Transportstyrelsen Risk Assessment for BVLOS Category 5C UAV Operations

Final Report

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This is the final report of the research project ‘Risk assessment for the UAV BVLOS Category 5 operations’ carried out by Linköping and Lund Universities with FOI and supported by LFV. Transprortstyrelsen commissioned a project to investigate risk assessment methods that will be appropriate and suitable to support the approval of Beyond Visual Line of Sight UAV operations. Specifically, for the Category 5C class of UAVs.

The original proposal had the following objective:

- Gain a better understanding of the risk landscape and emergent risks that arise from such a radically different and diverse airspace user such as drones
- To begin to determine a more salient assessment method that supports Transportstyrelsen risk assessment and equitable airspace utilisation prioritisation decisions that support and do not hinder the commercial development of drone operations
- To engage with the drone community to inform the research and ensure that it is salient and risk assessments are built on an understanding of the needs and capabilities of the drone community
- To understand the risk landscape with integration of diverse drone operations in airspace that have differing characteristics

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Executive Summary

Over six months in the latter half of 2018, a research project was undertaken in support of Transportstyrelsen and their continuing activity in the regulation and oversight of UAV operations in Sweden.

UAV operations are evolving as experience grows not solely for pleasure and personal use. As business opportunities are found and as the capabilities of UAVs are better understood so these shape emergent potential UAV use. The benefits of these, both new and current uses of UAVs, can provide significant benefits to society as well as business opportunities.

Within the UAV community, Beyond Visual Line of Sight operations (BVLOS) are perceived as a step change in UAV operational capability and an enabler to new classes of operational tasks. These hold significant potential for society as a whole as well as for more effective ways for many activities, be they industrial, agricultural, communications or saving lives at sea and overland.

In recognition of the need for Transportstyrelsen to facilitate the evolution and development of this step change, a need to better understand the nature of risk assessment for Beyond Visual Line of Sight operations was identified. Additionally, the potential need for a risk assessment method with which to undertake risk assessments was also recognised.

Linköping Universitet (LiU)in collaboration with Lunds Universitet (LU) were contracted for six months to carry out a small-scale research project to investigate UAV risk assessments and to identify a risk assessment method that is suitable for Transportstyrelsen to use in the approval of Beyond Visual Line of Sight UAV applications.

Linköping and Lund approached the task by undertaking e workshops that were intended to develop an understanding of:

- How the assessment of risk for UAV operations is made in the current approval process,
- How UAV operators approached and undertook risk assessment of their operational tasks
- The nature of Beyond Visual Line of Sight UAV operations and the differences from other UAV operations as seen from the perspective of the Transportstyrelsen UAV approval departments, other interested stakeholders and
- What are Transportstyrelsen's needs that must be met in any new risk assessment method
- To use the knowledge gained from studying the literature of risk assessment in safety science to inform the options for risk assessment methods
- Examine the Use Cases that represent the early implementations of Beyond Visual Line of Sight UAV capability
- Introduced both Transportstyrelsen and UAV operators to the detail of Urban UAV operating concepts
- To identify a candidate risk assessment method for use

Five workshops were undertaken which were well received by both the agency and UAV operators who participated. The richness of the discussions and the quality of the findings were a direct result of the coming together of those involved with differing functions and perspectives of BVLOS operations and the approval of such.

This report presents the findings of the workshops through the use cases that emerged, the differences between VLOS and BVLOS operations from the perspectives of UAV operators and the agency and presents a candidate risk assessment method for potential use by Transportstyrelsen in the approval of Category 5C BVLOS UAV operations.

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Document information

Revision		
Version	**Issue**	**Change**
D00.00.01	Initial draft of the	Draft of the structure of the report prepared by Anthony Smoker
D00.00.02	Revised structure	
D.00.00.03	Rewritten final report	Condensed the text for salience
D.00.00.04	Revised Draft	Revised draft following review by Jonas Lundberg, LiU
D.00.00.5	Revised Draft	Following the Final Report presentation, the following changes were made: • Expand the document to include all of the technical reports • Changes to the body of the report to include a full description of TSARA, the Use cases, Workshops and some arguments for how safety manifests itself in UAV operations • Comments received by Erik added were accepted and revisions made
D.00.00.6	Revised Draft	After a review of D.00.00.5 revisions made to the substance of workshop sections and subsequent discussion after revisiting source data: • Figures
D.00.00.7a	Revised Draft	TSARA model description expanded and additions made
D.00.00.7b	Revised Draft	Agency review and conclusions reviewed and amended. Future work items expanded
D.00.00.7c	Revised Draft	Figures reviewed for clarity and legibility; amendments made to figures .
D.00.02.01 Body Text	Revised Draft	Radical revision of the document structure. Revisions of nomenclature of Operational risks as hazards
D.00.02.02	Revised Draft	Restructuring of revised document structure corrected. Summary in Swedish added.
D.01.00.01	Final Version	Minor corrections made to structure and flow of the document.

Summary and conclusions

The capability of Unmanned Aerial Vehicles (UAVs) has evolved, is evolving and will evolve further. Each evolutionary step, it can be expected, will expand the operating envelope of UAVs in civil use as well as the nature of the tasks that UAV operators will seek to undertake. In some cases, state services such as the Police have and are already making extensive use of UAVs

Regulation and rulemaking that facilitates UAV operations has been introduced by some member states within the EU and around the globe. These are of necessity incremental and iterative because the nature of UAV operations is, to an extent, an unknown in civil operations. Experience has allowed positions to be taken that have shaped regulation and policy.

The potential benefits of UAV operations to society are being demonstrated daily in many ways around the globe. This is leading to a which is leading to an inertia to exploit these benefits. UAV operations also introduce risks associated with their operation and interaction with others as well as within the environment and society as a whole. Interactions with other airspace users – mid-air collision for example, or breaches of security or privacy of those on the ground are indicative of the risks possible.

UAV operations have evolved in the sense of the capability of the UAV platform as well as sensors and control mechanisms. UAV operations to date have been characterised by operating Visual Line of Sight (VLOS) and Extended Line of Sight (EVLOS).

An incremental step in the evolution of UAV operations is that of the introduction into wider society of Beyond Visual Line of Sight UAV operations (BVLOS). BVLOS is defined by the European Joint Authorities for Rulemaking of Unmanned Systems as '

> BVLOS is a means of flying the UAS without the direct´, unaided visual supervision of the aircraft by the person manipulating the flight controls' (JARUS, 2017)

BVLOS modes of operation are significantly different from VLOS and EVLOS because it introduces an operational capability that minimises the limitations introduced by VLOS and supports operations at and beyond EVLOS.

From the perspective of a regulator or NSA in a European Union Member State, what is required to be able to assess the risk associated with BVLOS operations? How does the risk landscape change with the introduction of BVLOS as compared with VLOS and EVLOS?

These are essential questions that support the approval of BVLOS.

This project set out to derive a risk assessment method that will support the needs of the agency in providing a means to assess and make decisions around applications that seek to operate UAVs in Category 5C Beyond Visual Line of Sight method of operations.

What was discovered, and what was learnt through the project, was more than might have been anticipated.

A view of the future risk landscape was determined which was shaped by engaging with UAV operators who envisage undertaking Category 5C BVLOS. Their experience and understanding of UAV operations came to the fore, for example, in revising the three use cases that the agency are interested in as early applicants for BVLOS operations. As a result, the use cases better represent the nature and characteristics of BVLOS operations as the UAV operators perceive them and wish to exploit the potential of this mode of operation. The risk landscape for 5C BVLOS UAV operations that is presented in this report, derived jointly with UAV operators, is not definitive but provides the basis for a reliable approach to assessing these applications and the basis for ongoing development. It informs the agency's requirements for a risk assessment method and was used as such in this project.

One use case was proposed by LiU and LU the urban use case, specifically low-density UAV operations in Urban operational environments. Urban operations are different in scope, complexity as well as the risk landscape. How different, from the agency's perspective was found where this particular use case was explored. It is materially and structurally different from the three other use cases.

The application for a 5C BVLOS UAV task, regardless of use case, is pivotal as it is the trigger for various steps that the agency takes. What emerged from the workshops with UAV operators and agency staff working together is that there are differences in interpretations of the application process and information between those making and those approving applications. There is scope for developing the application itself to better serve the needs of 5C BVLOS UAV applications.

Through exploring the agency's current application approval process and the risk assessment of UAV applications what was previously tacit is now better understood. It was also evident that the way that the agency conducts approvals of applications works and is in every sense robust and is grounded in a sound working knowledge of UAV operations. Assessment of risk assessments that are submitted are conducted intelligently by the agency. It also emerged that these risk assessments are not stand alone but situated within the approval of the application process much more fully

Moreover, the agency engages in a positive way with UAV operators despite the frustrations they may have. Transportstyrelsen has an effective capability in dealing with applications and assessing the risks of proposed UAV applications, which as a result of this project is now better understood in a formal sense. The challenge is to integrate this capability more formally so as to make decisions transparent and as far as is practicable repeatable. What is significant are the steps that capture and formalise the risk assessment decisions made.

These were used to develop an approval and risk assessment method – known here as TSARA - Transportstyrelsen application and risk assessment process for the agency. TSARA is a qualitative based method that uses a safety case structure for decisions which are in informed by a structured approach to the assessment of the application and associated risk assessment. The output is a reasoned argument for a particular decision.

TSARA fills the immediate need that the agency has as a means to approve applications of category 5C BVLOS UAV operations. The method was developed with the means to capture experience of early approvals and use this to update the inputs to the method.

Scope exists for TSARA to be developed with occurrence data as well as potential to develop quantitative iterations.

This report provides background on the nature of risk and its applicability to UAV operations. There then follows a description of the TSARA method. The report provides the background for TSARA that was derived from workshops that examined the nature of Cat 5C BVLOS operations and how such operations differ from other VLOS & EVLOS UAV operations.

Sammanfatttning på Svenska

Kraften hos obemannade flygfordon (UAV) har utvecklats, utvecklas och kommer att utvecklas ytterligare. Varje utvecklingssteg, som man kan förvänta sig, kommer att utvidga operativa kuvertet för UAV i civilt bruk samt typen av uppgifter som UAV-operatörer kommer att sträva efter att genomföra. I vissa fall har statliga tjänster som polisen och använder redan UAVs omfattande användning

Reglering och regelverk som underlättar UAV-operationer har införts av vissa medlemsstater inom EU och runt om i världen. Dessa är nödvändigtvis inkrementella och iterativa eftersom arten av UAV-operationer i viss utsträckning är okänd i den civila verksamheten. Erfarenheten har gjort det möjligt att ta positioner som har utformat regler och policy.

De potentiella fördelarna med UAV-operationer till samhället demonstreras dagligen på många sätt runt om i världen. Detta leder till en som leder till en tröghet för att utnyttja dessa fördelar. UAV-operationer introducerar också risker i samband med deras verksamhet och interaktion med andra såväl som inom miljön och samhället som helhet. Interaktioner med andra luftrumsanvändare - till exempel luftkollision, eller brott mot säkerheten eller integriteten hos dem som är på marken är en indikation på de risker som är möjliga.

UAV-operationer har utvecklats i betydelsen av UAV-plattformens förmåga samt sensorer och styrmekanismer. UAV-operationer hittills har präglats av operativ visuell synlinje (VLOS) och utvidgad synlinje (EVLOS).

Ett inkrementellt steg i utvecklingen av UAV-operationer är införandet i ett bredare samhälle av Beyond Visual Line of Sight UAV-operationer (BVLOS). BVLOS definieras av europeiska gemensamma myndigheter för reglering av obemannade system som "

BVLOS är ett sätt att flyga UAS utan den direkta, oberoende visuell övervakningen av flygplanet av den person som manipulerar flygkontrollen "(JARUS, 2017).

BVLOS-driftssätt skiljer sig avsevärt från VLOS och EVLOS eftersom det introducerar en operativ förmåga som minimerar de begränsningar som införs av VLOS och stöder operationer vid och utanför EVLOS.

Vad krävs för att kunna bedöma risken i samband med BVLOS-verksamheten från en regulator eller NSA i en EU-medlemsstat? Hur förändras risklandskapet med introduktionen av BVLOS jämfört med VLOS och EVLOS?

Dessa är viktiga frågor som stöder godkännandet av BVLOS.

Detta projekt syftade till att ta fram en riskbedömningsmetod som kommer att stödja byråns behov genom att tillhandahålla ett medel för att bedöma och fatta beslut kring applikationer som försöker driva UAV i kategori 5C Beyond Visual Line of Sight.

Det som upptäcktes, och det som lärt sig genom projektet, var mer än vad som kunde ha förväntats.

En bild av det framtida risklandskapet bestämdes som formades genom att engagera sig med UAV-operatörer som planerar att genomföra kategori 5C BVLOS. Deras upplevelse och förståelse av UAV-operationer kom till förfogande, till exempel vid revidering av de tre användningsärenden som byrån är intresserad av så tidigt sökande för BVLOS verksamhet. Som ett resultat av detta representerar användningsfallen bättre arten och egenskaperna hos BVLOS-operationer, eftersom UAV-operatörerna uppfattar dem och vill utnyttja potentialen i detta driftsätt. Riskbildet för 5C BVLOS UAV-verksamheter som presenteras i denna rapport, som härleddes gemensamt med UAV-operatörer, är inte definitiv men utgör grunden för ett tillförlitligt sätt att bedöma dessa applikationer och grunden för fortsatt utveckling. Den informerar myndighetens krav på en riskbedömningsmetod och användes som sådan i detta projekt.

Ett användningsfall föreslogs av LiU och LU urban use-fallet, särskilt UAV-operationer med låg densitet i Urban-driftsmiljöer. Urbanverksamheten har olika omfattning, komplexitet och risklandskap. Hur annorlunda, från byråns perspektiv, hittades där detta speciella användningsfall utforskades. Det skiljer sig väsentligt och strukturellt från de tre andra användningsfallen.

Ansökan om en 5C BVLOS UAV-uppgift, oavsett användningsfall, är avgörande eftersom det är utlösaren för olika steg som byrån tar. Det som framkom av workshops med UAV-operatörer och byråpersonal som arbetar tillsammans är att det finns skillnader i tolkningar av ansökningsförfarandet och informationen mellan de som gör och de som godkänner ansökningar. Det finns utrymme för att utveckla applikationen själv för att bättre kunna tillgodose behoven hos 5C BVLOS UAV-applikationer.

Genom att undersöka byråns nuvarande ansökningsgodkännandeprocess och riskbedömningen av UAV-applikationer, som tidigare var tyst, förstås nu bättre. Det var också uppenbart att det sätt som byrån utför godkännanden av ansökningar fungerar och i alla avseenden är robust och grundas i en bra kunskap om UAV-operationer. Bedömning av riskbedömningar som lämnas in utförs intelligent av byrån. Det framkom också att dessa riskbedömningar inte står ensamma men ligger mycket mer i ansökan om godkännande av ansökan

Dessutom bedriver byrån ett positivt sätt med UAV-operatörer trots de frustrationer de kan ha. Transportstyrelsen har en effektiv förmåga att hantera ansökningar och bedöma riskerna med föreslagna UAV-ansökningar, som till följd av detta projekt nu bättre förstås formellt. Utmaningen är att integrera denna förmåga mer formellt för att göra besluten transparenta och så långt det är praktiskt repeterbart. Det viktiga är de steg som fångar och formaliserar besluten om riskbedömning.

Dessa användes för att utveckla ett godkännande- och riskbedömningsmetod - känt här som TSARA - Transportstyrelsens ansökan och riskbedömningsprocessen för byrån. TSARA är en kvalitativ baserad metod som använder en säkerhetskonstruktion för beslut som är informerade genom ett strukturerat tillvägagångssätt vid bedömningen av ansökan och därtill hörande riskbedömning. Utgången är ett motiverat argument för ett visst beslut.

TSARA fyller det omedelbara behovet att byrån har som ett medel för att godkänna ansökningar av kategori 5C BVLOS UAV-operationer. Metoden utvecklades med hjälp av metoder för att fånga erfarenheter av tidiga godkännanden och använda detta för att uppdatera ingångarna till metoden.

Omfattningen finns för TSARA att utvecklas med förekomstdata samt potential att utveckla kvantitativa iterationer.

Denna rapport ger bakgrund till riskens art och dess tillämplighet på UAV-operationer. Därefter följer en beskrivning av TSARA-metoden. Rapporten ger bakgrunden till TSARA som härrörde från workshops som undersökte karaktären av Cat 5C BVLOS-operationer och hur sådana operationer skiljer sig från andra VLOS & EVLOS UAV-operationer.

Further steps and future work

During the workshops where understanding and eliciting the requirements for the TSARA method from those involved specific areas for further development and investigation emerged.

The TSARA Method

TSARA as described in this report is an initial iteration. A clear requirement for additional work to develop a means by which the risk elements can be quantified in a simple way that provides a numerical risk value was elicited. JARUS' SORA uses SAIL (Specific Assurance and Integrity Levels) provides a model that provides the basis for an extension to TSARA which provides both structure and rigour in the risk assessment decision. SAIL is described (JARUS, 2017) as a level of confidence, that is not quantitative, but on the objective are complied with, a narrative that supports this and the evidence that indicates that the objectives are complied with. This is
similar in philosophy to the Claim-Argument-Evidence structure of a decision that TSARA uses.

Therefore, a TSARA 'SAIL' is recommended for development.

Such an evolution of TSARA lends itself to the method then being developed on an electronic platform. This has, *a priori*, several benefits in both ease of use in collating the application data needed for the assessment process and visualising the proposed UAV operation in the environment. Structured and formalised assessments in a standard form can be a product of this.

Consideration should be given to undertaking a scoping exercise into the requirements and design for an electronic platform for TSARA and

Urban UAV Operations

LiU recommended that the Urban Use case was included in This provided insight into dimensions of the agencies task in giving approvals for diverse UAV operations in Urban settings. The reason for this is that urban deliveries occur currently, e.g. in Reykjavik and could therefore be an application case in Sweden as well at any time.

The scale of the undertaking for regulatory approval of UAV operations, BVLOS as well as other modes, is signally different. In TSARA terms, the UAV concept of operations for urban operations requires greater technical description at the level of the UAV platform the UAV operational control and the interaction with other UAV operations. Third party risks are different. In this project, we restricted the Urban Case to one use case and a detailed examination of this in only one workshop. The use case was one-hour deliveries of light-weight products from a storage facility in the outskirts of Norrköping, to the whole city. See the first image below.

Figure 15 illustrates three routes considered (with path measurements, in orange); an airport geofence in light yellow (as suggested in an ATM workshop in the project UTM50); and other coloured lines (lustrating drone movements from various simulated services and leisure operations).

Figure 1: Airport Geofencing

The second image illustrates the impact of an unplanned police geofence (light yellow), showing that it overlaps with landing sites of several planned drone operations, as well as some of the potential routes for low-ground-risk drone movements.

Figure 2: Unplanned police activated geofencing

UAV platform requirements are in particular a concern when considering ground risks, which are crucial in the urban case. Ground risks for instance regard people or moving vehicles. In the workshop it was suggested that requirements are then placed on for instance flight hours in conditions that are similar to the urban movements, with particular consideration to how contingencies during these flight hours were managed. The degree of similarity required, and the number of hours required, is an open question for regulation. Further, to manage ground risk, population density maps may be required, that may also have to reflect changes over the day (e.g. locations of work versus leisure and rest).

To manage ground risks, one option is to take less direct routes, over less populated areas (e.g. over water or "green" areas), or over buildings. This however induces risks due to a longer time in the air, and also induces risks of congestions if suitable areas are sparse. This thus relates to air risks. Another interacting issue is that of damage to the drone, or link-loss. This could be managed in the application, by specifying drone behaviour in these cases (E.g. route for returning to base, or routes to alternative specified landing spots)

Air risks are in particular that of mid-air collisions, with other drones or other aircraft. Regarding other aircraft, the situation was seen as more manageable. If a local geofence around airports (as suggested in the project UTM50) could be used for the times of airspace usage, restricted to the specific area used for the air movement) then it would be relatively easy to manage airport-related risks. However, this would require (as suggested as a major issue in the project UTM50) that drones or drone operators can receive geofence updates in real-time.

With regard to geofences established e.g. by police, the application must also cover how this can be managed. E.g., whether drone movements can then be re-routed or cancelled; how they can receive and act on real-time information on geofenced areas.

The issue of how the police should/could behave with regard to geofencing operations is also unresolved, e.g. should they in all or some cases allow some deliveries or fly-throughs in areas that they have geofenced for urgent operations? Further, new systems are required so that the police (or other emergency response services) can swiftly apply for new geofences at TS, that TS can then swiftly respond to.

Airspace congestion was also a major issue for the urban case, that cannot easily be managed by the UAV operator applicants. Here, several options were considered, which corresponded to the options for airspace structure management considered in the project UTM50 (layering, pipes, geocages). If different operators can restrict operations to non-infringing flight layers, or route networks then this can be seen as a safety measure. However, issues can emerge if others then request operations in the same area. Unless operators can then collaborate, some means for prioritizing traffic is required (that is not yet in existence), or more advanced means for keeping track of drones and assigning them to airspace structures is required (that is not yet in existence but is for instance explored in the project UTM CITY), or a combination. Thus, the ability of the UTM system to manage airspace structure (and for drone operators to be able to comply) is a capability that is important for high-density operations also from the perspective of approving drone flights.

In the urban case, current rules that exclude unregistered traffic (e.g. zones around airports) could actually be a benefit. In those areas, if approved by the airspace operator, the BVLOS flight could operate in the space above 50m without encountering unregistered drones (assuming that rules are followed). Unregistered drones were seen as a major issue. For instance, a 14-year old with a hobby drone (flying within line of sight) can nevertheless not be expected to take responsibility for avoiding a commercial BVLOS drone operation in the same airspace.

The techniques for assessing the risk for an application is therefore both technically and conceptually more challenging. This area is the subject of widespread research and development, nevertheless, it is recommended that the agency pursues some research that scopes the nature and regulatory approach to the approval of Urban UAV operations

Quantitative methods for the Assessment of BVLOS

TSARA is inherently quantitative. The development of a SAIL style TSARA is an extension of this qualitative approach.

The literature search identified approaches to risk assessment for UAV operations that fused both concept of operations with a quantitative means of assessing risk. This is one approach, and other choices for a quantitative approach exist.

It is proposed that a research task is undertaken that explores and develops quantitative approaches to modelling and assessing the risk of BVLOS UAV operations.

BVLOS Applications

One of the findings from the workshops was the significance of the application from that is used to apply for approval to Transportstyrelsen.

There are two dimensions to this. One pertains to the information needed to support the application for 5C BVLOS. Because of the change in the scale and scope of this particular type of UAV operation, the supporting information needs to change, Examples of this were evidenced of this in the workshops. The information required to assess the increased scope of both technical and operational characteristics needs to be provided. Risk assessments provided require greater depth, detail and robust arguments. This could be the subject of research to match the requirements of the approval assessment to that of the UAV operator and develop a more effective approval process.

The second dimension relates to the sense of the questions that are included in the application. In one point in the application, a question is asked that the UAV operator answered fully. The answer was given as the applicant interpreted the question, in a sense that was quite different and unexpected by the agency. UAV operators and the Agency have, quite rightly, different perspectives of the industry. How can these different perspectives become more closely aligned and contribute to a more salient approval process? Can an application for BVLOS 5C approval be derived that supports TSARA and increases the engagement with the UAV community?

