated with corrective measures

Below is a model of an operational manual, the model is as much as possible adapted to the Solaris project, and information that is known or is able to estimate has been filled in.
Operations Manual for Solaris
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2. Organization ......................................................................................................... 3
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      2.1.1 Accountable Manager .............................................................................. 3
      2.1.2 Flight Manager ......................................................................................... 3
      2.1.3 Technical Manager .................................................................................. 4
      2.1.4 The Pilot .................................................................................................... 4
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3. Activities ................................................................................................................ 5

4. Authorization Documents ...................................................................................... 5

5. Administration ....................................................................................................... 6
   5.1 Maintenance, distribution and publication of operations manual .................. 6
   5.2 Addresses ......................................................................................................... 6
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8. Risk analysis .......................................................................................................... 8
1. Preface

This operation manual is published by the project Board of the Solaris project. The aim is to formulate and establish rules and instructions in addition to government rules which shall govern the business.

This operation manual is owned by the Solaris organization and the organization is responsible for the content of the OM(Operations Manual). Anyone who discovers errors in the manual should report this to the flight manager. The ambition is to make OM as perfect as possible as all the constructive proposals for changes and improvements will be put to inspection.

Solaris Organization 2 May 2009
2. Organization

The organization for project Solaris consists mainly of 4 people. Accountable manager Gustaf Enebog, flight manager xxx, technical manager xxx and pilot xxx.

2.1 Responsibilities

Below is described which responsibilities lie on who in the organization.

2.1.1 Accountable Manager

All UAS organization must have an accountable manager, who is approved by the SBT. The accountable manager shall ensure that all activities are conducted in accordance with the restrictions and applicable laws issued by the SBT.

2.1.2 Flight Manager

Responsibilities:

- Management of operations and is responsible for that all permits are held.
- Instructions and safety procedures are established.
- To make sure that the skills required by operational staff are sufficient, approval of staff and to establish training and documentation.
- The expertise of the staff and the necessary training to maintain the skills of the staff.
- That there is sufficient documentation for the staff in flight operations ability to implement a mission.
- To establish a reporting and record system for flight operations.
- To ensure that notifications are made to the Authority.
2.1.3 Technical Manager
Responsibilities:

- Maintenance Operations and monitoring of any contracted maintenance
- The necessary documentation required for the maintenance staff is established and followed.
- Assessment of the skills needed by maintenance personnel and the implementation of the training required.
- Acquisition of equipment and materials required for maintenance activities
- Establish documentation and reporting system for maintenance operations.
- To ensure that any notifications to the authority are made.

2.1.4 The Pilot
As the first engine starts until the end of the last engine stops the commander is responsible for the UAS-aircraft and that all safety procedures are followed.

The Pilot is responsible for:

- UAS ship used as described by the aircraft handbook with all procedures and checklists.
- Establish a flight plan before each flight when needed. (See flight plan below)
- To notify the air traffic control for emergencies such as loss of control or that energy supply is insufficient to be able to land safely.
- To log the flights

2.2 Organization Chart
3. Activities
Activities will mainly consist of experimental flights, attempts to break altitude records and flight time records. Solaris can be equipped with camera and sensors to be used as a flying weatherstation or aerial photography.

4. Authorization Documents
Here shall copies of permit documents be attached and if the organization has received special conditions for their activities, these must also must be attached.
5. Administration
The purpose of the administrative procedures described in this operation manual is to provide stability and continuity to the activities.

5.1 Maintenance, distribution and publication of the operation manual.
Procedures for updating and changes to the operations manual are described here, and the amount of printed copies and where they are stored.

5.2 Addresses
Contact:

Solaris Project Mälardalens University
Högskoleplan
Box 883
721 23 VÄSTERÅS
Project Manager: Gustaf Enebog
Tel: 021-101656
E-mail: gustaf.enebog@mdh.se

Contact informations for the flight manager and the technical manager are also useful.

5.3 Marketing
Describe what and how to do this with the marketing of available services.

5.4 Insurance
Describe why and what the project's insurance policies shall apply.

More headlines should be added when it is exactly known how the organization looks and how it will work.
6. Training
Here is described the various programs for training the organization’s staff. Examples might be training the technical personnel in the handling, assembly and pre-flight check of the Solaris.

7. Flight activity
Here are described everything that affects flight operations.

7.1 Equipment Requirements
What equipment is required to assemble, complete, fly and operate with the UAS, a breakdown of the pilot’s equipment and other operational staff.

7.2 Operating limitations
Here are described the operational limitations that exist, as for demands on the weather, open space, safety distance, etc.

7.3 Safety Procedures
Here are described the safety procedures developed for the envisaged activities.

7.4 Preparations Before Flight
Here are described the procedures and checklists to be conducted prior to planned flight. For example, how to charge the batteries, check the controls and the aircraft’s structure, etc.