This recommendation is not to propose an easier route for the UAV operator to gain approval but to foster an enhanced understanding of the operational needs of the UAV operator as well as enhance the fidelity of both the information provided as well as constructed in the application.

UAV operations reporting

A limitation in the UAV world that has become apparent through this study is that there is very little occurrence data with which to draw upon with which to build a picture of the risk landscape. There are several reasons for this. The UAV operator community is not one that has evolved from within the aviation industry necessarily and therefore the approach and mindset of safe operations, of the significance of what is taken for granted in the wider aviation community is missed by some, dismissed by others and respected by many.

Is there a recognised need for UAV operators to file reportable occurrences? Currently, the major source of occurrences with UAV's are those filed by airspace users, not by UAV operators) They are not included in EU376/201 for example. What is the compelling catalyst that will create the recognition for the UAV operator that there are benefits in filing their 'occurrences' whatever they may (relevant to the UAV community, is this the same for the wider aviation industry?).

Having occurrence data from UAV operators provides a new and different dimension to the risk landscape. This can serve UAV's per se as well as support risk assessment and operational knowledge across aviation as a whole.

For this reason, it is recommended that a study working with the UAV community to explore occurrence reporting and the way in risk is perceived and is identified and mitigated in operations by the UAV operators.

UAV trajectory flight notification and its use for assessing collision avoidance by other airspace users

One cornerstone of the agencies ATM strategies to facilitate growing and emergent UAV operations concerns the management of operations <140 m operating in Class G airspace.

A study carried out by TS (The BULOS study) opted for collision avoidance to be achieved by either deconfliction strategically at the flight planning stage by general aviation and helicopter crews or tactically using the see- and- avoid principal.

Deconfliction at the flight planning stage is an activity that lends itself to a technical solution where the requirements of those planning flights have the support from technical systems that enables them to plan flight profiles that are free from interaction with UAVs. In essence the capability that is desired is a known traffic environment.

Developing a concept of operations that supports the generation of requirements that achieves the functional system is a candidate for further research. There are numerous operational questions around this concept that would require engagement with all of the stakeholders. The extent to which the airspace user community would wish to participate is an aspect of this research where the quality of the design is instrumental in a shift in attitudes and the willingness to use such a concept.

UTM and U1 UAV Information systems

The use cases that were chosen for this task, which characterised the BVLOS UAV Operations, included one that was purposefully chosen to consider BVLOS in urban operating environments. Through examining the TS approval and risk assessment process, limited exposure was given to the nature of the Agency's requirements for the and magnitude of the approval task for BVLOS operations in Urban operations. In this task, the BVLOS operations were limited to low density. Nevertheless, the magnitude of the task: the knowledge and understanding of UAV capabilities and urban operating concepts, the different forms of UAV interactions with the environment and society on the ground and in the air is considerable. Just as the differences in 5C BVLOS UAV operations became more tangible as they emerged, and with it an understanding of what the agency needs to do to be in a position to establish the capability to service the needs of UAV operators who wish to extend BVLOS, similarly insight was gained for the Urban case. It is significantly different, indeed an order of magnitude beyond what the capability is today.

There is considerable activity within programmes such as the European ATM Masterplan Drone integration plan with U Space and UTM in the USA which will provide systems that manage Urban UAV operations in systematic ways. These are, however, distant and the need for UAV operations in Urban areas will gain momentum as early implementations such as those in Iceland and Dubai prove the potential.

There are a number of possible paths that explore Urban operators from the NSA's specific position in the aviation system. We recommend the following

- Quantitative risk modelling of low and medium density UAV operations in Urban environments
- The requirement and design of a U1 Drone Information Service that supports the TS efforts for sharing of airspace at low level with other airspace users.

This potentially provides the agency with the basis for early implementation of initial Urban UAV operations.

What is Risk?

The meaning of Risk in aviation is well established. ICAO's Annexe 19, in the context of Safety Management Systems, defines safety risk as the *predicted probability and severity of the consequences or outcomes of a hazard* (ICAO, 2016). Or expressed differently severity and likelihood (or probability) of the consequences of a hazard occurring. A hazard is the potential to cause harm and risk is the likelihood occurring (within a specific time-scale (CAA, 2014).

Risk classification is that part of risk assessment where a classification is made and the judgement of the 'tolerability' (acceptability) of risk is determined. Typically, this is done using a risk classification matrix with which to assess safety arguments. The determinants of this classification are the probability of occurrence of hazard and the severity potential of this effect. ICAO 9589 provides guidance, it is in the sphere of safety risk management that risk assessment, classification and mitigation is situated within the SMS.

In keeping with current safety policy in aviation i.e. ICAO, no activity can ever be declared accident or risk free, or to have zero risk . i.e. there is no notion of absolutely safe. Risk is classified broadly as 'acceptable' or tolerable (undesirable risk), undesirable. (ICAO, 2013)

In the context of Safety Management Systems (SMS), aircraft operators are obliged to develop, implement and use and SMS under the provisions of Annexe 19 specifically to undertake a process of safety risk management.

Hazard analysis can adopt various techniques such as HAZID, Bow-Tie models, Fault Tree Analysis, the Safety Case approach, modelling per se. There are a multiplicity of techniques and models that are available. Most of these are dependent upon the availability of occurrence and technical data gathered from internal occurrence reporting systems.

There are two classes of analytical methods of risk assessment:

- Quantitative - mathematical based approaches
- Qualitative – approaches that use judgement and experience that may possibly be informed by quasi quantitative methods

Quantitative risk analysis and assessment needs data that is salient, reliable and appropriate with which to feed models or assessments. ICAO states that 'few hazards in aviation lend themselves to credible analysis through solely quantitative methods. Qualitative approaches, such as the safety case method, use clear comprehensible arguments that set out an argument that a system is safe or otherwise, and may use a probabilistic approach to the risk assessment that is then assessed using a matrix of tolerable outcomes

Intrinsic in any discussion of risk is the tolerable risk. What is the acceptable level of risk? Eurocontrol define this as 'The term "acceptable risk" describes an event with a probability of occurrence and consequences acceptable to the society, i.e. the society is willing to take or be subjected to the risk that the event might bring- (Eurocontrol, Skybray)

Another expression of this is from ICAO Annexe 11, the acceptable level of safety:

"The acceptable level of safety expresses the safety goals of an oversight authority, an operator, or a services provider. From the perspective of the relationship between oversight authorities and operators/services providers, it provides the minimum safety objective(s) acceptable to the oversight authority to be achieved by the operators/services providers while conducting their core business functions." (ICAO Annex 11, Attachment E).

There is no acceptable level of risk defined for UAV operations currently or standard for tolerable risk.

Risk assessment in UAV Operations

The nature of TS risk assessment for BVLOS UAV operations is twofold:

- Assessing the risk assessments undertaken by the UAV operators applying for approval
- Assessing the risks to third parties, wider society, other airspace users and within the environment

Risk assessment in civil aviation draws extensively upon risks identified from various sources of data be it occurrence data, reliability data etc to provide a risk landscape that provides the basis for decisions about risk.

The use of occurrence data for the assessment of risk in UAS risk assessment has been examined by Dalamagkidis (2015) amongst others. There is a paucity of occurrence reporting data on UAV operations (Clothier, Dalmadgkidis *et al*, Piloutsias *et al*, 2018). The 2015 Dalamagkidis study concluded that such approaches to risk assessment were very limited because the reliability of UAVs is questionable, they are *perceived* to tend towards unreliability. Should the components of a UAV system be sufficiently reliable, then it is conceivable that a UAV operation can be compliant with a target level of safety. In one study cited, by Piloutsias (2018), undertaken in the United States, it was assumed that fatality rates of manned aviation could be used as a surrogate for defining an equivalent level of safety. To date, no target level of safety as such can practically be applied to BVLOS UAV operations, therefore there is very limited use that can be made of such a perspective.

Other research (Hosseni, 2017) supports the premise made by Piloutsias that insufficient occurrence data makes probabilistic approaches to risk assessments for UAVs as impractical

Wild et al (2016) have undertaken a post-accident analysis of civil UAV operations between 2006 and 2015 to identify common factors in UAV safety occurrences. The report acknowledges that limitations in the data set i.e. lack of narratives (e.g., type of platform secondary hazards, in the occurrence reports and the limited number of reports make conclusions problematic. This report concluded that system component failures represented the majority of failures followed by human factors and loss of control in flight. This is a conclusion that makes intuitive sense but lacks the evidence to confirm it.

The current view of the UAV risk landscape has evolved. EASA (EASA, 2017b) considers the consequences of issues that were 'brainstormed' (EASA, 2017a, pg. 27) as :

- Ground risk (accidents/incidents involving persons on the ground or sensitive areas)
- Air risk (collision risk, air proximity, accidents and incidents with manned aircraft
- Violation of privacy, data protection, security; and
- Barriers to the market, burden for industry, locked potential for innovation and development

For the purposes of this project, the focus and scope is limited to the first three issues. However, the fourth issue is of significance to the agency as any risk assessment method needs to be mindful of the regulatory burden so that societal interests both in terms of safety and the innovative potential of UAV operations are kept in balance.

An observation of note in this regard is made by Dalmadgkidis *et al*, (Dalmadgkidis, 2012) in examining trade-off between regulation and UAV operations is that too prescriptive regulations will act as a barrier to the evolution and growth of the industry but provide the least burden on society. This is depicted in the FAA guidance shown in figure 1 below.

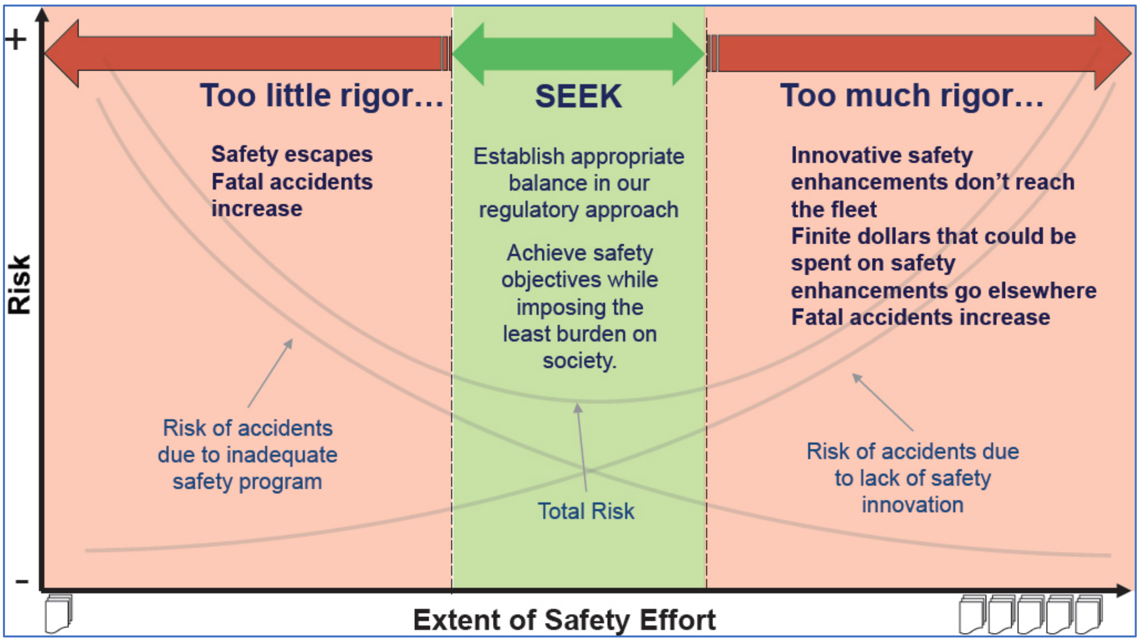

Figure 3: The Balance of regulatory rigour (Source: FAA, 2015)

Although it should be recognised that initially, the pace of operational implementation may be scaled to the experience and confidence that the agency has. The experience of BVLOS implementation by AHA.is in Iceland is worthy of note (Kristofferson, 2018). In this example, the operator and regulatory body collaborated in developing a common understanding that facilitated expanding the scale and scope of the UAV operation thereby realising the potential that autonomous BVLOS UAV operations can bring to the community.

A common view of the UAV risk landscape can be found in the literature (JAA/Eurocontrol, 2007, Clothier & Walker, 2006, Dalamagkidis et al 2008)

- Collision with other airspace users in the air or on the ground
- Collision with terrain or objects and people on the ground

In developing safety risk management method for UAV operations, Clothier and Walker (2014) categorised UAV hazards into two categories; primary and secondary, with the items above as primary. Secondary hazards are a result of hazards associated with the primary hazard. For example, damage on the ground due to falling aircraft or debris from a mid-collision. Secondary hazards have a particular relevance to the agency because of the need to protect wider societal interests and the environment.

In contrast. Wild et al (2016) have undertaken a post-accident analysis of civil UAV operations between 2006 and 2015 to identify common factors in UAV safety occurrences. The report acknowledges that limitations in the data set i.e. lack of narratives (e.g., type of platform secondary hazards) in the occurrence reports and the limited number of reports make conclusions problematic. This report concluded that system component failures represented the majority of failures followed by human factors and loss of control in flight.

UAV operations are recognised to introduce new failure modes, for which there is a paucity of data, which confounds the quantification and assessment of risk.

Within Europe, JARUS, as the European agency tasked with developing standards, technical standard and requirements for the UAV community. JARUS provides guidelines on risk assessment: Specific Operations Risk Assessment (SORA). The purpose of SORA is stated as:

> SORA provides a holistic model that should guide both the operator and the responsible approving authority in establishing whether an operation can be conducted in a safe manner. (JARUS, 2017)

SORA is positioned as an acceptable means of compliance for UAV operators and risk assessment and mitigation within EASA rulemaking (EASA, 2017). In the case of NSA's use of SORA, the scope is limited, for gaining confidence in a UAV operators' capability in being able to undertake and conduct an operation (JARUS, 2017) and not as method that is suitable for an NSA to deploy.

JARUS identifies three forms of harm that emanate from risks associated with UAV operations (JARUS, 2017)

- Fatal injuries to third parties on the ground
- Fatal injuries to third parties in the air – Catastrophic Mid-Air Collision (MAC) with a manned aircraft
- Damage to critical infrastructure

The latter is particularly salient given the societal impact, but it serves as an exemplar of the potential changes in the risk landscape that 5C BVLOS UAV operations may introduce. Therefore, this is one exemplar of a secondary risk that Clothier and Walker assert.

What does this mean for Transportstyrelsen?

The lack of data on UAV operations leads to a risk assessment method that must be qualitative in nature. This has implications for the approval process and in particular the applications made for approval for 5C BVLOS.

Luxoj & Luxoj (2017) developed a safety risk assessment method that uses the concept of operations (ConOps) for a UAV task as the framework for a quantitative assessment of safety risk. The concept pf operations for the research was based on a NASA ConOps for the applications UAV for agricultural tasks (Luxoj & Luxoj, 2017)). A ConOps is a description of a specific UAV operation defined in considerable detail. It presents "the operation's logistics, its associated environment, plausible scenarios, safety and performance considerations of the operation, and a possible plan for the execution of the operation" (Luxoj & Luxoj, 2017). In exploring the way that the agency assesses and approves applications, this approach has value to the agency in the context of the application and approval process.

Any assessment method must be mindful of primary and secondary risks. There may be consequences of adopting this within any risk assessment method in that the 5C BVLOS applicants need to be able provide hazard assessment and mitigation of such secondary risks.
encompassed a much broader understanding of the UAV operation including third parties as well as societal interests and a detailed appreciation of the technical capability of UAV platforms and operational factors. These all form part of any assessment of an application and not only shapes the assessment of risk but informs it directly.

LU Risk Assessment Literature review

A review of the literature was undertaken. One hundred and forty-three documents were collected, with a subset of fifty-seven documents which were selected as relevant to this study. (A full discussion follows in the section following this discussion).

Approaches to assessing and measuring risk take several forms. Typically, these are either quantitative or qualitative. The literature review introduced both quantitative and qualitative methods as well as a hybrid approach – Specific Operational Risk Assessment - SORA (JARUS, 2018).

JARUS has produced what is effectively an industry standard for UAV risk assessment with SORA. With the standard scenarios that complement the SORA method, there is a 'standardised' method of risk assessment possible. Possible only because consistent application of a method such as SORA is in practice difficult to achieve because of the practicalities of developing the knowledge and gaining the experience to be able to use the method confident of reaching a reliable result.

JARUS, in SORA, take a position on the type of risk assessment that is suitable for the risk assessment of UAV operations:

> A quantitative assessment in the context of the approval of UAS in the specific category is subject to large uncertainties in completeness, modelling and parameter values.
>
> The conclusion of this evaluation is that the likelihood estimation should be preferably of qualitative nature. (3.1.1 Approaches to risk analysis, JARUS,2017)

For the task that Transportstyrelsen have to undertake, a pure quantitative assessment is unsuitable. Indeed, this is the guidance given in the SORA method. Although, what kind of data could lead to eventually a risk assessment process that supported the Transportstyrelsen approval task?

SORA states that the risk that National Supervisory Agencies have an interest in are:

- Fatal injuries to third parties on the ground
- Fatal injuries in the air - catastrophic Mid-Air collision with a manned aircraft
- Damage to critical infrastructure

> *"it is acknowledged that authorities may consider additional categories of harm" (JARUS, 2017, 2.1)*

The literature search found one BVLOS Assessment Method, published in August 2018, by the Civil Aviation Authority of Singapore (CAAS). This is published as an Advisory Circular AC UAS-(0) (CAAS, 2018). The CAAS approval process is shown in the figure below.

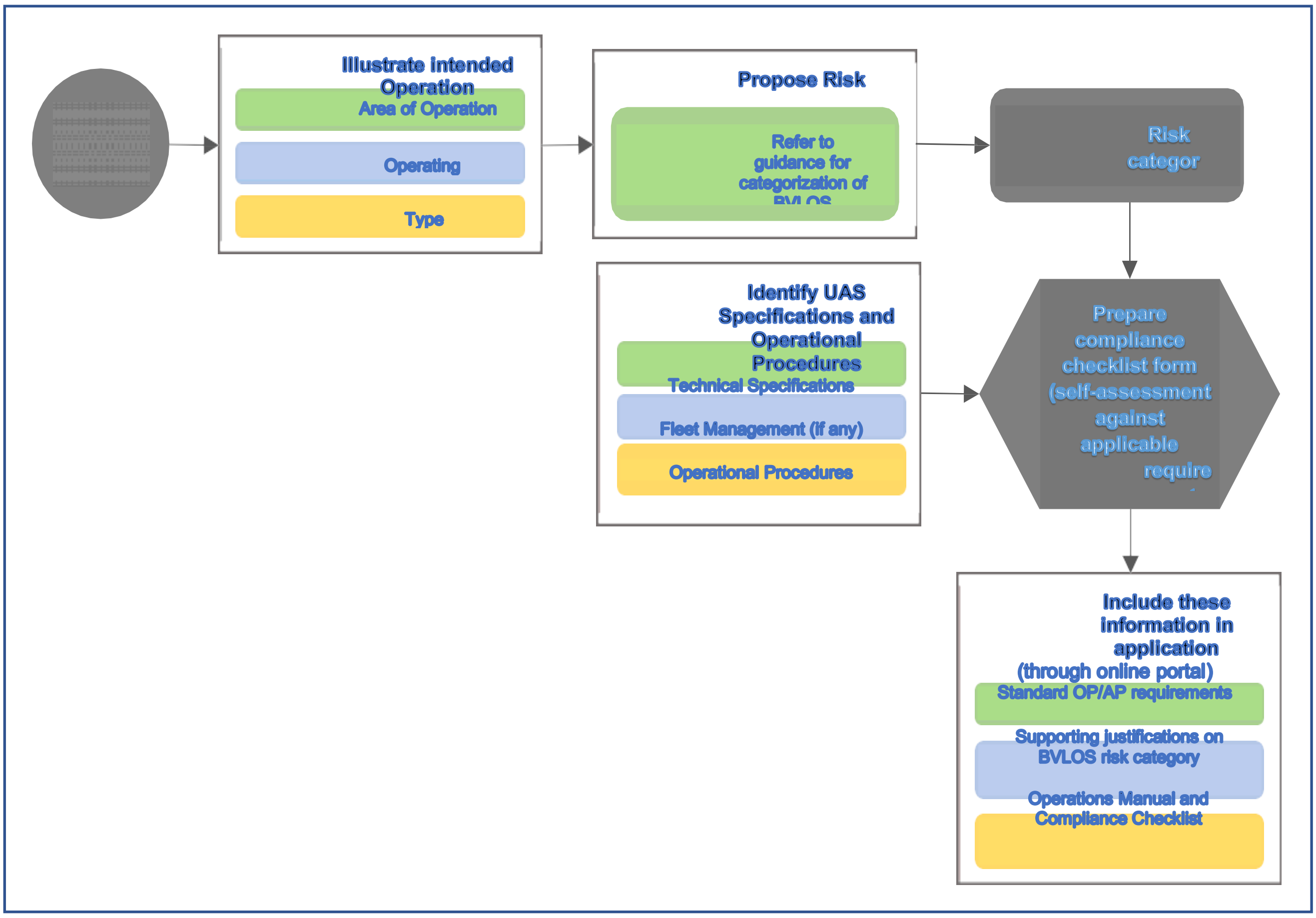

Figure 4: CAAS BVLOS Approval Process (CAAS, 2018)

The CAAS assessment is a qualitative risk- based method. The Advisory circular lays down a number of requirements standards, procedures and practices that a UAV operator needs to satisfy in order to derive the level of risk from which a risk classification can be derived, Dependent upon the risk classification will be the stringency of the risk mitigations using a three point -classification scale – Low, Medium and High. Figure 3 below provides an overview of risk classification.

<table>
<tr><th rowspan="2">Risk category</th><th rowspan="2">Intended scope of BVLOS Operations</th><th colspan="4">Requirement (Requirement Code)</th></tr>
<tr><th>Basic</th><th>Level 1</th><th>Level 2</th><th>Level 3</th></tr>
<tr><td>LOW</td><td>ï No overflying uninvolved persons
ï Operate away from people and in an area where it is reasonably expected that no uninvolved person will be present</td><td rowspan="3">ï General (BG)
ï Operational (BO)
ï Software (BW)
ï Others (BT)</td><td rowspan="3">ï Failure Management (LF)
ï Navigation (LN)
ï Communication (LC)
ï Detect and Avoid (LD)</td><td></td><td></td></tr>
<tr><td>MEDIUM</td><td>ï Flying in close proximity to uninvolved persons.
ï Flying over uninvolved persons, with flight duration not exceeding 30% of the overall flight.</td><td rowspan="2">ï General (MG)
ï Structural (MS)
ï Software (MW)
ï Navigation (MN)
ï Communication (MC)
ï Detect and Avoid (MD)
ï Propulsion (MP)</td><td></td></tr>
<tr><td>HIGH</td><td>ï Flying over uninvolved persons
ï High risk and complex operations</td><td>ï General (HG)
ï Software (HW)
ï Navigation (HN)
ï Detect and Avoid (HD)</td></tr>
</table>

Table 1: CAAS Risk Assessment Methodology for BVLOS UAV operations (CAAS, 2018)

The extent of the risk management process is governed by two specific hazards:

- Containment of the UAV within the specific area of operation at all times
- The risk to persons associated with the duration and population size exposed to the duration of the UAV operation

Source: CAAS, 2018, pg. 5

The CAAS approach is compliance based in nature. As such, its generalisability to other NSAs is limited where there are no detailed standards or procedures and practices because there is no common ground or agreement. As is the case in Sweden and in Europe. Although there is a tacit understanding of those that are used when TS make such assessments.

EASA, in a study in 2016 (EASA, 2016), assessed the key safety outcomes for UAVs in 2016 derived from expert judgement as:

- Airborne conflict
- Aircraft upset
- System failures
- Third party conflict

Several of the items in the literature review flagged 'loss of control' as a safety issue. This particular safety issue is akin to an aircraft upset and also maps to the system failure category. However, the nature of BVLOS UAV operations introduces new risks both technical and operational. Whilst as yet these are not defined, the agency approval sections do consider a broad range of risks beyond those categorised by JARUS and EASA

The literature review extends to the risks by the inclusion of secondary third-party risk, where harm is caused as an indirect consequence of an airborne collision. The airborne collision risk need not be

limited to a UAV and a collision with a manned aircraft, but from the agency's perspective the collision risk between UAVs is also of interest. This is especially significant in the Urban use case.
Risk assessment methods do use data from experience of operations in the past to develop a risk landscape and picture. However, in the case of UAV operation, such data is scarce and what is available is filed by other airspace users rather than UAV operators.

SORA has potential for UAV operators, JARUS makes the point that SORA is not intended for use by National Supervisory Agencies. Therefore, an alternative to SORA and the other methods such as Bow-Tie analysis, STPA or SESAR's Safety Reference Material needs to be found. These methods each have limitations and methodological concerns. For example, Bow-tie models are inherently linear whereas the nature of BVLOS UAV operations is more likely to be nonlinear and adaptive.

A subject for further research and for closer examination is the use of SAIL in the SORA method and its use in any BVLOS risk assessment method and approval process. The numerical output, whilst explicitly not quantitatively derived does provide a clear and structured approach to risk assessments. This is more around the simplicity of the presentation as well as the means to have a consistent manner by which they can be reported.

In the discussion that flowed from the presentation of the literature review conclusions, there was general agreement that a quantitative risk assessment method whilst desirable was impractical at the current time. Therefore, a qualitative approach will be the better option to pursue although a risk assessment method that can evolve when the means to adopt a qualitative approach is achievable.

For Transportstyrelsen to develop an understanding of the risk landscape, where does it gain the data from that supports the understanding. Occurrences involving the drone community are principally filed as a result of an airspace infringement or a proximity report. Rarely are these filed by the drone operator themselves. Thus, there is very little feedback that exists in other areas of the aviation system.

One approach found within the literature was recommended to the workshop as worthy of pursuing. Luxoj et al (Luxoj, 2017) developed a UAV risk assessment method based on the UAV concept of operations (ConOps) and uses this to develop a UAV safety risk model for UAV operations. This risk model was developed with the 'specific challenges of analytical modelling of novel aircraft in commercial aviation (Luxoj, 2017) Where the challenge is the lack of accident and incident data concepts' for nascent operations. This resonates strongly with what is required for TS to be able to make assessments that can facilitate approvals.

In Luxoj's ConOps/BBN model a UAV ConOps is used to derive the safety risk model that is quantitative in that the ConOps provides the initial step in a quantitative method that uses Bayesian Belief Networks to determine probabilistic measures of risk. The attraction of the ConOps/BBN model is that it recognises the complex nature of organisational work, more commonly known as socio-technical systems, and 'focuses on the interactions between people, technology and the environment' (Luxoj, 2017, pg.3). This approach is consistent with the research aims of this study in both scope and the characteristics of the system approach taken.

The Transportstyrelsen task in the approval of 5C BVLOS UAV operations is twofold:

- To conduct a risk assessment of the risk assessments submitted for approval by UAV operators.
- To conduct a risk assessment of the UAV operation application task that considers the interactions within wider societal interests and other airspace users

This is an important distinction. Transportstyrelsen have a requirement to assess the wider societal risk in conjunction with other agencies. The risk landscape that Transportstyrelsen are confronted with is different than that of the drone operators. The characteristics of the wider system that UAV operations are situated are those of a Socio-Technical system.

The attraction of the ConOps/BBN model is that it supports modelling of the operational environment and the interactions with society through adopting a socio-technical system lens. Additionally, the allows risk assessments for Category 5C BVLOS operations to be undertaken. Initially as a qualitative method, but with the possibility of evolving to. A hybrid method. As the ConOps element is a foundation for the qualitative element of the safety risk model.

It was proposed and accepted that LiU and LU explore a risk assessment method that uses a ConOPs based method which is able to be developed further with the addition of a quantitative model be it a BBN or other method.

TSARA – the Transportstyrelsen approval risk assessment method

The current approval process has four discernible steps that leads to a decision being made after an evaluation and assessment of the application.

- **UAV operations as envisioned:** essentially this step is the rationalisation of the operational task as presented in the application and in any discussions that lead up to the application being submitted. The concept and method of operations is one way that the UAV operation can be described that allows the UAV task to be envisaged by the agency. Which in essence is what the agency actually does albeit informally. This is consistent with JARUS SORA for example, who take a similar approach. What TS ask *of* the application currently when them is to answer the questions Who? What? and how?
- **Operational Hazards:** The envisaged UAV operation will contain hazards which TS will discover from any hazard analysis that is provided in the application as well as tacit knowledge and experience that TS have of UAV operations in general and specific to the proposed envisioned operations. Principally these will be as described previously.
- **Risk assessment and mitigations:** The hazards and risks derived in the previous step are assessed and mitigated by the agency. These assessments are documented and formalised in a risk assessment process that the applicant will be using in an organisational safety management system or formal process or method such as SORA. In other cases, the risk assessment may be bespoke and developed solely for the task by the applicant.
- **TS evaluation of the application of the risk assessment:** The task of the agency is twofold. One is to evaluate the risk assessment that is submitted and satisfy itself that it is salient, appropriate, that risk mitigations are commensurate with the risks found and that the operation will be conducted safely. A number of characteristics are considered by TS, such as the completeness and thoroughness of the application as well as the capability and competence of the UAV operator and organisation. The agency has its own separate risk assessment that it must conduct. The concept of operations and risk assessment and mitigations all provide the basis for undertaking this activity. This aspect of the approval process involves identifying who will be impacted by the proposed UAV operation and consulting with these required. The result of these consultations can materially affect the application's acceptance, perhaps by imposing restriction on the scope of task or requiring engagement with other parties.

Prior to this therefore, there is one other step that became evident in the workshops:

Generate the Concept of Operations

This project found that the 'concept of operations' of a proposed UAV application plays a significant part in the current approval process. This was evident in the workshops as well as in discussions with the agency. It is also consistent with other UAV risk assessment methods. For example, the revised JARUS SORA is believed to include a similar step.

At a number of places in the workshops it became apparent that the approval process and the application itself are important in and of themselves to any assessment and evaluation. They provide the means by which the agency and UAV operator making an application mediate and inform each other of what is required and how this is requirement is met. In formulating and preparing the application there has been and will be, in many cases, involvement between the UAV operator and the agency. This, at a very early stage, provides an appreciation of the quality, capability and competence of a UAV operator. In some cases, it is a step that acts as a filter that can lead to an application not being made

The risk assessment is not solely about the risk assessment that an application may include, however it is done, but extends beyond this. One facet of any assessment of an application involves building a view of whether or not the operation will fulfil its obligations in terms of undertaking the operation safely and with care to other airspace users and other parties with whom the UAV operation interacts. A view of this can be drawn from the contact and engagement between the agency and the UAV applicants before the application is actually made. The concept of operations of the proposed BVLOS UAV task becomes the common ground with which a shared understanding can be developed. Whilst preparing the applications therefore, any risk assessment needs to recognise this facet as a source of information that informs the assessment and thus it is recommended that it is formalised within any proposed method.

The outcome and results of the three workshops leads to the conclusion that at each and every stage of the TS Cat 5C UAV application and approval process there will be differences introduced with 5C BVLOS UAV operations that the agency needs to embrace

In the case of the Urban UAV use case, these differences are not understood currently whereas the other Use Cases sufficient clarity has been gained from the workshops to be able to develop a prototype 5C BVLOS risk assessment method.

An introduction to the TSARA method

The Transportstyrelsen approval and risk assessment method (TSARA) draws heavily upon the current approval process and develops this into a formal method. Additionally, a number of principles were used to frame the method's development, which were driven by the reality of not having any occurrence or accident data or appropriate experience with 5C BVLOS UAV operation and the need to make consistent decisions about approvals for applications for such operations.

The principles that were derived formed the requirements for the agencies risk assessment method for Cat 5C BVLOS UAV operations.

TSARA recognises the significance of the concept of operations and strengthens the approval process by using this as the framework by which the assessment of both the UAV flight profile and its operation can be conducted. Through this the risk landscape for the particular concept of operations can be evaluated for completeness and thoroughness in conjunction with the UAV operators hazard analysis and risk assessment.

The strength of the proposed approach is that it strives to make it possible for consistent decisions in approving applications and capturing the knowledge that is gained with each application as well as the execution of the UAV operation. Feedback loops are provided that informs the TSARA method and the base of knowledge that can be used in future applications for Cat 5C BVLOS operations .

The risk assessment method assumes that the decision made about an application, that has been submitted, will be structured in a way that encapsulates the essence of the argument that leads to the decision that has been made.

This, in the TSARA Method, takes the form of a reasoned narrative argument.

To fulfil this, an approach from current safety practise in aviation, that of the Safety Case, is drawn upon. In safety cases, a documented body of evidence that is developed that provides a demonstrable and valid argument that a system is adequately safe for a given application and environment over its lifetime.

In the case of 5C BVLOS applications it is the manner that the arguments are made and documented and how these support the claim made i.e. the approval decision (whatever it may be) and the evidence that justifies the decisions that an application BVLOS operation is 'safe'.

The use of a checklist supports the formalisation of the approval and risk assessment process. This is taking the current way that approvals are undertaken today, documenting what is done and building a structure around it. One benefit is that it provides a baseline description and process flow that can be built upon. This became apparent after the first workshop where TSARA was used. For the second workshop, a prototype checklist was tested.

There are five elements that were identified from the workshops around which a risk assessment needed to be designed.

This resulted in four process steps that flow to a final decision step. Each of three steps support the means to able to answer the questions that need to be answered in the fourth, decision, step – the assessment and evaluation of the application that led to the decision that is made. A fifth, pre-application step as described previously is also included.

The decision itself can take, it was found, one of four forms.

This reasoned argument constitutes the essence of the application of an approval, as seen through the lens of a Transportstyrelsen approval assessment and evaluation.

Generate the Concept of operations
Answers the questions:
what does the UAV operator intend to undertake?
how do they intend to undertake it?
↓
Describe Drone operations
(Answers the question: the UAV ConOps contain hazards and risks – what are these?)
↓
Operational Hazards
(Answers the question: what the hazards are that need to be assessed and mitigated and who or what interacts with the task).
↓
Drone Operations Risk assessment and mitigation
Answers the questions:
What are the risks associated with the operational hazards
How the identified risks are mitigated and is there residual risk?
What are the third party and societal risks and derive the mitigations)
↓
TS Evaluation
(The decision)

Post operation feedback

Figure 5: Transportstyrelsen UAV application approval flow process

The decision element of the approval process is important for many reasons. It needs to provide the basis for the determination and the argument. TSARA adopts the safety case structure of Claim-Argument-Evidence i.e. the claim that this application is approved on the basis of the arguments that the task can be undertaken safely and without harm to third parties on the basis of this evidence. In some respects, this is what is carried out today. ‘Can the UAV operator discharge their obligations?’ is a question that is asked in assessing applications today, TSARA formalises this in a structured process.

One other process step has been added to TSARA. This is a feedback loop that provides the opportunity to contribute to the understanding that the agency develops and is built from each approval of a 5C

BVLOS UAV operation. The source of such feedback are many and varied, but it is envisaged that it will include:

- Internal reviews of approvals
- Audits and visits by TS of UAV operators including where 5C BVLOS tasks that have been approved are being undertaken
- BVLOS operational experience shared with the agency by the UAV operators
- Eliciting the views and experience of a range of actors with vested interests in BVLOS operations and their perspectives

The basic TSARA method is depicted in figure 7.

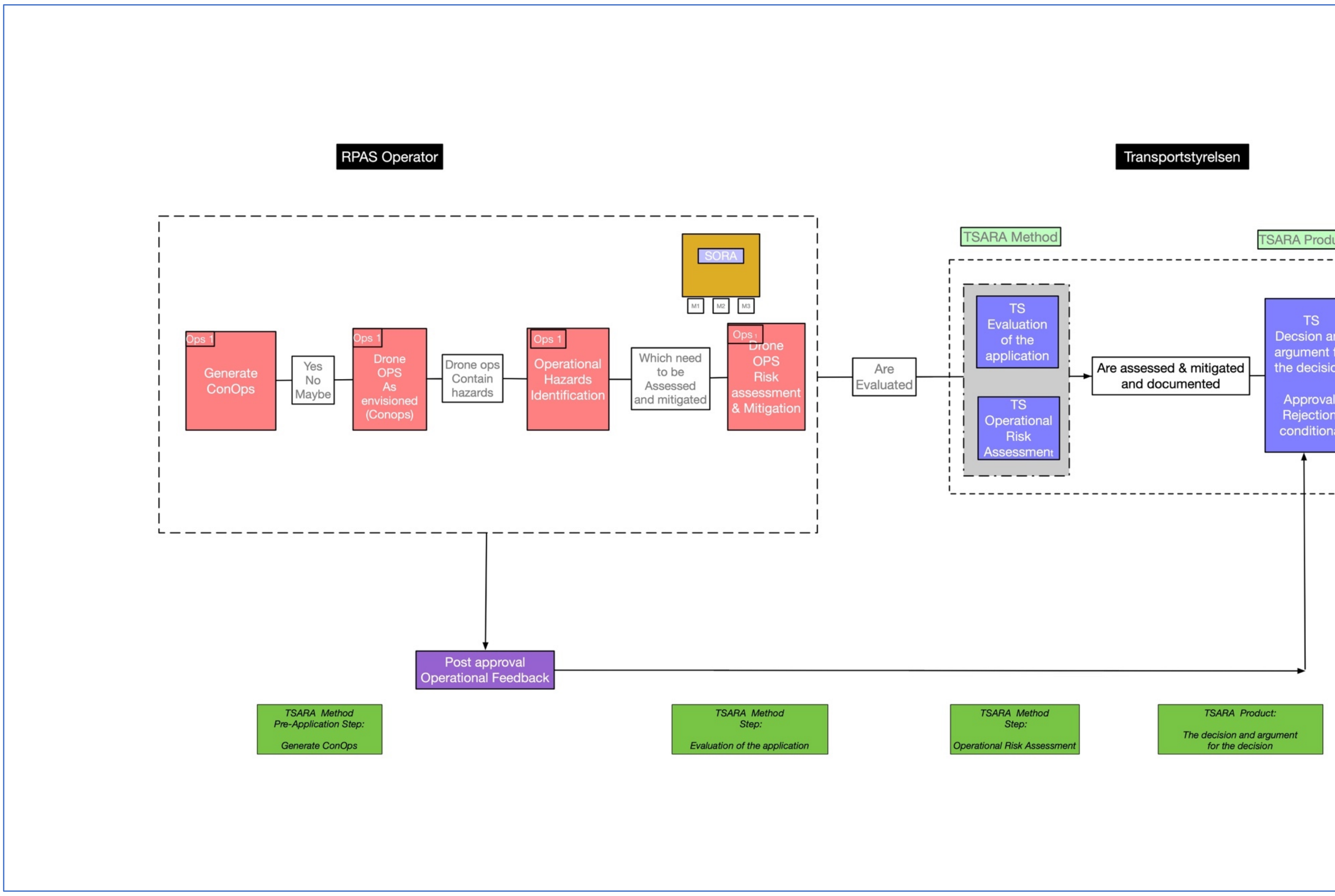

Figure 5: The Baseline TSARA Method

The TSARA method has four discreet steps as depicted in figure 9 and one preapplication step. One of these steps includes the TS specific aspects of the method. These three

- TSARA Method: Pre application concept of operation generation – Generate ConOps
- TSARA Method: Evaluation of the application
- TSARA Method: Operational Risk assessment and
- TSARA Product: The decision and argument for the decision

There is one other step in TSARA

- TSARA Product & Method: Post approval operational feedback

The baseline model depicts the process steps that the TSARA method is built around.

There are a number of information flows that enable the method when it is applied. These information flows are means by which applications can be assessed and adjudged. Figure 8 provides a summary of the TSARA method and the flows of information that emanate from the elements that comprise TSARA.

The flows of information are representative of the types of information and what they bring to the evaluation of an application. These are not solely limited to the information contained in the application, but other sources that help determine the completeness, comprehensiveness and quality of both the application and the UAV operator's risk assessment.

Additionally, as can be evidenced in the lower half of the illustration, there are a number of sources of information that support both the TS Evaluation and TS's own risk assessment. These specifically address the interests of third parties, other airspace users which the airspace section of TS support.

Concurrent applications as well as external risks that the agency must mitigate when necessary are also matters of interest in assessing and evaluating the application.

Also included in the information flows is the knowledge that comes from past BVLOS UAV operational tasks that have been approved – post operations feedback that develops into the history and experience that can be drawn upon in the processes leading to a decision. Additionally, this knowledge can be a source in determining mitigations or constraints that support limited approvals that enable more to be learnt about a particular concept of operations that a new approval may require because there is little experience or knowledge of the precise nature of the concept of operations and the specific operational task.

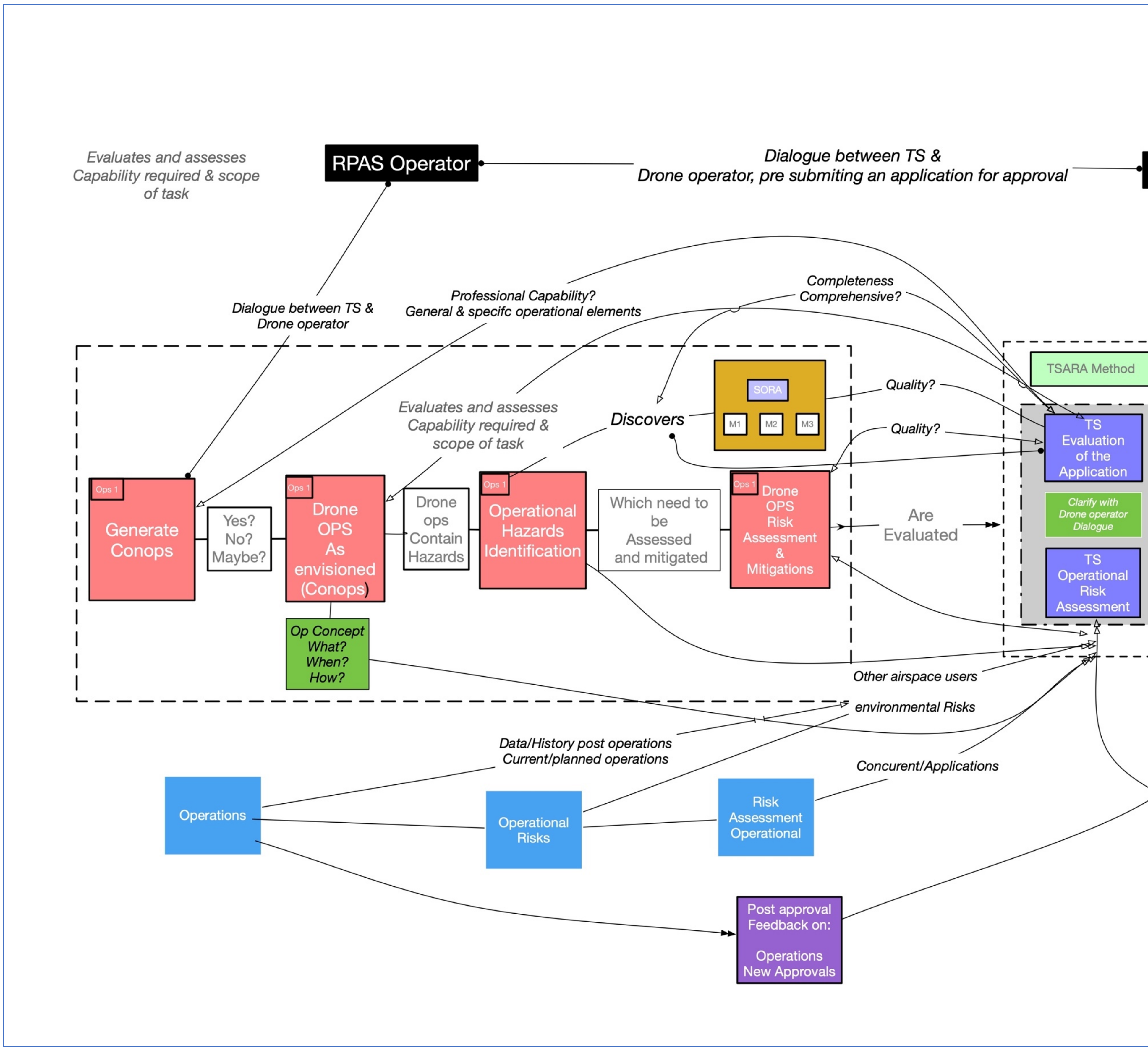

Figure 6: The TSARA Method information flows and questions

The TSARA Method in detail

Generate The Concept of Operations: Consideration of the application begins with activities that take place before the application is submitted as the UAV operator consults with the agency as they are preparing the application which is subsequently submitted.

In this period, a view of the concept of operations is developed which is formalised within the eventual application. Developing a detailed 'model' of the concept of operation provides a reference profile of the planned operation that enables consideration of how and with whom the proposed UAV task will potentially interact with both in terms of the operational environment i.e. other airspace users and ATC as well those who can be affected by the operation in the wider community e.g. the local population, livestock etc

This step facilitates a working description of the proposed UAV concept of operation to be generated.

TSARA Method: **Evaluation of the application:** the evaluation of the application is a wide-ranging examination of many features of the application.