7.5 Flight Mission
Here are set out the instructions and checklists developed for the different types of flight missions that can be implemented, such as photography or weather observations.

7.5.1 Minimum flight altitudes
Here are instructions for determining minimum flight altitudes at IFR flight for each type of flight.
7.6 Environment
Here is described procedures when flying in areas where special demands on the environment exists. These may be noise levels or different exhaust emissions.

7.7 Routguide
Here shall be a route guide for IFR flights. The book shall for each route contain information about radio frequencies, navigation aids, air traffic control, rescue, airports and approach procedures.

8. Risk Analysis
A risk analysis shall be made and presented here. In the analysis all possible faults and corrective actions to be made shall be presented.
APPENDIX D. Project Approval

An application for project approval shall be submitted to the SBT when a new project is being developed. What should be included in the application can be found in the BCL-M 1.6, mom. 4.1 and covering the following points:

- Applicant’s name or business name, address and phone number.

- Preliminary technical specification for the aircraft containing the following: Drawing in three projections, basic data, intended use and classification in the BCL-M 1.4 and the applicable design rules as BCL-M,-M4 and M5.

- A snapshot of the project organization with assigned responsibilities of, project management, calculation, design, internal type review and testing.

- Reference to accreditation certificate issued to manufacturers or application for manufacturing approval under BCL-M 3.1.

After the application has been reviewed, the applicant, if necessary shall supplement the application with the information deemed necessary. When the application has been approved the SBT determines the design standards, including changes and additions, which shall apply to the project, and the latest time at which approval may be issued with these design standards as a basis. When changes occur which make the conditions no longer apply, this must be notified to the SBT.

An applicant who is the holder of an authorization certificate for manufacturers will recive an approval for a new production object, in the form of prototype aircraft. Applicants who do not have such certificate must apply for one under the provisions of the BCL-M 3.1. The application must also account for the project manager and an internal type auditor. The internal type auditor is a person in the applicant’s service, designated by the applicant and cleared by the SBT, with special instructions to be responsible for the applicant control of construction requirements and to be a contact for the SBT’s type reviewers.

The developer must hold a type journal where all changes in the design as a result of changes to the file, flight test, or for any other reason will be apparent.
Project approval application for Solaris

Solaris Project Mälardalens University
Högskoleplan
Box 883
721 23 VÄSTERÅS
Project Manager: Gustaf Enebog
Tel: 021-101656
E-mail: gustaf.enebog@mdh.se
Organization number xxxxxxxxxx

Organisationsnummer xxxxxxxxxx
Preliminary technical specification
Below is a preliminary technical specification for design, performance, intended use and classification presented.

Type drawing in three projections

Concept sketch

Performance and dimensions

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing span</td>
<td>4-8m depending on configuration</td>
</tr>
<tr>
<td>Cord</td>
<td>0.8 m</td>
</tr>
<tr>
<td>AR</td>
<td>5-10 depending on configuration</td>
</tr>
<tr>
<td>Wing area</td>
<td>3.2-6.4 m² depending on configuration</td>
</tr>
<tr>
<td>Height</td>
<td>0.6 m</td>
</tr>
<tr>
<td>Weight</td>
<td>3-5 kg depending on configuration</td>
</tr>
<tr>
<td>Propulsion</td>
<td>2-4 20 w electric motors depending on configuration</td>
</tr>
<tr>
<td>Batteries</td>
<td>Lithium-Ion 7.2 V 3 Ah</td>
</tr>
<tr>
<td>Solar cells</td>
<td>Maximum effekt 10-40 W depending on configuration</td>
</tr>
<tr>
<td>Controlling</td>
<td>RC-control and programmable GPS-oriented control computer.</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>70 km/h</td>
</tr>
<tr>
<td>Stall speed</td>
<td>25 km/h</td>
</tr>
<tr>
<td>Rate of climb</td>
<td>1 m/s</td>
</tr>
</tbody>
</table>
**Intended use**
Solaris will primarily be developed to carry out experimental flights and attempts to set altitude records and flight time records. Solaris can be equipped with camera and sensors to be used as a flying weatherstation or aerial photography.

**Classification and design rules**
Solaris is supposed to be classified under the special or experimental class as a UAS Category 3.

The design rules will be implemented from those of ultralight aircraft in BCL-M5.4 and -M5.2. It will also use part of the EASA CS-23 and -VLA (Very Light Aircraft), which largely overlaps with the BCL rules with respect to the structure.

**Project organization**
The organization for Solaris project is different from other types of projects. The reason is that the project for the most part will run through the thesis work of students at Mälardalen University. This means that many people will be involved during the years of the project. Project leader is Gustaf Enebog which is the only person in the organization who will be involved from start to finish. Therefore, it is difficult now to describe the organization with appointed responsibilities, so this work will be submitted at a later period of the project phase.

The tasks which will be reported are: project management, calculations, construction, internal type review and testing.