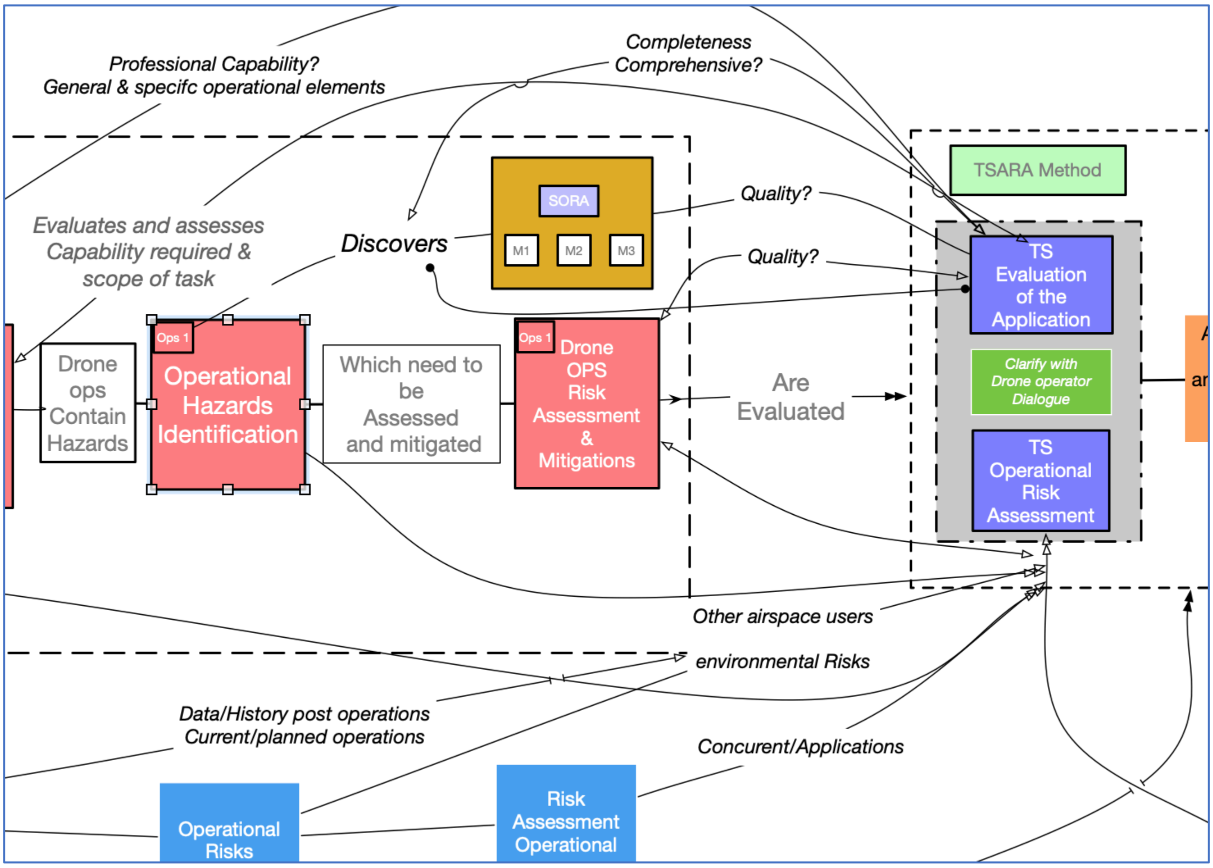

Figure 7: TSARA - Evaluation of a 5C BVLOS UAV Application

The step forms one part, albeit an influential step, in assessing the quality and completeness of the application.

It is through this TSARA method element that an assessment of how an applicant can, as one Transportstyrelsen assessor described it 'fulfil their obligations to a safe and effective operation'.

Professional capability of those operating the UAV forms a part of the assessment as will the organisational aspects of both the UAV operator and the team operating the vehicle.

Any dialogue between the drone applicant and Transportstyrelsen will be a feature in TSARA method element. It is through this part of the method that an initial view of the operational hazards will be discovered. Other elements will discover Drone pilot competency and currency, insurance provisions, the cost benefit of the task, the procedures that will be used for normal operation of the drone, coordination and consultation with any third parties and specific operational and technological capabilities. These adding further detail to articulate the concept of operations.

TSARA Method: Operational Hazard identification

The application is required to provide a risk assessment that is developed from analysis and identification of the operational hazards that the proposed UAV operation will contain and be confronted with. This, from the agency's perspective, involves two risk landscapes.

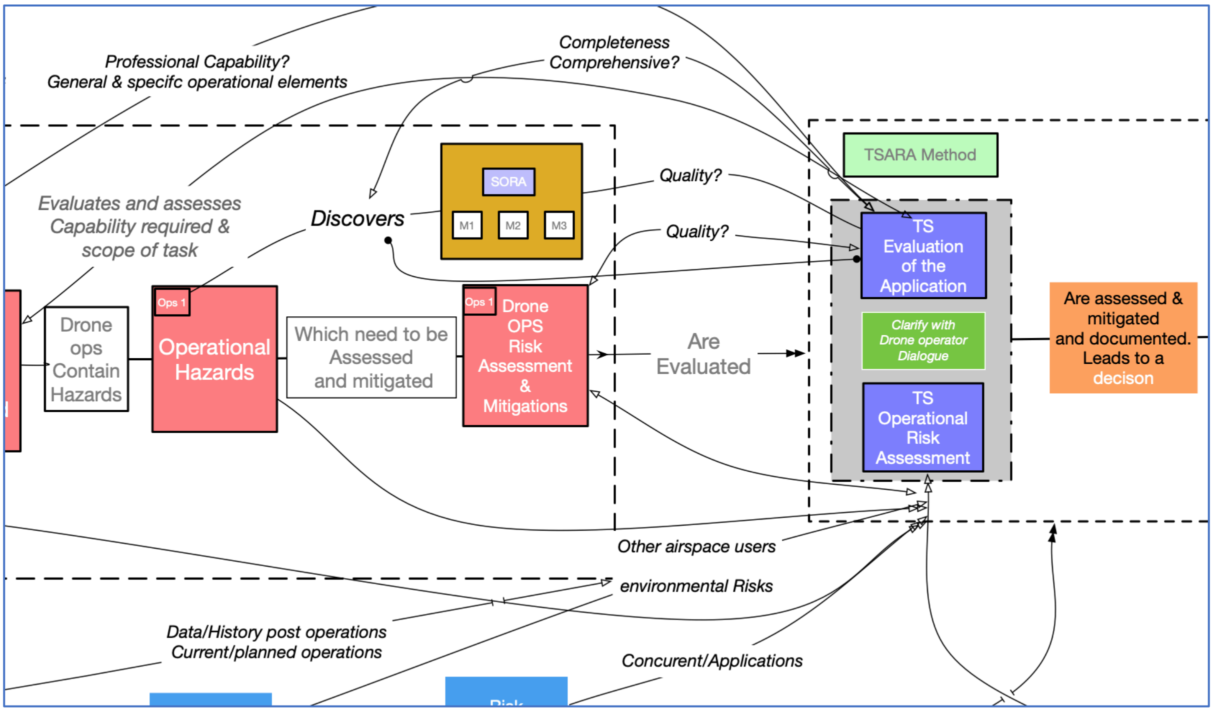

Figure 8: TSARA Operational Hazard identification and Risk Assessment

The first is grounded in the hazard identification that the UAV operator's hazard analysis of the operation itself submits. Transportstyrelsen are not conducting a risk assessment in and of itself but examining the applicants hazard analysis and risk assessment for completeness, quality etc. One of the outputs of this is the determination of requirements that may need to be put in place to notify other airspace users of the UAV activity e.g. NOTAMS, temporary restricted airspace etc Previous approvals may inform any assessment.

In the context of BVLOS operations there are potentially many more that will be impacted by BVLOS UAV operation. Furthermore, there will also be a need to consider the wider societal risk. Thus, many more actors and stakeholders, within the agency and beyond, who will need to be consulted and who each contribute to the building of a coherent risk picture for the specific application and operational task.

Transportstyrelsen will look for completeness and thoroughness for the applications engagement with the various agencies that will need to be consulted and views sought and coordinated. It will be necessary for the agency, nevertheless, to consult some involved agencies e.g. ANSPs and the military inspectorate.

In both this step, and the previous step of the method, there are particular areas of interest for the eventual building of a risk argument for assessment that leads to a decision being able to be made, potentially with safety requirements added.

This can be supported in a checklist or algorithmic format that allows specific knowledge to be represented and applied consistently.

Previous approvals will inform this TSARA method element as will other concurrent approvals that will provide context of potential conflicting airspace users.

TSARA Method: Risk assessment and mitigation: two distinct risk landscapes are examined in the TSARA risk assessment:

- The risk landscape that the UAV operator derives and uses to make a risk assessment
- The risk landscape that satisfies the Transportstyrelsen requirements for third party risks, critical infrastructure and other societal considerations
-

Catalogued typically in some form of risk table or matrix and which will include an assessment of the itself be it qualitative reasoning or quantitative assessment, included in the application.

The second risk assessment is conducted by Transportstyrelsen itself and involves an assessment of the risks with other airspace users, airspace structures or other salient operational interests in the operational environment.

In the application, it is assumed by the agency that there will be a risk assessment of ground collision risk for example.

TSARA Product -An argument for the TSARA decision: The philosophy used in the TSARA method is that the preceding steps develop sufficient understanding of the UAV operation through eliciting the concept of operation and using this to evaluate the application and undertake an operational risk assessment. These steps support the TSARA method in creating an argument or arguments that enable a decision to be made. This step of TSARA therefore brings together the results of the earlier steps so that they can be reviewed and analysed to develop the basis through arguments that become the decision that is the desired TSARA product.

The way that these arguments are crafted is by drawing upon aspects of the model of safety cases.

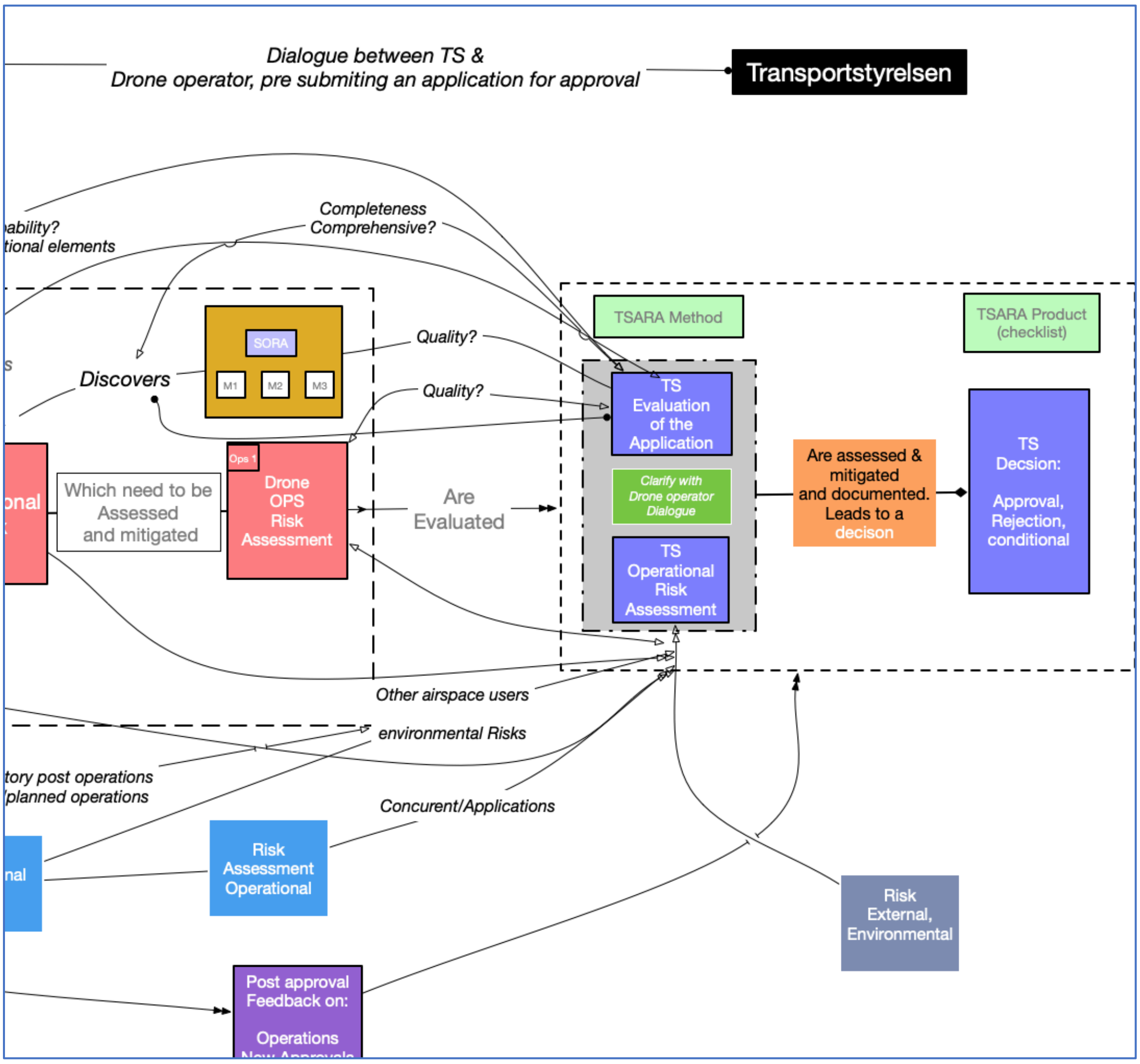

Figure 9: TSARA -The argument for the decision

A safety case is a safety method where a document is written that demonstrates that a system is acceptably safe. In ATM, NSAs and regulators use the safety case as a means of assessing that the system has been subject to analysis and demonstrated to be safe. There are numerous forms that a safety case can take and can be supported (CAA, 2010).

In the case of TSARA, it is the structured argument and claim format that is recommended as opposed to fuller use of safety case elements. However, there is merit in developing these at a later stage e.g. safety matrices

Acceptable safety is demonstrated through statements that use evidence to support arguments that substantiates a claims that safety is achievable. The arguments are thus supported by evidence found that justifies the reasoning behind the argument and the claim. A safety case should present a clear, comprehensive and defensible argument that a system is acceptably safe to operate within a particular context.

As stated in Cap 670 (CAA, 2010), 'it is not enough to merely state a safety objective or requirement has been satisfied, it must be proven'. This, it is proposed for the agency is achieved by constructing reasoned narratives drawing upon what is found in the concept generation, operational risk assessment and evaluation steps. The reasoned narratives thus follow the safety case format of a claim that is justified by an argument supported by evidence.

In some cases, safety requirements may be decided upon in approving an application. In such cases, there will be a claim that the operation is acceptably safe because a particular it will be argued that a particular safety requirement provides a mitigation to a hazard or external risk. Evidence, again in a narrative form is used to support the argument.

This structured approach makes it possible to have a consistent and repeatable set of decisions to be made.

The use of checklists or flow models and decision tools assist in embedding knowledge into the process.

Examples of three checklists that were used can be found in appendix.

It is desirable to explore methods such as SORA's SAIL that can provide a quasi-quantitative approach to risk and hazard mitigations.

TSARA Product - Decisions and justifications

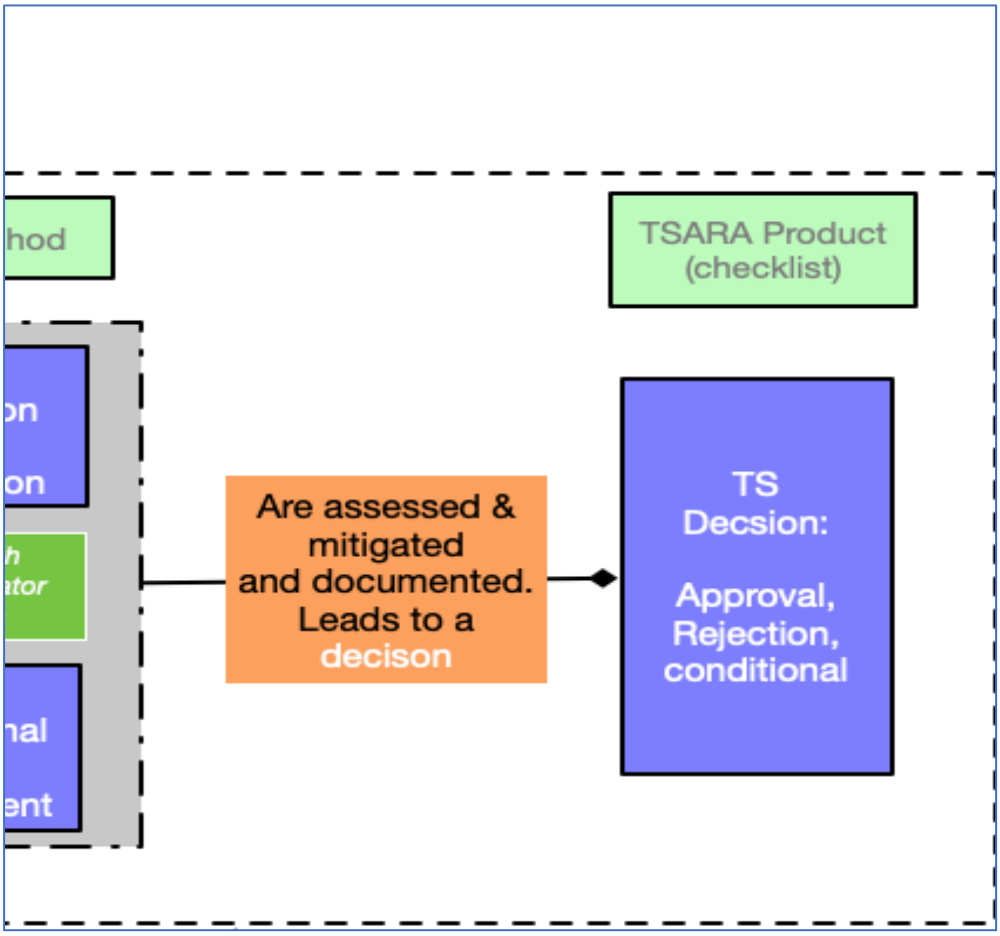

Figure 10: TSARA Decisions and judgements

The TSARA product is a decision about an application. This decision is argued for in the Claim-Argument-Evidence format that the determination of the assessment of the application undertook.

There are at least four possible outcomes – decision – that can flow from such assessments:

- Approved
- Rejected
- Partial approval – that is reviewed after a specified time period and maybe the subject of restrictions in the scope of the drone operating envelope etc.
- Conditional approval subject to the results of flight tests etc that inform confidence in the drone operation itself (and supported by a claim-argument-evidence narrative incorporated into the overall decision)

It is the intention of the structured approach to 5C BVLOS risk assessments that these decisions can be made effectively by adopting the preceding steps. And to do so in a consistent way that is repeatable.

Post Approval Feedback loops

The full TSARA method, as shown in figure 8, includes a number of feedback loops that contribute to the continuing development of the TSARA method. For example, the specific characteristics described and listed in figure 4.

Post operation history and narratives provided by Drone Operations provide meaningful information that helps to expand the understanding of the reality of Drone Operations and what is experienced in operation. The strategies that are developed to deal with operational surprises form a practical source of data that shared with others can enhance operations.

The basis of a CAT 5C BVLOS Risk Method

The literature review examined both qualitative and quantitative approaches to risk assessment. In the workshops it was argued that quantitative risk assessment methods that can be used in the approval of 5C BVLOS UAV approvals are not possible currently. Probabilistic approaches are available but will require adaptation and development. Notwithstanding this, the base information (occurrence and reliability data) is not available in any reliable sense currently with which to calibrate the models that will be used and to be able to develop a meaningful risk landscape.

The task of the agency is not to conduct a risk assessment of 5C BVLOS UAV operations *per se*, but an assessment and evaluation of the *UAV operators risk assessment.* The principal risk assessment responsibility the agency has, other than that discussed above, is an assessment of the risks to third parties and others who may be affected by 5C BVLOS UAV operations including inter alia other airspace users including UAV operations and critical infrastructure and their mitigation. An agency evaluation may conclude that mitigations are needed in the approval decision itself by way of restrictions on the operating envelope pending the outcome of a review of experience of the task.

- *Quantitative* approaches are rejected at this stage because there is an absence of reliable lack data to draw upon and build models of risk by which to accept or reject quantitative based assessments. Numerous methods exist, but as yet, such models cannot be populated with risk data for the TS task

JARUS's SORA provides a method which, when applied by UAV operators, provides the basis for a consistent risk assessment that may be repeatable and forms a basis or 'standard' that facilitates the agencies assessment of applications. SORA is not immediately suitable for NSAs – it is not designed or intended for use in this way. There are benefits from the agency using it as JARUS states in SORA to better understand how BVLOS UAS risk assessments and operation are conducted.

The SORA methodology does include a means of a quasi-risk quantification using an additive method of risk scores to sum the overall risk score of a risk assessment. This uses a series of risk matrices known as SAIL – Safety Assurance and Integrity Levels. SAIL Is not quantitative but uses a descriptive narrative reasoning in three steps that leads to a level of confidence being assigned that based on lethality and which leads to a SAIL Level. This is conducted for ground and airborne risk. The narrative argument takes the form of a reasoned and principled argument:

- Objectives to be complied with for the operational task
- Description of activities that might support compliance with these objectives, and
- Evidence to indicate the objectives have been satisfied

(Source: JARUS SORA, 2017)

SAIL has potential for use by the agency in any risk assessment process but needs to have a risk matrix devised for its specific risk assessment obligation. Going forward it may be possible to devise risk matrix specifically for an NSA risk assessment of the application that builds on the arguments that the agency's approvals team developed.

JARUS's standard scenarios provide a practical means of standardising the process of risk assessment. Whether or not it is able to replace a detailed concept of operations or supplement this is unclear at the moment. But there are potential benefits in terms of effectiveness of the assessment of BVLOS UAVs that could flow from the use of standard scenarios or adaptation for TS needs.

JARUS has chosen, principally, a qualitative approach. For TS such an approach is recommended as the way forward too, albeit an interim step towards a later iteration when data is available that can be used to model the risk more precisely or further research can be undertaken to develop a quantitative method. During the workshop two drone operators showed how it is possible to conduct, for their operations, a quantitative risk assessment that is simple in execution, uses available data and provides the means to be able make quantitative judgements. These may not necessarily be a complete answer to the agency's needs, but they could contribute to a robust assessment of risk, but not on its own

- *Qualitative approaches* are proposed on the grounds that, although not without challenges, an assessment based on reasoned argument that sets out the evidence for a decision in narrative terms is used and is an acceptable method. It allows knowledge and understanding to be gained. It is also a method that provides transparency. Consistency in assessments does requires methodological rigour.

Throughout the workshops, the different characteristics of a VLOS, EVLOS and BVLOS UAV operation were explored from the perspective of the agency. In setting out to develop a risk assessment method the assessment of the differences framed the starting point in the derivation of a new 5C BVLOS risk assessment method.

The output of workshops 1 – 3 were reviewed and synthesised to explore the additional requirements that BVLOS risk assessments require from the agency's perspective, as well as . As the workshops with the Transportstyrelsen UAV team and UAV operators explored the approach taken was to explore the differences in the context of the approval process as a whole.

The figure below synthesises a flow model of the current approval process derived from the first workshop in the series. The basic approval process flow was interpreted by the LU/FOI as having four discrete steps:

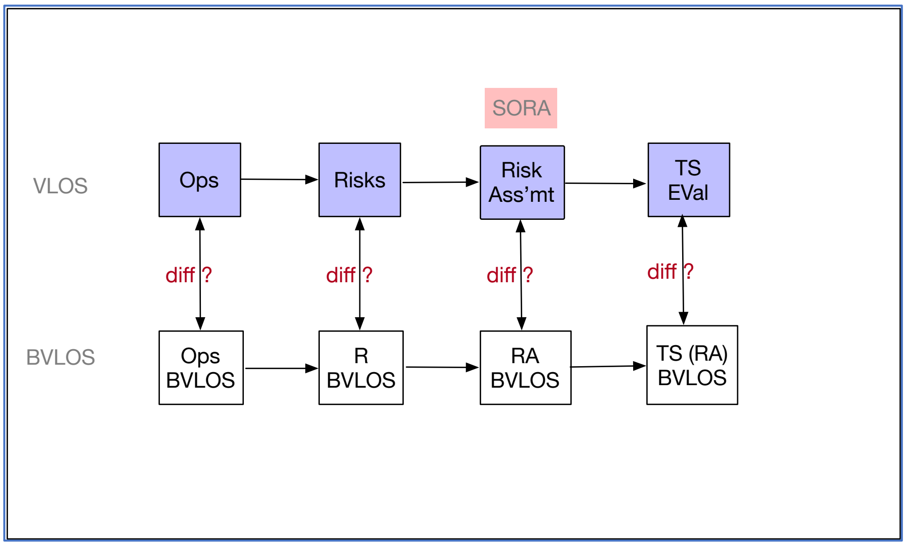

Figure 11: *The TS Current approval assessment process*

TS review of TSARA

An end of project review was undertaken on the 29th of January 2019. The project approach and findings were presented as was the TSARA method.

Transportstyrelsen staff present engaged with the premise of the findings and discussion ensued.

Some comment was made concerning the nature of risk assessment methods in general and for UAV operations in particular. Whist risk assessment is nothing new to the commercial aviation industry and has evolved over many years, this is not the case with UAV operations. It is a matter of debate for example, whether commercial aviation approaches to risk assessment and the associated methods have value for UAV risk assessments.

There were a number of points made about the approach and the method. In many cases the comments related to the lack of a formal risk assessment methods that are currently used in civil aviation. For example, the use of a target level of safety or required level of performance. These are not available currently for UAV operations. ICAO has proposed (ICAO, 2018)

There are undoubtedly lessons and experience to be learnt, as this project has used by adopting structured and formalised arguments. The agency may look for the use of Safety Management Systems as a risk-based management tool within UAV operators, other aspects of risk and safety assessment remain to be developed for the UAV domain. Especially quantitative assessment of risk using probabilistic models of risk that can lead to the use of risk matrices that formalise risk decisions.

Whilst numerous operational risk assessments methodologies and system safety processes exist therefore, standards as such do not exist, which was a subject of discussion and evident is a requirement for some agency staff.

Uppermost in the discussion was the plain fact that there are few specific safety requirements for UAV operations. ISO/DIS 21385-1/2/3/4 (Parts 1-4) provide a basis of some standards for example but JARUS -SORA does not as such.

There are no safety requirements such as a Target level of safety that is common in ATM or required system performance.

The issue is how the existing body of current and existing airworthiness, operational risk assessments and safety analyses map to the specific and varied nature of UAS operations being scalable to Category 5C BVLOS as well as other categories of UAV classification as used in Sweden.

Another aspect raised by Transportstyrelsen is the different risk landscape particularly the greater number of stakeholders, actors and interested parties that Cat 5C BVLOS operations engages with or involves either directly or indirectly. The approach taken in exploring the risk assessment for BVLOS UAV operations is one grounded in a systems approach where determining the broader system actors is implicit. It is not just new actors and stakeholders that need to be recognised in the use cases, but also that the interactions with current actors may change in unexpected ways.

The benefits of TSARA do not come from a new method as such, but stem from gaining an understanding of the current approval process and using this to develop an approach that is structured and formalised. A structured approach to build an argument that is grounded in the way that applications are assessed currently and using the 'safety case' approach of:

- Claim
- Argument
- Evidence

Which will provide the basis for a means to achieve consistency in making approval decisions.

It is recognised that there is potential for a 'SAIL' style tool to inform judgements through a risk matrix derived through experience with BVLOS applications. The feedback loops play a significant part in facilitating the capture of this experience that can be used to update TSARA.

A draft final report was used as the basis for this review in conjunction with a number of technical notes.

A number of comments were subsequently received and incorporated into this final report

Results of the workshops: Use Cases, TS risk assessment requirements and a philosophy

Workshops

The approach taken to determining the needs of TS BVLOS risk assessments was to explore the current risk assessment process and future needs of both the agency as well as those needs of UAV operators who wish to undertake BVLOS operations.

A series of five workshops were planned and undertaken that adopted an iterative approach to both the elicitation of knowledge and identification of the needs of both TS and the UAV operator as well as, to understand how risk assessments were undertaken.

Pivotal to the salience of the workshop findings was the engagement and involvement with the Drone community. TS were able to attract members of this community who made a very significant contribution to the discussions and the output. This they did through not only bringing the experience that they had of current applications of UAVs in their specific domains, but also in sharing openly their approach to development of Cat 5C BVLOS UAV operations and the specific requirements that they had derived. This included, for example, the various UAV operational tasks and characteristics as well as approaches to risk assessment.

The workshops explored:

- the current assessment processes including how risk is assessed by the agency and UAV operators
- The derivation of Use Cases
- Today's approval process
- How the UAV community conduct risk assessments both for current as well as for BVLOS),
- TS requirements for both approval and risk assessment
- Risk assessment techniques and methods
- Selection of a candidate risk assessment
- Exploring the value and suitability of the candidate method
- Examining the candidate method with UAV operators using pilot BVLOS Cat 5C applications through the use cases

Early on, in the first workshop, it became apparent that the risk assessment of UAV operations is subordinate too and in support of a wider agency function, that of the approval of the UAV operation and operator for specific UAV applications. This perspective showed that the application approval

A workshop report produced after the workshops can be found in Appendix C

Workshop 1: August 14th, 2018

This first workshop invited agency and LFV practitioners solely and served a number of purposes:

- The status of UAV related rulemaking and regulation both in Sweden and at the European level
- Presentation and discussion of the TS Airspace project undertaken by Lt Col Lars-Erik Blad (the BULOS project)

- Examine the current TS processes for risk assessment when considering applications for UAV operations
- The TS Use Cases that will be used for the initial Category 5C BVLOS candidate tasks
- Risk assessment of new technologies – a case study of Multiple Remote Towers (LFV)

The regulatory landscape is emerging as the EASA rule making activities that lead to the regulations being implemented pass through the regulatory processes. That there is a lag is unfortunate. In the case of Sweden recent changes will align with the EASA regulations.

The current categorisation of UAVs used in Sweden, introduced in 2018 is shown in table 1:

Table 2: Categorisation of UAVs in Sweden, 2018 (as presented in Workshop 1)

Kategori	TS Tillstånd	Vikt	Operativa begränsningar	Märkning av luftfartyg	Övr
1	Nej	0-7kg	• Inom synhåll • Max flyghöjd 120 m (i okontrollerad luft) • Max 10/50m höjd i kontrollzon och TIZ minst 5km från bana • Säkert avstånd från människor/djur	• Operatörens namn • Telefonnummer	
2	Ja	7-25kg	• Inom synhåll • Max flyghöjd 120 m (i okontrollerad luft) • Tillståndskrav vid flygning i kontrollzon • Etablerad kommunikation med flygtrafikledning i TIZ • Minst 50m säkerhetsavstånd från människor/djur	• Operatörens namn • Telefonnummer • Tillståndsnummer	
3	Ja	25kg-150kg	• Inom synhåll • Max flyghöjd 120 m (i okontrollerad luft) • Tillståndskrav vid flygning i kontrollzon • Etablerad kommunikation med flygtrafikledning i TIZ • Minst 50m säkerhetsavstånd från människor/djur	• Operatörens namn • Telefonnummer • Tillstånd nummer	
4	Ja	-	• Bortom synhåll med Detect & Avoid utrustning (D&A) *Samma regler som bemannad luftfart*	• Registrering	
5a	Ja	-	• Flygning möjlig 120 m + 50m över/sida om hinder	Enligt viktklass i kat 1-3	
5b	Ja	-	• Begränsad flygning bortom synhåll möjlig med observatör	Enligt viktklass i kat 1-3	
5c	Ja	-	• Alla operation som inte ryms under 1-5b. T.ex: • Bortom synhåll <u>utan</u> D&A, • flygning över människor, djur, m.m	Enligt viktklass i kat 1-3	

TS Drone Project

One response to the expected growth of UAV operations in Sweden, is an agency study that examines the strategies that can be adopted to enable and facilitate the growth of operations. This study , the BULOS study, was presented in this, the first workshop by Lt Col. Blad the author of the research.

Whilst the agency recognises that the demand for growth is across the UAV industry, a particular focus of the study was on low level operations < 140M and the interaction between General Aviation, helicopter operations, low level military and similar low -level coastguard, SSRS and police tasks.

The principal conclusions from BULOS were that management of UAVs <!40 m was best achieved by a policy of segregation and by collision avoidance by manned aircraft. Practically, manned aircraft will be able to take collision avoidance more readily than a UAV operator given the limitations of the see-and-be seen principle of used in Class G airspace.

Avoidance can also be achieved by manned aircraft operations during the flight planning phase, by creating a 'known traffic environment'. In order to achieve this, it is a pre-requisite that a means for UAV operators to 'file' their planned trajectories in a manner that makes such data accessible to other airspace users is available. This facilitates other airspace operators being able to flight plan in such a way that they could avoid UAV operations altogether or assume the task of collision avoidance in. There is value in the SESAR U1 UTM approach to a Drone Information System that can support such an approach.

The precise definition of the creation of a known traffic environment for airspace users is a subject for consideration for further research. Other alternatives involve the use of some form of electronic conspicuity, although this was not directly considered in the BULOS study. .

Collision avoidance is a pertinent factor in risk assessment from a number of perspectives. One consideration is the responsibility that Transportstyrelsen has to other airspace users when reviewing applications and considering the risk associated with the envisaged operation and other airspace users.

The current approval process

Attending the workshop were agency personnel who are actively engaged in the processing and , consideration of applications that lead to them being able to decide upon approval of UAV operators' applications for operations. The approval process was explored from the point at which the application is received until a decision is made and communicated with those who will undertake the operational task.

An application typically undergoes five steps:

> **Receipt of the application**: No application is made for Category A UAVs. For other categories, 2 & 3 were examined in the workshop, an application is made via the agency's portal. Prior to the applications there is often contact between UAV operator and the agency.
>
> **Registration of the application**: all applications need to be formally registered in the Agencies database. Typically, an application is processed and a decision made, for Category B, in ten days
>
> **Processing of the application:** There are a number of procedural steps that are undertaken. These involve checks of pilot theory and flight operation within the records that the agency

holds as well as insurance provisions that the UAV operator holds. An approval is only ever given to one UAV operator in any given application.

Assessment leading to a Decision: The assessment of the application is a collegiate activity involving different sections of the agency e.g. Airspace section, ATM section as well as external agencies e.g. LFV, Military etc.

The application is examined in detail from various operational perspectives and technical perspectives. The capability of both the UAV platform and operation are examined including the experience of the UAV operator. The way that the application is presented and the detail of what it contains all go to building a view of what is involved in the operation task and whether or not an applicant has the capability with which to fulfil it as well as an organisation that supports the operation. For example, specific aspects of the way that the operational task will be operated: will the task be operated with one or two crew? What provisions are there in any operations manual of safety management system for various operational contingencies.

The agency assesses the risk assessment submitted as well as carrying out a separate and different risk assessment of its own. This is a particular agency activity that considers the interaction with other airspace users including ATC, other activities and communities within the operating envelope of the UAV operational task.

A decision is made on the basis of a consideration of all of the above (and more) as well as the inputs from others within the agency and externally. It may be that further information is obtained from the UAV operators' applicant.

Ultimately a decision is made and communicated.

The following became apparent from the discussions that ensued:

- The contribution of Post hoc review of approvals and the operation was discussed. It could bring or contribute to the regulatory understanding and capability growing and evolving as information is gained on how effective the approval process was and how the operational task was undertaken and what risks were mitigated or identified during the task. Secondly, the process itself can be enhanced if it embraced a consideration of the SMS processes that drone operators undertook
- It is recognised that different risk models of the operating space will be held by different stakeholders. GA pilots will view risk differently than drone operators and Transportstyrelsen themselves. Such variations are entirely legitimate of course. It is understanding that these differences exist, but how are they reconciled?
- Use of electronic support for regulatory process – what is the possible scope and potential for developing a future risk assessment mechanism?

From the perspective of a developing a BVLOS 5C risk assessment, the scope of the activity needs to go beyond risk assessment and should extend to the entire application process.

Use Cases

Three use cases are proposed by the agency as the focus for the development of a risk assessment method being anticipated early uses of Cat 5C BVLOS. These are contrasting in terms of the scope of the activity as well as the regulatory approval process. The three use cases that the agency wish to use are:

- Pipeline Inspection: 5A & 5C: up to 500M, including emergency powerline inspection
- Forestry: 5C
- Search and Rescue Operations (SAROPs) Missing person: 5C, Up to 500M. This use case includes time criticality, a dynamic task and one where recent experience has shown that the operational task my call upon to augment drone operations with local drone operations as operational assets.

The use cases have a number of assumptions that they are built upon:

- Need to have a discrete 5A and 5C
- Pre-condition is BVLOS
- Possibility of mixed mode

It is critical that realistic use cases are developed possible. To achieve this, there are a number of criteria that need to be fulfilled:

- Drone operator view of the operation and considerations of their risk landscape and the way that they perceive risk needs to be embraced
- There are numerous variations and adaptations in the way that the use case operations can be undertaken and that will need to be understood
- Conditions of possibility for approvals need to be explored and thus the use cases need to provide the means to explore this
- Limitations of the use case operations in practise as well as the regulatory approval process need to be elicited. This can provide the basis for deriving requirements for technical innovations that contribute to a timely and effective approval process

It is recognised that the pace of development and change in drone operations is very fast. In order to be able to support this the future of drone development and evolution will need to be both considered and embraced. Of these, one use case that was recommended by LiU and LU for inclusion in the use case set is the Urban case study. A video example was shown to illustrate the potential use case.

A discussion was entered into with consideration of more complex scenario's city/urban. It was felt that exploration of such cases was desirable but that the three use cases that had been initially identified by Transportstyrelsen provided an evolutionary path to exploring more complicated use cases. However, the urban case can be included but with limited scope. For example, an urban case where Norrkoping is an exemplar and might include operations in Class G and Class C airspace.

Conclusions

The first workshop was deemed to be very profitable and generated the first glimpse into the approval process. The nature of the risks that would be explored in BVLOS are evidently different. Identified in this workshop was the need to explore the use cases with drone operators and also to understand the wider context of the approval process.

These formed the foundations of the second workshop

Workshop 2: August 28th, 2018

The second workshop was designed to explore the Transportstyrelsen use cases with drone operators and the agency staff.

To this end, drone operators and ATS service providers were invited to participate. Six drone operators, who between them had experience with all of the TS use cases. In addition, the UAV participants all had experience with, or planned to undertake, Category 5C BVLOS operational cases.

Of the two ATS providers who were invited, only LFV were able to participate. TS were able to provide members of the Drone approval team as well as members of the airspace team who are also engaged in drone approvals.

Use Cases

From the first workshop *three* plus *one*-use cases were introduced to the workshop:

- Powerline representing linear feature style use cases
- Forestry tasks
- Search and Rescue task involving a missing person

In addition:

- An urban city case was proposed by LiU and LU

The principal three use cases were explored in group sessions where the groups were comprised both UAV operators and agency staff. These sessions took the agencies use case definitions and elaborated upon this. (See the next section for the detail of these)

In the case of the Urban/City use case the group session took place with the by means of a visualisation of the use case that provided by LiU from an ongoing UTM project

Each of the groups reported back to the whole workshop in plenary.

Overall, the TS base use cases were agreed to be appropriate with respect to the task of the risk assessment project.

However, the detail of the uses cases as originally derived were found to be incomplete in that a number of assumptions were found not to represent how the Drone Operator community envisaged undertaking BVLOS Category 5C operations for the three use cases. Specifically:

- the weather conditions were found to be too conservative e.g. Not CAVOK
- BVLOS would make new platforms available with a greater operational envelope e.g. at night
- The capability of the platform and sensor opened up new operational capabilities and flexibilities
- Risk analysis will be required to be more rigorous than VLOS or even EVLOS because of the expanded capability of platforms and operational tasks. This is not just a case of 'more of the same, but also new hazards and interactions within both the operational environment and the environment and society as a whole
- The nature of SAR operations is dynamic and may well involve coordination with a multiplicity of diverse stakeholders

- The design of the platform can be optimised to minimise risk. The two commonly held risks airborne conflict and collision with ground objects humans can be mitigated by design of the platform as presented by Smartplanes.
- BVLOS 5C is approved currently to the Swedish Police. Risk assessments are carried out and enacted. There is an accountable officer/manager who is integral to such risk assessments

The use cases that had been envisaged were therefore conservative with respect to the scale and scope of the operation of the use case. One reason for this is that Category 5C BVLOS offers significant operational benefits in terms of the range and flexibility of operational capabilities. These operational benefits lead, potentially, to new scales of economy in UAV operations to achieve more effective production of operational tasks. For example, multi-task operations where two or three different tasks, with differing operating characteristics that being undertaken in the one sortie. These tasks may be undertaken in geographically different locations such a transit is involved. It becomes readily apparent that new operating modes are introduced. One that was discussed in this workshop is that of 'land away' rather 'out and return' flight profiles.

The power line use case is an example of how diverse UAV operations can become with Category 5C BVLOS.

Today operations are characterised by:

> 5-10 miles tasks have been good. 400 miles a year. Today's drones are used for damage location and assessment in local areas, occasional pole investigations, maintenance requirements for wooden joists. Post 50m out in water, but within view up to 300m.
> Even in the switchgear environment UAVs can be used e.g. identifying bird's nests & discoloured insulators

Future operations that capitalise on the potential of Category 5C BVLOS that are being considered include:

> Short distances
> Overview with 7km. Where are people in motion (hard to see for longer distances, is there a Tivoli?). Not to happen before we can start. Move one mile at a time (5km in each direction).
> What happens if the drone falls down? Summer cottages, The public are staying. Water? Building? (Sometimes it is built under power lines such as car parks, summer house, swimming pool, shopping centre, owner's tower, greenhouse on ready-made land. National park, bird shelter areas, restriction areas, e.g. that one may not fly / possibly restrict at height. I.e. NOT LESS than 300m or 150m).
>
> Long distance operation
> Systems that work with 3G, planned route, where out and return is the basis or a tactical change. Classic radio link. About 5 miles. (license required by PTS). No extra equipment along the way. Satellite dish in the right direction, you lose contact 10 miles away with ("eagle").
> (Long-term operation, solar-cell-driven, April to September, can fly all the time.)

Considerations such as these are germane to the application process both in terms of risk assessments that are undertaken by the UAV operator and for the Agency.

Other observations for consideration include:

- that there are two (at least) forms by which UAV operations can be undertaken:
    - Those within an organisation, often with multi-person teams
    - Drone operations in small entities with single person operation
- The design of the UAV platform and its capacity to cause harm to third parties
- a great deal in preparation, do you disturb something, do you hurt anything? Even with conventional helicopters (scare horses, trotting tracks, ...). Drone disturbs/scares less. Moose can be disturbed .... (Powerline group session)
- Low flying paths with Gripen and Helicopters? Is the power wire a drone zone? Temporary restriction area (maybe something else, blunt, shut out EVERYTHING else? (Powerline group session)
- Varied meteorological conditions
    - Powerlines: Weather, other conditions. Avoid rain, avoid lower than -10 for battery and condensation. Wind 10m / s.)
    - SAR: fly if it at all possible
- This leads to the question how do UAV operators know the prevailing meteorological conditions at distance from the UAV operator?
- Another meteorological consideration is wind effect on UAVs especially with respect to wind shear
- Category 5C BVLOS opens up the opportunity to use a wide variety of sensors beyond RGB cameras. Varying sensors lead to different operating characteristics and tactical operational requirements
- There is the potential, as well as an operational need for day and night UAV BVLOS operations

From the original three use cases, a number of variations were identified. This meant that there were now nine possible use cases. The assumptions that the use cases are built on need to be reviewed in light of drone operator experience. This was carried out by LU and the output was written up as a technical note and distributed on the third of September (see technical note that accompanies this report).

The Urban UAV Case

The Urban use case yielded extensive discussion and demonstrated that both the scale and scope of UAV operations in urban areas is little understood currently. Research, such as that being undertaken at LiU, provides an insight into the characteristics of urban UAV operation developing an understanding of the risk landscape and, more fundamentally, examines the manner by which .

There are a range of operating characteristics for Urban UAV operations – from manned UAVs to autonomous with modes in between. There is also a wide range of technical solutions to operational risks such as airborne conflict with other UAVs as well as other airspace users. Some urban operational environments will have aerodromes in the proximity – which can lead to potential interactions between UAVs and aerodrome operations, possibly in mixed airspace types.

Within the scope and scale of this project, it was agreed to retain a version of the Urban case where operation is assumed to be human UAV operators for two applications:

- Package delivery
- Police activity.

Time will be allocated for a presentation of urban UAV risk assessments in the third workshop.

Workshop 3: October 4th, 2018

This workshop had as its focus risk assessment methods, exploring risk in the context of UAV operations from three perspectives:

- Urban UAV operations
- What the UAV and safety science literature contributes to approaches to the risk assessment of BVLOS UAV operations
- How a UAV operator perceives risk
- How Category 5C BVLOS operations differ in terms of risk assessment and assessing applications for approval

Urban UAV Risk Assessment

LiU provided a presentation on the scope of risk assessment and a quantification of the magnitude of specified safety events from several studies of UTM and low density – high density urban/city scenarios.

To begin, to provide context, a review of the way that UAV technology which can facilitate urban UAV operations demonstrated that technical developments in the miniaturisation, battery life and capability of UAV avionics was advancing such that electronic conspicuity of UAVs in urban operating concepts was perfectly feasible. There are issues around the capacity of the links that support dissemination and transmission of such data, however, these problems are within the bounds of reason to find solutions as projects such as a significant implementation in Dubai has shown.

An ADS-B based UAV traffic management system for UAV is feasible. Such concepts for managing Urban UAV operations require a regulatory environment that evolves from an understanding of the specific hazards and associated risks associated with the Urban UAV operational environment.

Concerns around safety in UTM concepts are significant, characterised by the uncertainty that flows from the lack of experience and gaps in knowledge around numerous operational aspects of the operational concept. For example, the technical requirements and standards that will be needed to enable consistent provision of any UTM service. Service provision of UTM services themselves is uncertain, in part because of the lack of clarity around the form of business models that can support effective UTM – who pays for such a service?

One key area in urban UAV operations concerns capacity. By capacity it is meant the carrying capacity that an urban area of UAV operations can sustain – the number of UAVs that can be supported by the urban UAV management system either instantaneously or for a defined unit period of time or by volume. How much UAV traffic can operate before?

- Safety is compromised
- Too much noise is generated
- Communication links are swamped or saturated
- Delays to UAV operators are imposed and that cause suboptimal operations and pose a risk to the viability of UAV business models

Technical and operational capabilities to these issues may exist, however, it is the marrying of the technical capability and the philosophy within the concept of operation that allows assumptions to be made about:

- The hardware to be used and associated capabilities and technical standards

- The functionalities that support the concept of operations
- The method of operations to enable urban operations – manned and autonomous concepts of operation

That allows decisions to be made around he capacity that can be supported, what technical solutions need to be mandated that supports the design carrying capacity and what this means for the requirements and standards that are placed upon the UAV industry.