**Application for manufacturing approval**
Here, an application for a permission to manufacture an aircraft will be attached. Without this permission the project cannot be approved as a commercial project, but only as research project.
APPENDIX E. Manufacture Approval

Since the Solaris’ organization intends to construct the Solaris on their own, it is required that the organization submits an application for manufacturing approval. This applies primarily if the intention is to construct a commercial product and aim for serial production. The following information must be submitted with the application in accordance with APPENDIX 1 to BCL-M 3.1:

- Applicant’s name or business name, address and phone number
- A description of the organization and management as referred to the planned production
- The variety and extent of the construction for which approval is sought, including references to actual manufacturing proposal
- Curriculum vitae for company manager, technical manager and the heads of other responsibilities functions
- Data for other staff members with regard to skills and numbers
- A proposal for a workshop manual
- Depending on if the organization is a company or is operated by a private individual either registration or birth certificate needs to be attached to the application
APPENDIX F. Workshop Manual

A workshop manual adapted for the UAS - company's organization and operations shall be established to ensure a reliable control of maintenance activities. A draft of points to include in the workshop manual is presented below:

- The extent of the maintenance organization and distribution of work in their own maintenance engineering activities and external maintenance services and the division of responsibilities between them
- An explanation of self-maintenance activities illustrated by an organizational chart with names given function responsible personnel. Organization description shall identify the company's technical and operational functions and management
- Instructions for technical manager and other responsible functions
- Instructions for subcontracting that are not bound by agreement
- Owned or leased property with buildings and other facilities for maintenance operations revealed plan sketches with the given scale. Sketches showing the premises for the parking of aircraft, other workshop premises with substantial fixed equipment and processing and office premises.
- Instructions for acquiring and updating the necessary publications and regulations.
- Description of current maintenance procedures for each existing UAS-type being used.
- Reference list of current instructions regarding the general practices and instructions for working, according to chapter 3.7.9. (Working methods).
- Description of the verification system and list of effective control instructions to the extent it occurs, according to chapter 3.7.10. Control system.
- Instructions for reporting of maintenance as prescribed in BCL-M 3.2, “maintenance and modification of flight equipment”, and in case of systems of technical records, accounts there of.
- List of all personnel who are authorized to sign documents showing of completed work.
- Guidelines for internal training of technical staff.
- Where appropriate, list of specific technical routine maintenance instructions, instructions for coordination of technical maintenance and flight operations.
APPENDIX G. Kinetic energy

The figure below shows the weight VS maximum speed, where the kinetic energy developed by the UAS is the limiting factor. Kinetic energy = ——
APPENDIX H. Project data

The figure below shows a page to be inserted into the Solaris design tool. The design tool is an excel document compiled with all the data collected from each feasibility study.

<table>
<thead>
<tr>
<th>UAS</th>
<th>category 1a</th>
<th>category 1b (^3)</th>
<th>category 2</th>
<th>category 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximum energy</td>
<td>150J</td>
<td>350J</td>
<td>no limit</td>
<td>no limit</td>
</tr>
<tr>
<td>maximum speed</td>
<td>14m/s</td>
<td>10m/s (7 kg)</td>
<td>no limit</td>
<td>no limit</td>
</tr>
<tr>
<td>maximum weight</td>
<td>1.5kg</td>
<td>1.5kg &lt; UAS &lt; 7kg</td>
<td>7kg &lt; UAS &lt; 150kg</td>
<td>no limit</td>
</tr>
<tr>
<td>maximum altitude</td>
<td>Well within sight</td>
<td>150m</td>
<td>150m</td>
<td>no limit</td>
</tr>
<tr>
<td>cost (estimated)</td>
<td>2000-5000SEK</td>
<td>2000-5000SEK</td>
<td>&gt;5000SEK</td>
<td>&gt;10000SEK</td>
</tr>
<tr>
<td>safety system</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>flying out of sight</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>transponder and ACAS</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>Yes</td>
</tr>
<tr>
<td>flight area</td>
<td>isolated</td>
<td>isolated</td>
<td>isolated</td>
<td>isolated flight not required</td>
</tr>
<tr>
<td>organization</td>
<td>low</td>
<td>low</td>
<td>medium</td>
<td>high</td>
</tr>
</tbody>
</table>

1) The maximum amount of energy developed by a UAS
2) Speed calculated from the kinetic energy formula if the energy is a known factor. When speed is "no limit" air traffic regulation apply.
3) Maximum altitude above ground or water. It is possible to recieve a special permit - allowing Solaris to fly at higher altitudes than allowed in its category. When altitude is "no limit" air traffic regulation apply.
4) The S&T estimates the cost for Solaris to a few thousand SEK (permit and Inspections)
5) E.g. "go-home" system
6) Aircraft Collision Avoidance System
7) the extent of the organisation and airworthiness requirements
8) Solaris