Ground risk i.e. the risk of harm to those on the ground from UAVs, be it directly or indirect as a result of an airborne collision is but one aspect of safe performance. The significance of this is that new methods of collision risk modelling will need to be developed to estimate harm and the ground risk for Urban UAV operational acceptance. There is considerable research about this subject.

Thus, regulators and UAV operators who are approving and designing as well as operating BVLOS UAV operations, both experience uncertainty because there is only vague detail around what can or could be approved, or what technical solutions can be found that facilitate Urban UAV operations.

Research and development communities are able to provide a much greater understanding of these issues. In part, this was demonstrated in the second workshop where it was possible for participants to see, through visualisation, what potential urban UAV operations may look like. These types of methods are also able to provide estimations of ground and airborne collisions risk that can inform decision making.

What is the risk that Transportstyrelsen needs to consider in approving Category 5C BVLOS applications? The requirements for a Transportstyrelsen Approval risk assessment process

In the afternoon session, an example of how a drone risk assessment is undertaken for a Category 1 & 2 drone operation was presented and discussed. This was introduced as indicative of a UAV operators risk assessment and a baseline from which to explore a Cat. 5C BVLOS risk assessment from the perspective of the UAV operator. The breadth of the risk assessment presented and the extent that operational features of the task are described are characteristics of the depth of a risk assessment.

This was followed by group exercises (with two groups of agency staff) that explored two aspects of the agencies risk assessments and approval process when approving UAV operations application. How the risk assessments are conducted was first examined, exploring what is involved with making a decision and what makes an application acceptable. Then, how this might differ specifically for Cat. 5 BVLOS was explored.

The two groups worked up different ways by which applications can be assessed such that the decision can be made:

- One group began with asking three questions of the application – What? Where? How?
    - Then examining how the UAV operator was going to meet the obligations as the commander of an aircraft
    - The benefits of the specific operational task that the application supports is then assessed in a 'cost-benefit' question where the costs to other airspace users and those on the ground are considered against the benefits of the task itself
- The other group took a different approach focusing on the:
    - Technical capability of the UAV e.g. sense and avoid, cockpit view visualisation
    - The capability of the UAV operator e.g. education and certification, performance requirements and the ability to fulfil these

- Operational aspects of the application e.g. the capability of the platform to fly the task, the effects of weather on the task and in the planning of the operational task
- The extent of the interaction with society as a whole

What is evident from these two sessions of the workshop is that there is a significant amount of detailed knowledge that is applied in approvals that flows from personal discussions between the approvals team and the applicants. In some cases, this acts as a filter that shapes the way that the applicants themselves subsequently view the feasibility of the application that they have made.

Can this knowledge and information be developed into a checklist with Carl and Eric? This was undertaken and used in the fifth workshop.

A particular risk for Transportstyrelsen was identified in that those engaged in processing and approving applications hold the knowledge used as tacit knowledge that is not often shared or if it is, it is only partially so. There is no one repository or source of knowledge around UAV operations that is used in making the assessments.

In many respects, this is also the case for the other agency sections who contribute to the assessment of the application and the subsequent decisions i.e. the ATM and Airspace sections. In certain cases, these sections are the source of arrangements that facilitate an application decision to be approved by using airspace restrictions or instigating coordination with Air Traffic Services

From the sessions, what Cat. 5C BVLOS introduces to the agency's risk landscape was identified. This is not exhaustive and neither is it a complete set of what needs to be considered, however it provides an indication of the change in scope and extent that both UAV operator and TS need to embrace. Appendix D details these. These will be used as input into the new risk assessment method.

From the workshop on the 4th October, and in the synthesis meeting, a number of requirements for any risk assessment process to facilitate approvals emerged:

- Qualitative as opposed to quantitative
- A structured, formalised approach possibly checklist based that enable or builds in:
    - Redundancy (reduced use of TS team's tacit knowledge)
    - Reduces the vulnerability and exposure to risk to Transportstyrelsen
    - Enables the assessment of the operator's application risk assessment, the other drone operators and airspace users and also the societal risks Transportstyrelsen are responsible for.
    - That supports consistent decisions, is transparent and traceable Provides legal security and is perceived and seen as fair and equal
- Anna's team conduct this already and so this should be incorporated or be the basis of a method
- Helen's airspace team also contribute to the approval risk assessment and airspace requirements can be derived that involve other stakeholders – LFV, ACR, Swedish military
- There are other stakeholders and interested parties too – environment, wildlife and nature
- Some drone operating organisations do use an SMS. Some exemplars would be of value for the fourth workshop
- The risk assessment process that TS undertakes is an integral part of the application process itself. In preparing applications, UAV operators engage with TS and at this stage - a pre-application step – the agency is able to gain appreciation of the capability a competence of the UAV operator and their ability to undertake the operational task that is the subject of the application.

A discussion followed and it was agreed that LU and LiU would develop this approach further for use in the fourth workshop. Especially, the concept of operations approach that the literature identified was consistent with the way that TS conduct current risk assessments and approvals

A synthesis meeting was held on the 11th of October and the output of the 3rd workshop was analysed and reviewed by Dr Jonas Lundberg, Dr Anthony Smoker, LU & Dr Rogier Woltjier, FOI.

The basic processes of the TS UAV application approval process were examined leading to the flow model illustrated in figure 13.

With this basic process and flow model consideration was given, drawing on the output of the workshop, to assess the differences that 5C BVLOS operations will introduce. As can be seen in figure 14, the expectation is that each and every step of the approval and risk assessment process will be impacted.

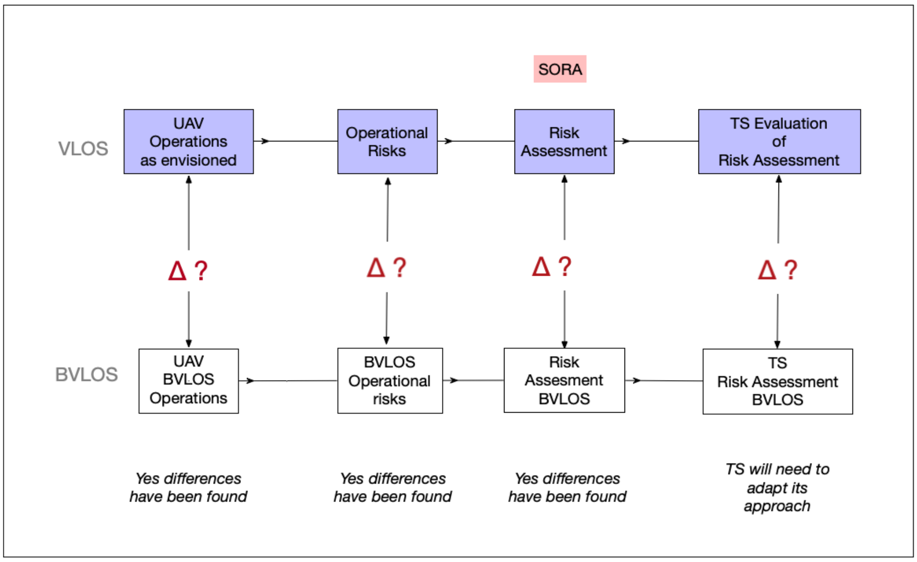

Figure 12: Differences that BVLOS introduce to the current assessment flow

From this workshop, the Transportstyrelsen Approval and Risk Assessment Method was derived and is discussed in detail in a following section.

Workshop 4: 15th November 2018

The objective of the fourth workshop was to apply a candidate BVLOS risk assessment in a workshop with participants from both the Agency and invited UAV operators. The UAV operators were invited to bring examples of a Cat. 5C BVLOS application with them. Working in groups that comprised both agency staff and UAV operators, risk assessment of a 5C BVLOS application was worked through. There were four iterations that covered the three TS cases.

After the third workshop, LiU, LU and FOI held a one-day workshop and with the output from workshops 1 to 3 developed a candidate risk assessment method. (a full description of this can be found in a section after this). The method was presented to the TS UAV application approval team prior to the workshop.

The workshop began with an overview of both the project and the workshop to date before a detailed introduction to the risk assessment method itself. This went into some detail around the agency's requirements and needs. A discussion did take place at this point, principally around the scope of the assessment with particular concern around third parties who will be affected by the trajectory of the proposed UAV operational task. The operational characteristics of BVLOS UAV operations means that a wider geographical area is covered by the UAV platform increasing both the scope and scale with which the UAV can interact with people, animals and many more activities and users.

Thereafter, the groups considered a 5C BVLOS application, for two specific use cases (forestry and pipeline inspections) using a TS application and using the candidate method. These group exercises met with a modicum of success. It became apparent that the groups were drifting away from the intent of the task, with elements of the application being explored. In part this is because preparation for the submission of the approval application itself, the construction of the approval, plays a significant part in the risk assessment process. The lack of familiarity led to time being used by developing the application in collaboration. The workshop being a unique opportunity for the agency and UAV operators to collaborate.

A second round of application of the candidate method using the two use cases followed. On this occasion, the use cases were exemplars of BVLOS applications provided by participants for potential tasks that are being considered for Cat. 5C BVLOS. The two tasks reflect line features being powerline and railway track inspections.

These two sessions achieved the objective and the candidate method was used to explore an application. In doing so, the application process itself came under scrutiny too.

Only one element of the new risk method was able to be examined. This being the pre-application and assessment of the application elements. This yielded insight into the philosophy of the approval of applications. For TS there is a legitimate concern about the scope and completeness of the application. The quality, completeness and scope of the risk assessment and mitigations that make and are integral in an application, as well as the other elements fulfil a role in the overall assessment of an application for an approval. This leads to the question: to what extent should the guidance material in the submission of an application lead the applicant into a successful application?

There was agreement that the application should leave some elements of the agency assessment and evaluation strictly outside of the application itself. The presence or otherwise of items that are assessed is an indication of the robustness and quality of the application and forms a part of the overall assessment. To include these explicitly, removes a quality marker that the agency uses. This is in stark contrast to the CAA Singapore approval process where the precise standards and requirements are specified. The agency places considerable value in not doing this, for good reason. There can be considerable engagement between the agency and a UAV operator applicant prior to the application being filed. This was recognised in the building of an understanding of the agency's approval process. This is reflected in the TSARA method in that both Drone operator and TS engage in discussions that help to define the scope and nature of the application.

When applying the candidate method to the powerline inspection use case, the significance of the application came to the fore again. On this occasion as a result of different interpretations of items that applicants have to answer in the application. In this case it related to a technical capability. The agency and the UAV operator having a different understanding of the technical capability.

From the agency's perspective, the TSARA method showed promise. However, in essence what the method does is formalise how assessments and approvals are conducted currently. This is and of itself a productive exercise as it can support consistency in the decisions made as well as formalising aspects of the approval process. In effect formalising tacit knowledge.

The workshop agreed that there was potential in the first iteration of TSARA. A number of improvements were suggested that broaden the risk assessment method in ways that enable it to be recalibrated with the experience of Cat. 5C BVLOS approved operations. A number of feedback loops are suggested that overcome the limitations that Luxoj (Luxoj, 2017) and others emphasise, the lack of occurrence or accident data for example. By using post-operation reviews, BVLOS risk landscape can be refined and with it a better understanding of the nature of risks attendant with BVLOS operations.

Workshop 5: December 7th, 2018

Following on from the preceding workshop, the fifth workshop provided a second opportunity to apply the candidate risk assessment method to the use cases with the TS teams and UAV operators.

Minor amendments and revisions, in line with the comments made in the November workshop, were made to TSARA. In addition, after a meeting with members of the TS team, TSARA was reviewed and a new requirement was derived. This builds on the formalisation of the approval process by developing checklists that embed the critical points in both the risk assessment as well as the application approval process. These were reviewed with TS staff before the fifth workshop.

In part the use of checklists helps to bring consistency in the decisions made. A record of these and the judgements built and the trace that led to a decision are one means that a traceable record can be built.

This workshop differed from the November workshop in that each group were asked to work with an Urban City use case. For this exercise a specific scenario to be explored with TSARA was developed Urban One Hour Delivery. Additionally, there remained one TS Use Case Search and Rescue: missing person, that was not used in workshop 4 but was used in the December workshop.

As a result of this workshop, all three TS use cases were therefore used to explore the application of the TSARA method: Pipeline Inspection, Search and Rescue: missing person and as well as the additional use case Urban one-hour delivery.

UAV operators were invited to provide exemplars of Cat 5C BVLOS applications to use in the group exercises.

For the Urban Use case, LiU and LU proposed a set of UAV operational task characteristics based on the UAV Urban city operations that have gained approval in Iceland, around Reykjavik, In Reykjavik, Urban UAV commercial operations delivering parcels and packages have evolved since 2017. The purpose of including the Urban one-hour delivery UAV task was to enable both of the groups to have the basis of an application for BVLOS UAV operation with which TSARA can be applied.

The characteristics of the Urban use case are presented in figure 5 below:

Use Case – Urban One hour delivery

Characteristics

- Will run when Conditions allow – what is this? (application)
- BVLOS
- Manned – Configuration Single pilot, multiple drones (How many)
- Sense and avoid stationary objects only
- 30 mins duration, 15 Kms range, ‘there and back flightpath’,
- Weight of Drone – 7Kgs
- Free route environment over Norrköping desired
- If not, use Reykajvik scenario
- Norrköping Airport geofenced (Final Approach track only)
- If nit, Reykjavik option
- Landing spots – land in gardens or pre-defined delivery spots

Figure 15: Urban Use Case: UAV operational characteristics

The Urban City use case was simulated using a visualisation table prepared by LiU.

The workshop revisited the basic idea of the TSARA method and then introduced the checklists followed by a discussion around their use, before breaking into two groups and undertaking the first found of group sessions.

The group exercises were more productive in this second iteration,

The two other use cases were used to examine TSARA as a means to assess an application and undertake risk assessments. On the basis of the ‘evidence’ presented in the application, TSARA checklists are a suitable way to proceed through a number of additional elements that need to be included in an application for 5C BVLOS UAV operational tasks. The exercise confirmed the value of the specific concept of operations as a means to build an understanding – a framework – by which an application can be assessed.

Using the checklists provided the means to structure the data collection that would provide the input into the Claim/Argument/Evidence structure of decisions. It was emphasised that these decisions needed to be transparent and reasoned.

The Urban/City use case evolved into sessions where what was needed to be included in an application for approval was the focus. This is the ‘Left Hand Side’ of the TSARA method. .

The overall impression of the two Urban/City use case sessions was that this is much more involved and complicated than first imagined. The nature of the concept of operations are not well understood or defined. However, as a key input into any TSARA determination is the concept of operations, then further research is required into this aspect of the use case to support Transportstyrelsen in preparing for such applications. With respect to TSARA, the method is suitable with modification for the Urban City Use case. The structure and approach is consistent with the requirement; however, it will need closer examination of the secondary risks and the mitigations of the airborne collision aspects of risk as these are significantly different from the other Use Cases.

In the two other use cases, prepared applications from SSRS and an exemplar based from experience that Smartplanes, one of the participating drone operators, were introduced. These were noteworthy because of both their quality and thoroughness.

The SSRS application showed well the extent of preparation and the scope of supporting information that will be required for the agency to undertake an evaluation of a 5C BVLOS application. To an extent, the CAA Singapore BVLOS risk assessment embraces only some of that which the two exemplars used in the workshop included. Both SSRS and Smartplanes used a thick description of the operational task including a detailed concept of operations. As well as a risk matrix.

Smartplanes introduced their approach to risk assessment. Arguments supporting the application included both qualitative as well as quantitative approaches to risk assessment that are straightforward once established. This risk model included parameters for population density and values for the probability of harm to humans involved in collisions with drones, for which Sailplanes worked with Uppsala University to develop.

It was evident in the discussion that followed, that the addition of a SORA/SAIL style quantification of risk is worthwhile pursuing in further research, to extend the TSARA method. It also became evident that the JARUS Standard scenarios although not tested, provide a tool by which an application process can be made more effective as there are potential savings in their use. The standard scenario effectively forming the common ground between NSA and UAV operators. This provides a means to shape expectations from the actors involved.

The five workshops were recorded and, along with contemporaneous notes, the recordings were used to analyse and produce a summary report after each workshop. Additionally, after each workshop a synthesis meeting was held to review the workshop, determine the contributions to understanding of the BVLOS risk assessment and determine the requirements and criteria for the following workshop.

The results of the workshops effectively yielded five outputs:

- The current TS risk assessment process
- TS Cat 5C BVLOS Use Cases and Use Case operational characteristics
- The differences that 5C BVLOS UAV operations will bring and need to be embraced by the agency
- The requirements for the TransportStyrelsen BVLOS risk assessment methods
- A proposed 5C BVLOS Risk assessment and the results of using it in two workshops

The TS current approval and risk assessment process

Transportstyrelsen has considerable experience in the approval of diverse UAV operations. Including exposure to BVLOS. There is an established process through which this is undertaken.

Experience with BVLOS has principally been with agencies such as the Swedish Police that makes extensive use of UAVs of varying types and capabilities. Other UAV operations cover a range of commercial and private operators.

The approval process has evolved and today a formal application process is used whereby applications are submitted online through a Transportstyrelsen portal. The application is the principal source and means of assessment of the nature of UAV operation and risk assessment where it is provided by the UAV operator.

Once submitted, the application is processed with checks made on the status of the UAV operator and operator in the registration of the application with respect to:

- UAV theoretical knowledge
- UAV flying test
- Insurance
- Previous applications and decisions

Already at this stage some understanding of the capability of the UAV operator is undertaken through the way that the application has been constructed and completed.

The following step in the process is that where an assessment of the application takes place and a decision is made. This step draws upon information in the application that facilitates building an understanding of:

- what the UAV operation is – the type of flight
- how is it to be undertaken,
- the location of the UAV operation,
- the capability of the UAV platform
- The capability of the UAV operator
- A check of the documentation surrounding the UAV operator and the platform

It is with the knowledge gained from the above that an assessment of the application can be undertaken.

Whether or not a safety assessment in support of an application is conditional upon the category of flight. For Category 2 UAV operations no safety assessment is required to be provided. An assessment is carried out by the agency.

These entail consideration of a range of information and knowledge about UAV operations and their conduct, features of the operational environment e.g. the locations of other airspace users and activity in relation to the planned operation and airspace, UAV capability, the location of areas of wildlife and bird activity.

There is also an appreciation of the capability of the UAV operator that is gained from knowledge and experience, in some cases from discussions with operators who have sought information from the agency. Applications that have been approved also prove a source of knowledge. The quality of the application itself provides some feeling for the completeness and thoroughness of a UAV applicant. Whilst the application may contain a risk assessment, these can be of variable quality.

With this knowledge a decision is made, which considers the safety ramifications in different ways. The risk to other airspace users, the risk to third parties on the ground, the impact on society in various ways (privacy, intrusion) and the impact on wildlife, nature and the environment.
In making a decision about an application, whether or not a UAV operator will fulfil their obligations as the commander of an aeroplane is also an element for some who make some decisions. This tacit knowledge that is used to make a decision is personal in its nature, borne out of experience and represents the 'engine' of the risk management process.

From this the agency assesses the risk assessments that are submitted as well as conducts risk assessments of its own in relation to the interaction of the UAV with other actors and interests in society and the operational environment.

The assessment of the application involves a number of different dimensions of the UAV operation. The 'What', 'When' and 'Where' of an application provides the means to build an understanding and picture the UAV profile. This supports building a picture of who the UAV will interact in both the operational environment (other airspace users) and with the communities, environment and landscape. This then supports an understanding of how the UAV will be operated e.g. will the flight plan/trajectory follow a line feature, pipeline etc.

The maturity of the operational task is also considered – how can past UAV approvals inform the application under consideration for example.

There are certain facets that can be drawn from an application that provides an indication of the competence and capability of the operator. What the agency considers a 'good' application:

- A comprehensive application and risk methodology and mitigations
- The explicit identification and discussion of harmful effect
- Proof of the ability to competently exercise the provisions of the approval
- An application that shows the professionalism of the UAV operator
- It will provide both general and specific detail on the UAV operation being applied for
- An indication of the third parties that the UAV will interact with and evidence that consultation and negotiation has been undertaken (e.g. including ATS and airport authorities
- Personal contact through consultation with the Agency in formulating the application

There are a number of questions that influence the granting of an approval:

- How will the UAV operator meet their obligation as the commander of an aircraft?
- In VFR, how will interactions with other airspace users be managed? Does the application include the procedures or techniques that will be followed?
- What are the benefits of the application?

This not an exhaustive list of the factors that go into making a decision. Such decisions look for a balance between the risks and the CONOPS as well as the wider benefits to society and the community.

With the detailed picture of the CONOPS that all of the above facilitates an understanding of the risks identified and mitigations to resolve them, the input from others in the agency e.g. Airspace section and other agencies such as LFV then an approval decision can be made.

One of at least four decisions are possible:

- Approve
- Conditional Approval for a limited period or restricted flight profile until experience can be gained that proves the viability of a particular CONOPS
- Maybe subject to further information, a test flight etc
- No approval can be given

TS risk assessment requirements for Cat 5C BVLOS UAV operations

Within the current application approval process, there is a wealth of knowledge not just about UAV operations and the UAV regulatory landscape both in Sweden and Europe but additionally a deep understanding of effective application of the effect of regulation in UAV operations. This is highly nuanced and makes a very significant contribution to the engagement that the agency and UAV community have.

Transportstyrelsen recognise that BVLOS operations will be different from VLOS and EVLOS. The scope and magnitude of these changes are to an extent understood by the agency as it has experience of granting approvals for specific BVLOS drone operations.

It was evident from the workshop, as well as what was gleaned from in depth discussion with the agency application approval teams, that there is a significant amount of detailed knowledge that is applied in making a decision about an approval, that comes from the personal discussions between the approvals team and the applicants before the application is made and whilst it is being developed. This can and does act as a filter that shapes the way that the applicants themselves subsequently view the feasibility of the application that they have made. For example, an early impression is gained around how professional an applicant is; how the obligations for safe operation will be fulfilled.

A particular risk for Transportstyrelsen was identified in these discussions in that much of the knowledge that is used in the approval of applications is tacit knowledge that is not often shared or if it is, it is only partial tacit knowledge. Can this knowledge and information be developed into a checklist or some other means to formalise this artefact of the approval process as well as support consistency of application decisions?

For Transportstyrelsen to develop an understanding of the risk landscape, where does it gain the data from that supports the understanding of Cat 5C BVLOS UAV operations? Occurrences involving the drone community are principally filed as a result of an airspace infringement, a proximity report with a UAV by another airspace user or where a technical failure has occurred. There is very little occurrence data that relates to the operation of UAVs. Rarely are these filed by the drone operator themselves. Thus, there is very little feedback that exists in other areas of the aviation system that informs the agency's assessment of the risks of 5C BVLOS applications. One requirement that emerges is that the risk assessment method should add to the knowledge that the agency builds as it approves 5C BVLOS applications for UAV operations.

The knowledge gained from eliciting this knowledge , combined with exploring the agencies current approval process in the workshop, led to the following requirements for a risk assessment method to support the approval of Cat 5C BVLOS applications:

- The method should include the concept of operations as this plays a fundamental part in the agencies approach to considering an application:
    - It is an essential precursor in an assessment of the applicant's tasks operational intent, its scope and the technical and operational capabilities required to both undertake the task and the completeness of the application
    - As 5C BVLOS UAV operations will naturally lead to extended flight profiles the operational task and profile of the drone can be understood and rationalised in ways that can support examination of the task's operational implications, interactions with other stakeholders and actors and the interaction with both the operational environment as well as wider society which supports the agencies own risk assessment – the impact of the UAV operation on third parties including who they are

- The concept of operations needs to be described in sufficient detail that enables the agency in assessing the application to examine
    - How the BVLOS task will be operated and the obligations for safe operation by the commander of the platform and those engaged in the operation will be met
    - How the UAV's limitations have been understood and the concept of operations accounts for these
    - What will happen in the event of technical malfunction and the range of events, threats and hazards that can typically be anticipated in operations
- A framework or skeleton with which to visualise the UAV operational task and flight profile and determine that the risk assessment satisfies the needs of the risks identified as well as its completeness including an assessment of any harmful effects
- The risk assessment method needs to support the agency in assessing the concept of operations against the risks associated with operations in a structured and formalised way
- In support of this, the risk assessment method should be able to draw upon the body of knowledge of past approvals and ideally post operation reviews of 5C BVLOS applications that have been approved
- The risk assessment method additionally needs to be able to capture the third-party risks that the operation will be exposed to in a structured and repeatable manner
- Decisions made when approving an application need to have the means that demonstrate the rationale for the decision, provide the means to contribute knowledge that is gained about both BVLOS and UAV operations generally
- The method needs to include feedback loops that draw upon applications that have been assessed and for those that have been approved feedback on the UAV operators experiences e.g. new risks encountered, the salience and effectiveness of mitigation strategies etc

These requirements were used as the principles for the development of the proposed risk assessment method.

One final observation gleaned from the workshop. In order to grow the understanding of BVLOS operations for category 5C, the view and perspectives of a wider group of Drone operators as well as those already granted approval should be sought in some way, informally as well as formally. This activity has gone some way towards establishing a base for further development.

TS Cat 5C BVLOS Use Cases and Use Case operational characteristics

The agency has identified three use cases that it believes is representative of the initial set of Category 5C BVLOS UAV operations.

These three use cases were defined in terms of their operational criteria and characteristics. These were reviewed in the first workshop and after discussion, some minor changes were made. Then were then examined in the second workshop with the UAV operators who had experience of the use cases. Additionally, LiU and LU introduced a discussion around the use of UAVs in urban operational environments. *A priori,* this type of operation will be significantly different from the other three operations as the density of both third parties on the ground as well other UAVs operating in the same airspace will be denser and lead to a different risk landscape. Whilst Urban UAV operations are perceived as being not imminent, the pace of change is such that in such operations are nearer than envisaged. The scale of the risk assessment and approval process is greater than for the other three Use Cases because of the differences in the risk landscape and the nature of specific operational issues. As a result, it was agreed that it would be beneficial to explore Urban UAV risk assessment

Transportstyrelsen Derived Use case operational criteria

Table 3: Transportstyrelsen Derived Use case: Forestry Survey

Base Use case

Drone Category	5C
Location of flying activity	Forested areas with boundaries defined by the specific forest of interest. (Will include trails, tracks and roads through the forested area of interest)
Range BVLOS	Within 500 metres (vertically?) and 1000 metres form the remote pilot
Type and purpose of flying	Data capture
Applicable Airspace classification	Class G
Meteorological Conditions	Daylight, VMC, Wind < 5kts*, CAVOK

Base Case after the workshop

Drone Category	5C but an operational task may involve
Location of flying activity	Forested areas with boundaries defin tracks and roads through the forested a There are three distinct use cases One operational task may involve mult within one defined geographical area i Another will involve dispersed as well a Tasks can involve searching for a single
Range BVLOS	Vertically: 180-200 metres is optimal Optimal altitude influenced by technica Laterally: Range 3 – 5 Kms, can be disp
Type and purpose of flying	Data capture – can be wide area or mo trajectory characteristics
Applicable Airspace classification	Class G
Meteorological Conditions	Daylight and night time operations (the VMC, Wind < 5kts*, CAVOK
Additional criteria	Extended line of sight used Organisational risk management proce Multiple operator drone operation

** the wind velocity at <500 m*

Table 4: Transportstyrelsen Derived Use Case: Powerline Inspection

Base Use case

Drone Category	5C
Location of flying activity	Along a defined power line linearly (as a line feature)
Range BVLOS	Within 500 metres (vertically?) and 1000 metres form the remote pilot
Type and purpose of flying	Image capture
Applicable Airspace classification	Class G
Meteorological Conditions	Daylight, VMC, Wind < 5kts*, CAVOK

* *the wind velocity at <500m*

Base Case after the workshop

Drone Category	5C
Location of flying activity	There are three potential use cases wit • Short run powerline inspecti include planned and ad hoc i • Long distance pipeline inspec • Remote area inspections, du showers, searching for fallen • Tasks can make use of rem location
Range BVLOS	Vertical: 120 metres is a suitable oper the platform means that the use case powerlines so any segregated area may Lateral: 10 to 15 kms in short range tas
Type and purpose of flying	Image capture including thermal imagi Forest development around power sta time
Applicable Airspace classification	Class G and control zones
Meteorological Conditions	Day and night time operations The platform dictates the characteristi
Additional criteria	Operational task may involve multiple c Powerline inspections by drones are ty (one pilot plus one other) and helicopte Typically, the demand is for one power

Table 5: Transportstyrelsen Derived Use Case: Search and Rescue - Missing Person

Base Use case

Drone Category	5C
Location of flying activity	A circle diameter 500 metres centred on the remote pilot
Range BVLOS	Within 500 metres (vertically?) and 1000 metres form the remote pilot

Base Case after the workshop

Drone Category	5C
Location of flying activity	Wide areas which may change rapidly i Can be over land or sea, urban remote, The base use case a circle diameter 5 search sector within a much larger defi Nature of search pattern can be flown The operational nature of this use case practical as it can induce and inherent
Range BVLOS	Lateral: Range of BVLOS too small for Area of interest will cover a b Within one defined area o concurrently

Type and purpose of flying	Find missing person
Applicable Airspace classification	Class G
Meteorological Conditions	Daylight, VMC, Wind < 5kts*, CAVOK

* *the wind velocity at <500m*

	Vertical: search may start at 120 metre 120 metres is too low for a w 200 metres is a reasonable altitude for
Type and purpose of flying	Find missing person
Applicable Airspace classification	Class G and inside controlled airspace c
Meteorological Conditions	Day and night time operations Will operate if it is flyable (Windspeed c n.b. there is a different wind effect on c
Additional criteria	SAROPs are inherently unpredictable a demand going beyond an approval at sl A search may involve multiple dro characteristics and capabilities How can collision avoidance be assured in both segregated and unsegregated c of vehicle) The nature of SAROPs demands the coordination mechanisms for mult competences Single and multi-crew remote operation Ideally, the defined area of operations achieved Range of task against telemetry/datalin

Table 6: Additional Transportstyrelsen Use Case: Drone operations in Urban areas, low density

Drone Category	5C
Location of flying activity	Over urban areas in the proximity and adjacent to airports and aerodromes
Range BVLOS	Lateral: Vertical: 120 metres or lower.
Type and purpose of flying	Two candidate activities: • Package delivery • Police activity e.g. surveillance of demonstrations
Applicable Airspace classification	Class G and inside controlled airspace associated with airfields/airports
Meteorological Conditions	Day and night time operations Will operate if it is flyable
Additional criteria	The urban operation proposed is of a form that uses human drone operators as opposed to ‘autonomous operation’. Control mechanisms will be limited to the provision of aeronautical and drone related information. This is defined in the SESAR ATM Masterplan as U1 (in terms of U space) the foundation of U space and will provide information to enable permissions to fly. ‘See and be seen’ will be the collision avoidance strategy although early deployment of DAA (Detect and Avoid) may be fielded.

As can be evidenced from the tables, the operational characteristics of the Use Cases became more representative of 5C BVLOS UAV operations by working through the concept of operation of each Use Case with those who have extensive operational experience of UAV operations.

These amendments provide an insight into the scale of the increased flexibility and scope that BVLOS is anticipated to bring too UAV operators. Which in turn will yield benefits in terms of effectiveness of UAV operations as well as efficiency. In addition, there is also an indication from these results that the design of the UAV platforms currently in service are not optimised for BVLOS and can be expected to change. Especially as battery life improves. This introduces new factors in risk assessments, as can be found in the revised use cases – operating at the limits of telemetry and datalink coverage for example. Which in turn introduces new operational profiles such as 'Land away' as opposed to 'out and return', this profile enables a new way of optimising the range for operational profiles.

A number of additional factors emerged from the Use Case exercise that can provide more detail in the description of the use cases. Table 7 lists and contrasts the two sets of operating characteristics.

These are also legitimate areas of interest that the agency has when considering approval of applications for BVLOS UAV operations. These additional items assist in building an understanding of specific facets 'that the application is seeking to approve and answers questions such as what and how it will be undertaken - the concept of operation enacted in other words.

Original	Drone Category
	Location of Drone Flying Activity
	Range BVLOs
	Type and purpose of flying
	Available airspace classification
	Meteorological Weather Criteria

Additional	Concept of operations including non-nominal operational mode
	Specific operational procedures e.g. collision avoidance with other aerial platforms Sense and Avoid, See and Avoid. Detect and Avoid
	Platform type and operational organisation
	Datalink and telemetry coverage. (including provisions and procedures for link failure
	Operator competence and capability
	Organisation of the Drone Operator including operations manual and SMS
	Risk assessment method and process
	Multiple or single drones
	Drone platform working with other aircraft

Table 7: Use case components original and potential

What is also evident from the revised Use Cases is that the assumptions around the capabilities of UAVs and how they are exploited to achieve the operational task can be very conservative. The detailed knowledge and experience of UAV operators is an invaluable resource that can make a significant contribution to the salience of the UAV approval and assessment processes. In so doing this may make a contribution to the ease by which UAV operators make applications as the application process can include specific items that enable a better understanding of the concept of operations and the risk landscape that is derived from this that the application risk assessment method presents.

The differences that Category 5C BVLOS UAV operations brings: How does BVLOS change the nature of UAV operations?

The nature of the changes with 5C BVLOS became apparent when the Transportstyrelsen use cases for the project were reviewed, as discussed above. More diverse concepts of operation were envisaged and both heights/altitude and distances that tasks would be flown that were not anticipated. This diversity extended to the operational profiles and tasks that an operation might entail. The flight conditions to expand with BVLOS e.g. operation at night and in weather conditions marginal rather than nominal etc. Therefore, understanding the differences that BVLOS operations will bring is a key contribution to the risk assessment method as here are implications of this for the approval and risk assessment process, as it is undertaken today,

Over the three workshops where joint UAV operators, their experience with operations or their considerations of how they intend to operate UAVs in 5C BVLOS concepts of operation enabled an understanding of the differences between VLOS, EVLOS and BVLOS UAV operations to be gleaned. Therefore, there is some authority in the content that emerged from the discussion sessions that were undertaken.

From the UAV operator's perspective, Cat. 5C BVLOS introduces significant operational benefit through:

- Extended duration of operational tasks e.g. powerline inspections and forestry tasks
- Increased range for operational tasks – with different operating modes e.g. 'out and return' or land away e.g. as above
- Enhanced flexibility in undertaking operational tasks whilst airborne and unplanned trajectory changes
- Different operating methods that enable effective operation of the UAV platform
- Collect and gather data from a wider operational area, potentially with multiple and different sensors
- Flexibility in task planning in being able to plan to undertake multiple tasks in different geographical locations
- The potential for new operational uses
- New business models that exploit the potential of changed operating characteristics

BVLOS operational tasks can therefore be expected to be a step-change in UAV operations. Bringing with it a diverse range of concepts of operation that exploit the potential that BVLOS brings to operational tasks. To better understand the differences from VLOS and EVLOS UAV operations, the workshops undertook joint sessions with TS and UAV participants. Three discrete aspects of BVLOS UAV operations were explored corresponding to three elements of an assessment process .

Differences between VLOS, EVLOS and BVLOS: UAV Concept of Operation -the UAV task as envisioned

The first element is to understand the differences that can come in nature of VLOS, EVLOS and BVLOS operations. Table 8 provides the output from the exercise.

1	Ground and air operational scope- go further in space and time
2	Platform/Vehicle more advanced/bigger/Heavier: operational characteristics • Personnel: • Certification • Training • Experience • TS records
3	Awareness of Risk – the concept of operations introduces new risks or new variations of risk in the current risk landscape
4	Drone Operational team and teamwork: UAV operating crew and support team
5	Weather across larger geographical area, Local variations
6	Technology for sense & avoid (including training and MOPS)
7	Benefit of task/operation versus risk – Justification & reasoning
8	Threats to the operation – greater scope in operational capability means a different threat environment
9	Sensors – broader range of sensor capability possible and the potential for real time downlink and analysis of data
10	Concept and Method of Operation:
11	Procedures
12	UAV operating crew • Crew composition: • Sensor operator role • Drone Pilot role • Crew Coordination (CRM)
13	Mode and modes of operation – new modes of operation are introduced as a result of the change in the operational capabilities that permit different operating modes as well as mixed mode/tasks in one sortie
14	Coordination with other agencies, actors
15	Trajectory/flight planning
16	Interaction with other airspace users
17	Interaction with ATS
18	Procedures for operating within Controlled airspace

Table 8: Differences in the concept of operations from current and Cat. 5C BVLOS operations

BVLOS introduces new operational capabilities.

A number of examples were presented in the workshops for powerline inspections, forestry applications as well as search and rescue where BVLOS is anticipated to facilitate and enable more effective operations e.g.

- Powerline inspections when power supply has been compromised because of very inclement weather and the speed by which the location of the break in supply can be identified is enhanced by the use of UAVs operating BVLOS

- Forestry surveys that can perform multiple tasks in the same sortie flying different profiles and using different sensors including night time surveys of livestock and animals using thermal imaging
- SAR ops that exploit the extended range and duration potential leading to a new SAR organisational model

(These examples are illustrative of some of the potential that can come from BVLOS operations. There will be many more to follow and that will come).

The scope of these, in terms of the operational envelope, will enable UAV platforms to travel further both in distance and time. Concepts of operation that will be devised to fulfil operational tasks will therefore change over what are currently used as well.

It should be noted that the extent of the differences can extend to every aspect of the operation and organisation of the BVLOS UAV operational sortie.

- In terms of the operating environment, the greater range at which UAVs can operate in BVLOS means that it is not just proximal weather that must be considered and provision and managed but also the weather at the furthest reach of the UAV platform for the task
- The greater geographical area that can be covered in planning and executing an operational task means that in any BVLOS UAV task will interact with many others on the ground or in the air in the greater area covered.
- Thus, there are many more potential actors to consider and possibly engage with in the operational environment as well as agencies on the ground, Where coordination activities are necessary there are potentially many more to engage and coordinate with.
- This can lead to new modes of operation. In the sessions held in the workshops, 'land away' was discussed as opposed to 'fly and return' style of operations.
- UAVs capable of flying 5C BVLOS can be expected to be capable of using a broader range of sensors which can be used in sensor packages onboard a platform. This makes it possible for agile UAV operations where different tasks can be undertaken in the same operational profile potentially exploiting real-time download and analysis or data
- To realise such capability may see more structured and formal organisations as well as operational teams
- Category 5C BVLOS UAV operational tasks may be more productive, effective and offer new levels of benefit to society as a whole.
- In some cases, to achieve this and exploit the flexibility that BVLOS UAVs can bring, some tasks will wish to operate within both controlled and uncontrolled airspace. Potentially operating in both in one operational task
- As the platforms evolve so it can be anticipated that the operational characteristics will evolve with new concepts and methods of operation that will naturally flow in ways that exploit these

Differences between VLOS and BVLOS: Operational Risks identified

The second element of Cat 5C BVLOS UAV operations that were explored was to identify the differences in the operational risks between VLOS; EVLOS and BVLOS UAV operations.

Table 9 provides the results that were gained. In some cases, these are limited to particular classes or statements of the risk and not necessarily the consequence or effect of such risks

1	Technical failures
2	Amplified Risks (see CONOPS)
3	More 3rd parties in GND + Air at distance (see next element)
4	Collision risks: • Other airspace users • Other airspace types • Secondary risk at distance from UAV operator (team
5	Communications: • Pilot – UAV • Pilot – Sensor operator • Pilot/Sensor Operator/others • Pilot- ATS
6	Effective 'see and be seen' • Man -machine interface • Capability and practicability of acquisition and identification of conflicting airspace users • Timeliness of collision avoidance manoeuvre
7	Managing distant Weather
8	More energy in the platform, more harm that can be done

Table 9: Differences in the operational risks identified between current and Cat. 5C BVLOS operations

To some degree, the nature of the risks elicited are more about the consequences of current known risks or the amplification of these. However, new risks have been identified as well.

A number are associated with the distal nature of BVLOS UAV operations – the distance from the UAV operator. These are not only introducing new risks but amplifies many of the risks that are currently understood and known about.

In theory, in VLOS and EVLOS UAV operations, the platform can be visually acquired and monitored. At distance this is not possible necessarily. Therefore, how can tasks that currently depend on direct visual means be accomplished, where it is necessary to at distance from the UAV operator?

During the workshop, UAV operators discussed the ways that collision avoidance is undertaken in current operations where these issues are confronted. Strategies have developed that use as a trigger the sound that other airspace users generate as the indicator, as opposed to visually acquiring the conflicting traffic first. In such cases, a common strategy is for the UAV to fly an escape manoeuvre typically landing or flying close to the ground. How effective such strategies are at distance from the operator in a BVLOS task is unknown.

Also emerging from operating the UAV platform at distance from the operator is the effectiveness of the 'see and be seen' collision avoidance philosophy. One concern being the timeliness of collision avoidance manoeuvres using collision avoidance strategies based on . Electronic means such as 'sense and avoid' are possible and the technical maturity is evolving. There are other potential ways that collision avoidance for BVLOS can be undertaken e.g. electronic mechanisms

Moreover, how can a UAV operator be accountable for the UAV platform and to discharge the obligations of safe operation if they are unable to observe the UAV platform in some way. The loss of communication with the platform, for example, will provide some indication of a malfunction or failure but not the condition or state of the platform. This amplifies the third-party risk.

Differences between VLOS and BVLOS: Operational Risk landscape and third-party risks

One of the differences identified in the first element of the exercise is that of changes from the current risk landscape. The enhanced operating envelope that BVLOS operations will enable means that the scope for engagement and interaction with a larger range of actors and stakeholders of both society and the aviation operating environment. Table 10 shows the results from the workshop.

1	More Third parties and actors within the scope of the ConOps: • Identification • Consultation • Effect and risks derived
2	Acceptability of the risk versus benefits • Societal risk versus benefit • Task risk versus benefit
3	More threats and hazards
4	More comprehensive and structured risk analysis and assessment required • Technical capability and considerations e.g. communications mediums coverage
5	More actors to consult and engage with
6	Weather and environment broaden the mitigations ended
7	More sensitive to the environment
8	More aware and sensitive to the practical limitations of the vehicle, platform and operating performance envelope
10	Risks associated with loss of control of the operation expand
11	Risks associated with loss of communications/link

Table 10: Differences in the operational risk landscape between the current operations and Cat. 5C BVLOS operations

The risk landscape changes not just because there are more threats and hazards that are found or are introduced into the risk landscape. But because the nature of BVLOS tasks themselves change and these hold potential benefits to society. In undertaking such tasks, it is conceivable that the benefits of a task may offer societal benefits that may outweigh task risks.

Glossary

ACR	Aviation Capacity Resources AB
ATS	Air Traffic Services
BULOS	
BVLOS	Beyond visual line of sight
EASA	European Aviation Safety Agency
EVLOS	Extended line of sight
FOI	Totalförsvarets forskningsintitut
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
LFV	Luftfartsverket
LiU	Linköping University
LU	Lund University
LUSA	Lund University School of Aviation
SORA	Specific Operations Risk Assessment
SORA -SAIL	JARUS Specific Operations Risk Assessment -Safety level
SSRS	Sjöräddnings Sällskapet
TS	Transportstyrelsen
TSARA	Transportstyrelsen Approval and Risk Assessment method
UAV	Unmanned Aerial Vehicle
UTM	UAV Traffic Management
U1-UTM	SESAR U Space Stage 1 UTM

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Appendix A: The TS BVLOS Risk assessment project

The essence of the project

Between July and December of 2018, the project was undertaken. In an initial meeting with Transportstyrelsen in May 2018, the basic approach to the task was outlined and subsequently developed further.

A three-axis methodology was developed that set out too:

- Understand how risk assessments for UAV operations are undertaken currently, from the perspectives of Transportstyrelsen and by drone operators
- Explore the literature in risk and risk assessment and identify a candidate method or methods with potential for application by Transportstyrelsen for BVLOS operations
- Develop a risk assessment method that could be used by Transportstyrelsen in a limited application of the method

The scope of potential applications of BVLOS UAS operations in Category 5C is broad. The agency sought to limit the scope under consideration to three use cases

- Category 5C: Forestry Applications
- Category 5C: Powerline applications
- Category 5C: Search and Rescue: missing person

The methodology considered risk and risk assessment methods *per se*, derived the fundamentals of the requirements that the agency believe is necessary for Category 5C assessments and approvals and developed use cases proposed by the agency as exemplars of early requests for approval.

A fundamental question surrounding the extrapolation of the agencies needs for a new risk assessment method is how do BVLOS UAV operations change the risk landscape, if indeed they do?

The project adopted an inherent system approach which manifested by embracing the view and experience of the UAV operators themselves.

How the project was undertaken

The three project methodological axes were entered into through three workshops (two with the agency alone and one with UAS operators) which ran in parallel with a literature search. After this ,and following two meetings with the agency to clarify the workshop output, LiU, LU & FOI evolved a candidate method. This method was then applied in two further workshops with BVLOS UAV operators where these operators used their model BVLOS applications

LiU, LU and FOI adopted a systems approach to the task. By this it is meant an analytical approach that sees the wider system of a socio-technical system and builds an understanding of how it functions through exploring, for example, the interactions and dependencies between the elements that comprise the wider system and examining the patterns of activity in the work system.

For this task a specific question was explored 'how is risk assessment undertaken and how does it differ with Category 5C BVLOS UAV operations?' It being the objective to explore varied and diverse BVLOS UAV operator requirements and the agency perspectives.
LiU, LU & FOI developed a qualitative method that is described in this section.

It was developed to be used first in one workshop with both TS and UAV operators and then, subject to the participants comments either rejected, modified fundamentally or amended so that a second iteration could be undertaken.

After the first iteration, there was agreement that the TSARA method held promise, if not radically different from the way that the assessments are undertaken currently.

Revisions were made and checklists introduced that illustrated how the tacit knowledge

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Appendix C: Workshop Reports

Executive Summary

During 2018 a series of workshops were undertaken in support of a requirement that Transportstyrelsen (TS) identified for the approval of UAS that involved Beyond Visual Line of Sight (BVLOS) operations. The workshops tool place between August and December 2018.

The approach taken to the task was to determine the needs for TS by exploring the current risk assessment process and to derive the needs for UAV operators who wish to undertake BVLOS operations.

A series of five workshops were planned and undertaken that adopted an iterative approach to both the elicitation of knowledge and identification of the needs of both TS and the UAV operator.

Early on, it became apparent that the risk assessment of UAV operations is undertaken in support of a higher task, that of the approval of the UAV operation and operator. This was established to encompass a much broader understanding of the UAV operation including third parties as well as societal interests.

Pivotal to the salience of the workshop findings was the engagement and involvement with the Drone community. TS were able to attract members of this community who made a very significant contribution to the discussions and the output.

The workshops explored:

- the current assessment processes
- The derivation of Use Cases
- how risk is assessed, today
- how the UAV community conduct risk assessments (for BVLOS),
- TS requirements for both approval and risk assessment
- Risk assessment techniques and methods
- Selection of a candidate risk assessment
- Exploring the value and suitability of the candidate method
- Examining the candidate method with UAV operators using pilot BVLOS Cat 5C applications through the use cases

A candidate method was developed and labelled TSARA: Transportstyrelsen Approval and Risk Assessment method. This method was developed in a workshop by Linköping, Lund University and FOI drawing on the TS requirements.

Introduction

Transportstyrelsen (TS) tasked Linköping (LiU) and Lund Universities (LU) to develop a risk assessment method for the approval of Beyond Visual Line of Sight (BVLOS) UAV operations.

The approach taken to this task was developed and agreed with Transportstyrelsen in a workshop that was undertaken at LiU in Norrköping on the 29th of May 2018.

Transportstyrelsen have conducted a number of items of research that examine the management, from the aviation system perspective, of BVLOS UAV operations. This work recognised that the evolution of BVLOS will pose operational issues that will require interventions from Transportstyrelsen to achieve safe operation, not solely for UAV operation, but also other airspace users as well as society as a whole.

BVLOS UAV operations do differ, this was recognised *a priori*, from VLOS and EVLOS UAV operations. Thus, it is recognised that there are emergent risks from the introduction of BVLOS operations.

Some limited approvals have been given to UAV operators, but these differ substantially in their operational capability and the nature of their task e.g. Swedish Police and SSRS.

As both the UAV platform has evolved and UAV business models have developed, the demand to operate BVLOS UAV operations is expected to grow. Transportstyrelsen therefore needs to be able to respond to this demand and develop both the means and the capability to approve BVLOS UAV operations

The setup workshop in May 2019

The initial workshop in May 2019 explored the subject of approval of UAV's from the perspective of the competent authority and also delved into the regulatory landscape for UAV's in Europe. The European Union, through EASA, have undertaken rule-making activity that will lead to a European Union wide rule making implementation in 2019.

Transportstyrelsen has implemented some regulatory changes that it is intended to accommodate some, albeit limited, approval for new UAV operations that have the capability for BVLOS operations.

In the May workshop, the TS team introduced their perspectives to the problems, challenges and issues on BVLOS approvals and risk assessment. The agency needs to grow its knowledge of BVLOS operations and to expand its understanding of the risk landscape to be able to make access to Swedish airspace accessible. Equally, the agency needs to assure the safety of the wider aviation community and society as a whole.

From this exposition, it was evident that there were a number of perspectives that needed to be understood that shaped the risk assessment of BVLOS operations:

- Swedish airspace is highly integrated with many diverse operations concurrently active
- What is the flight safety risk and what are the tools for assessing these risks?
- The agency needs to build a knowledge basis with which to develop policy and rules
- At the same time what are the 'values that the agency is trying to protect? And from which or whose perspective

A number of research questions were identified from the discussions in this setup workshop:

- How is the risk assessment process undertaken currently?
- What is the difference between LOS/EVLOS and BVLOS? From the perspective of the agency, TS, UAV operators and other stakeholders
- What of the issues of liability and privacy? How are these taken into account today, and does BVLOS alter these?
- What place or value does the JARUS SORA hold as a method for the agency's requirements for a new (or enhanced) risk assessment method?

The approach taken to eliciting knowledge of the current risk assessment process, understanding BVLOS operations and operators needs and the nature of the risks of BVLOS UAV operations

The research design adopted three strands:

- A scientific literature review of risk assessment methods and approaches
- A series of workshops to determine:
    - How risk assessment is undertaken currently
    - Which use cases to examine for BVLOS risk assessment
    - The differences between VLOS, EVLOS and BVLOS UAS operations
    - Determine how UAS operators conduct risk assessments today and plan to do so for future BVLOS
    - Explore new or alternative risk assessment methods and establish the agencies requirements for BVLOS assessments

- Develop and propose a new candidate risk assessment method that meets the agencies requirements

The underlying philosophy of the research is grounded in taking a system perspective. System approaches recognise that an activity, in this case a regulated activity, is situated within a particular context and that this context provides various perspectives that shape the way that the system performs.

Therefore, exploring the risks of BVLOS, and the assessment of these risks, from different meaningful perspectives or system views, does not privilege one system actor and allows varying different needs to be understood as well as the dependencies that may be present and that enable system performance.

The schedule and purpose of the workshop programme

	Date	Focus of the workshop
Workshop 1	14th August 2018	How TS works today: • The baseline approval and assessment process • The BULOS project • Current and future regulation of UAVs • The TS use cases
Workshop 2	28th August 2018	Understanding the Use cases and the regulatory processes • First workshop with UAV operators • Examined the TS Use cases with TS approval teams and the UAV operators • Use cases; Forestry and Powerlines • Use cases SAROPS (missing person) and Urban High Density (including airports)
Workshop 3	4th October 2018	Risk assessments for the Transportsyrelsen approval process • Quantitative drone risk assessment for cities • LU results of the risk assessment literature review • The Transortstyrelsen approval process: how will BVLOS differ? • Requirements the TS needs for a BVLOS risk assessment process
Workshop 4	15th November 2018	Transportstyrelsen approval of BVLOS Drone operations: exploring a proposed method and process – 1 • The revised TS Use cases • An introduction to the Transportstyrelsen Approval and Risk Assessment (TSARA) process • Applying the Approval and risk assessment method – to the use cases and the applications that UAV operators bring • The SSRS risk assessment method
Workshop 5	7th December 2018	Transportstyrelsen approval of BVLOS Drone operations: exploring a proposed method and process – 1 • The TS Use cases • A review of Transportstyrelsen Approval and Risk Assessment (TSARA) method now with checklists • Applying the Approval and risk assessment method – to the use cases and the applications that UAV operators bring • The Urban Low Density use case approval using the LiU Visualisation table

Workshops to be held

Workshop 6	29th January 2019	Review of Draft report

Workshop Reports

Workshop 1: 14th August 2018, LiU Norrköping

Workshop 1 focused on understanding the TS use cases as well as the current approval process used for approval of drone operations in all five categories in the TS drone classification system

Use cases

Three use cases are the focus, that are contrasting in terms of the scope of the activity as well as the regulatory approval process

- Pipeline Inspection: 5A & 5C: up to 500M, including emergency powerline inspection
- Forestry: 5C
- Search and Rescue Operations (SAROPs) Missing person: 5C, Up to 500M. This use case includes time criticality, a dynamic task and one where recent experience has shown that the operational task my call upon to augment drone operations with local drone operations as operational assets.

A discussion was entered into with consideration of more complex scenarios city/urban. It was felt that exploration of such cases was desirable but that the three use cases that had been initially identified by Transportstyrelsen provided an evolutionary path to exploring more complicated use cases. For example, an urban case where Norrkoping is an exemplar and might include operations in Class G and Class C use case.

The use cases have a number of assumptions that they are built upon:

- Need to have a discrete 5A and 5C
- Pre-condition is BVLOS
- Possibility of mixed mode

It is critical that realistic use cases are developed possible. To achieve this, there are a number of criteria that need to be fulfilled:

- Drone operator view of the operation and considerations of their risk landscape and the way that they perceive risk needs to be embraced
- There are numerous variations and adaptations in the way that the use case operations can be undertaken and that will need to be understood
- Conditions of possibility for approvals need to be explored and thus the use cases need to provide the means to explore this
- Limitations of the use case operations in practise as well as the regulatory approval process need to be elicited. This can provide the basis for deriving requirements for technical innovations that contribute to a timely and effective approval process

It is recognised that the pace of development and change in drone operations is very fast. In order to be able to support this the future of drone development and evolution will need to be both considered and embraced.

Transportstyrelsen Drone Operation approval process

With those present, the approval process was explored. Anna Ahlberg was very helpful in providing the detail of the process.
In the discussion a number of points emerged:

- Conditions and variations for each use case need to be derived, eliciting these are a key objective for workshop 2
- Regulatory process: how is competence of the operator and organisation assessed? The baseline derived from workshop needs amplifying in preparation for the second workshop in this respect
- In the discussion, the contribution of Post hoc review of approvals and the operation was discussed. It could bring or contribute to the regulatory understanding and capability growing and evolving as information is gained on how effective the approval process was and how the operational task was undertaken and what risks were mitigated or identified during the task. Secondly, the process itself can be enhanced if it embraced a consideration of the SMS processes that drone operators undertook
- It is recognised that different risk models of the operating space will be held by different stakeholders. GA pilots will view risk differently than drone operators and Transportstyrelsen themselves. Such variations are entirely legitimate of course. It is understanding
- Use of electronic support for regulatory process – standard, computer support in the safety assessment add to workshop 5: SMS and computer support to the

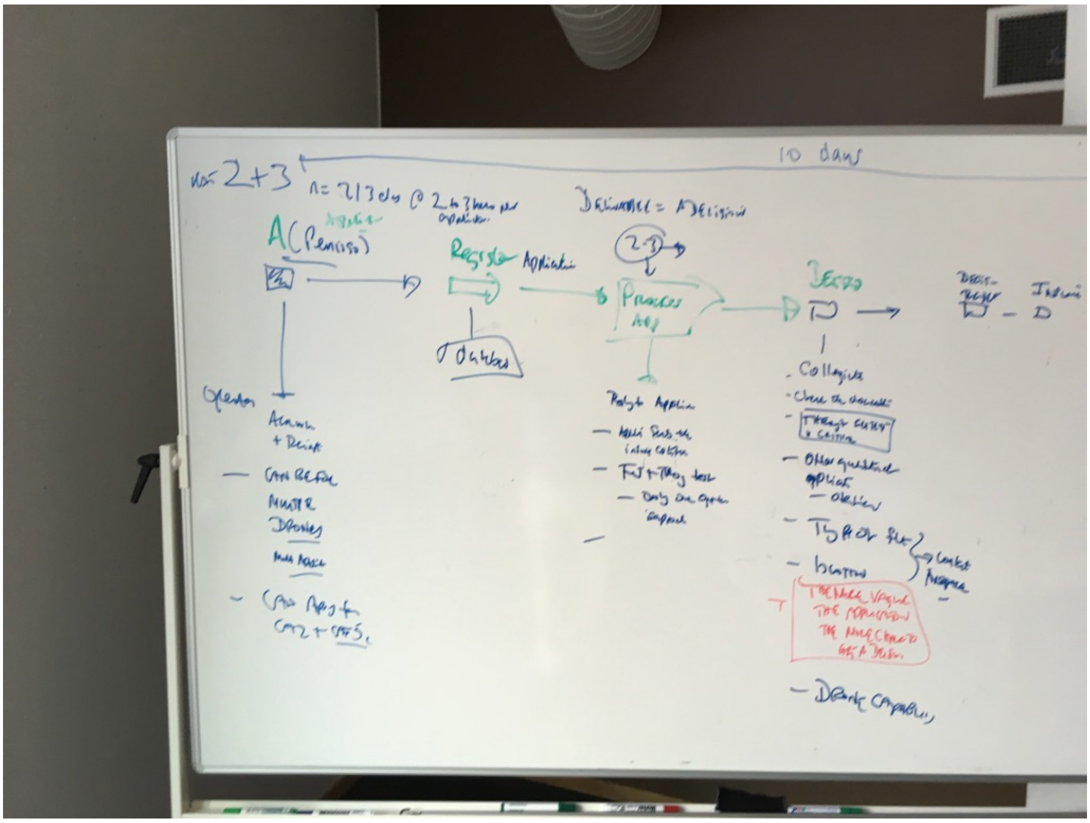

Figure 1: The derived TS drone approval process for Category 2 &3

The BULOS project

Lars Erik-Bled presented the results of an agency study of UAS operations and the agencies focus for interventions and creating the conditions of possibility to permit the growth of operations as well as the UAV sector of the aviation industry.

The emphasis in the study was on low level operations, >140m, and the interaction with GA, helicopter operations, low level military and low-level coastguard & police tasks.

The principal conclusions from BULOS were that management of UAVs > 140 m was best achieved by a policy of segregation and by collision avoidance by manned aircraft. In order to achieve this, it is a pre-requisite that a means for UAV operators to 'file' their planned trajectories in a manner that made it accessible to other airspace users so that they can flight plan in such a way that they could avoid UAV operation altogether or assume the task of collision avoidance.

The electronic conspicuity of UAVs is recognised as advantageous but equally it is problematic.

Conclusions

The first workshop was deemed to be very profitable and generated the first glimpse into the approval process. The nature of the risks that would be explored in BVLOS are evidently different. Identified in this workshop was the need to explore the use cases with drone operators and also to understand the wider context of the approval process.

These formed the foundations of the second workshop

Workshop 2: 28th August 2018

The second workshop was designed to explore the use cases with drone operators and the TS drone approval team.

To this end, drone operators and ATS service providers were invited. Six drone operators, who had experience with all of the initial TS use cases were invited and attended. Of the two ATS providers who were invited, only LFV were able to participate. TS were able to provide members of the Drone approval team as well as members of the airspace team who are also engaged in drone approvals.

Use Cases

The use cases were explored in group sessions. The use cases were extended with the Urban/City use case making four in total. In the case of the Urban/City use case, a visualisation of the use case was provided by LiU from an ongoing UTM project

Each of the groups reported back to the whole workshop in plenary.

Overall, the TS base use cases were agreed to be appropriate with respect to the task of the risk assessment project.

However, the detail of the uses cases as originally derived were found to be incomplete in that a number of assumptions were found not to represent how the Drone Operator community envisaged undertaking BVLOS Category 5C operations. Specifically:

- the weather conditions were found to be too conservative e.g. Not CAVOK
- BVLOS would make new platforms available with a greater operational envelope e.g. at night
- The capability of the platform and sensor opened up new operational capabilities and flexibilities
- Risk analysis will be required to be more rigorous than VLOS or even EVLOS because of the expanded capability of platforms and operational tasks. This is not just a case of 'more of the same, but also new hazards and interactions within both the operational environment and the environment and society as a whole
- The nature of SAR operations is dynamic and may well involve coordination with a multiplicity of diverse stakeholders
- The design of the platform can be optimised to minimise risk. The two commonly held risks airborne conflict and collision with ground objects humans can be mitigated by design of the platform as presented by Smartplanes
- BVLOS 5C is approved currently to the Swedish Police. Risk assessments are carried out and enacted. There is an accountable officer/manager who is integral to such risk assessments

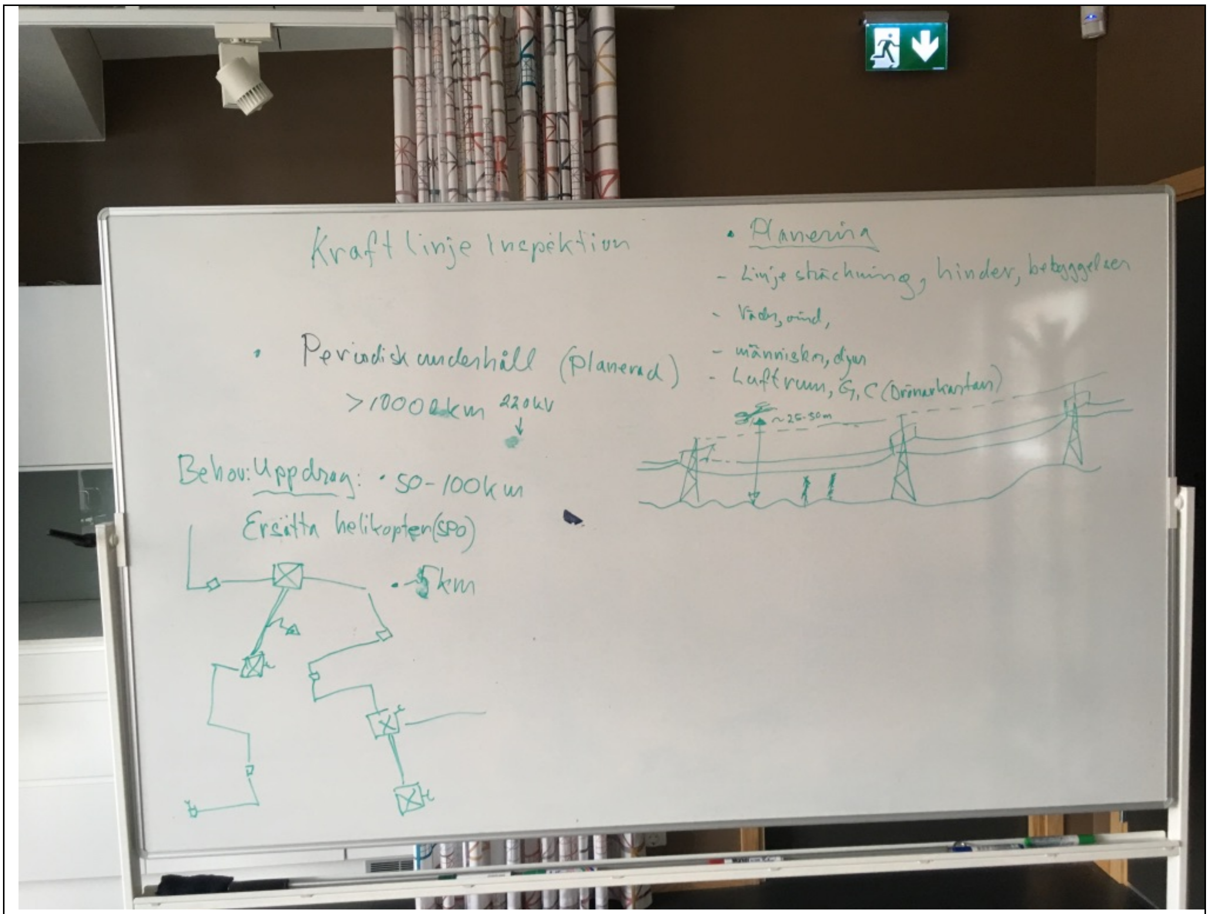

Figure 2: BVLOS 5C Powerline use case

From the original three use cases, with variations, there were now nine. The assumptions that the use cases are built on need to be reviewed in light of drone operator experience. This was carried out by LU and the output was written up as a technical note and distributed on the third of September (see technical note that accompanies this report).

One aspect for consideration is that of the two (at least) forms by which drone operations can be undertaken:

- Those within an organisation, often with multi-person teams
- Drone operations in small entities with single person operation

The discussion that was entered into with consideration of more complex scenarios city/urban in the previous synthesis meeting   felt that exploration of such cases was desirable but the three use cases that had been initially identified by Transportstyrelsen provided an evolutionary path to exploring more complicated use cases. (Use Norrkoping as an exemplar for Class G and Class C use case).

The revised use cases will form the basis for subsequent workshops

Workshop 3: 4th October

Risk assessment methods.

This workshop had as its focus risk assessment methods.

LiU provided a presentation on the scope of risk assessment and a quantification of the magnitude of specified safety events form several studies of UTM and low density – high density urban/city scenarios.

The literature review introduced both quantitative and qualitative methods as well as a hybrid approach – SORA.

For the task that Transportstyrelsen have to undertake, a pure quantitative assessment is unsuitable. Indeed, this is the guidance given in the SORA method. Although, what kind of data could lead to eventually a risk assessment process that supported the Transportstyrelsen approval task?

A subject for further research and for a closer examination of SORA and the use of SAIL in the SORA method.

The Transportstyrelsen task is to conduct a risk assessment of the risk assessments submitted for approval by drone operators. This is an important distinction. However, Transportstyrelsen also have a requirement to assess the wider societal risk, if

SORA does offer a means of a quasi-risk quantification using an additive method to sum the overall risk score of a risk assessment. This feeds into a risk matrix.

The risk landscape that Transportstyrelsen are confronted with is different than that of the drone operators. The afternoon workshop sessions highlighted this.

Proposed approach: The literature review examined both qualitative and quantitative approaches to risk assessment.

- *Quantitative* is rejected because there is a complete lack of data to draw upon and build models of risk by which to accept or reject quantitative based assessments. Numerous methods exist, but as yet, such models cannot be populated with risk data for the TS task
- *Qualitative* is proposed on the grounds that, although not without challenges, an assessment based on reasoned argument that sets out the evidence for a decision in narrative terms is used and is an acceptable method. It allows knowledge and understanding to be gained. It is also a method that provides transparency. Consistency in assessments does requires methodological rigour

A discussion followed and it was agreed that LU and LiU would develop this approach further for use in the fourth workshop. Especially, the concept of operations approach that the literature identified was consistent with the way that TS conduct current risk assessments and approvals

In the afternoon session, an example of how a drone risk assessment is undertaken for a Category 1 & 2 drone operation was presented and discussed. The depth of this risk assessment and the extent that operational features of the task are notable features of an in-depth assessment.

What is evident from the workshop is there is a significant amount of detailed knowledge that is applied in approvals that flows from personal discussions between the approvals team and the applicants. In some cases, this acts as a filter that shapes the way that the applicants themselves subsequently view the feasibility of the application that they have made. Can this knowledge and information be developed into a checklist with Carl and Eric? A particular risk for Transportstyrelsen was identified in that Eric and Carl have the knowledge as tacit knowledge that is not often shared or if it is, it is only partial tacit knowledge.

For Transportstyrelsen to develop an understanding of the risk landscape, where does it gain the data from that supports the understanding. Occurrences involving the drone community are principally filed as a result of an airspace infringement or a proximity report. Rarely are these filed by the drone operator themselves. Thus, there is very little feedback that exists in other areas of the aviation system.

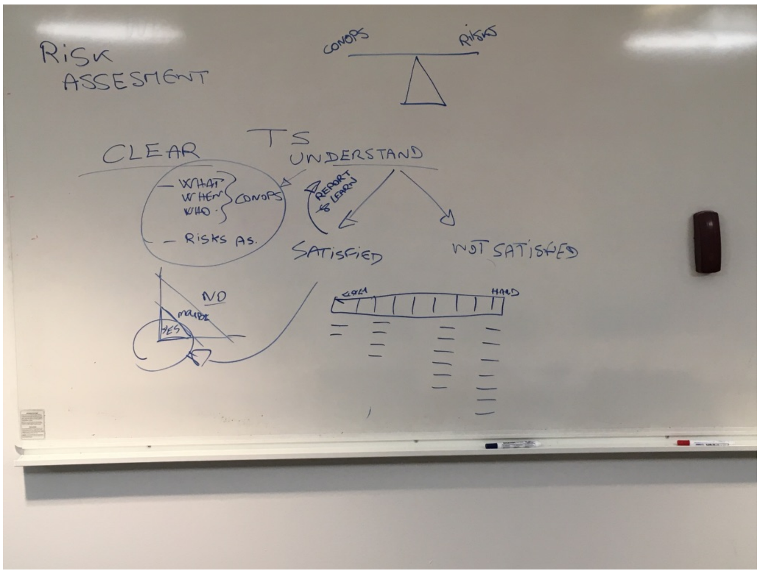

Figure 3: One TS group view of the desired risk assessment process

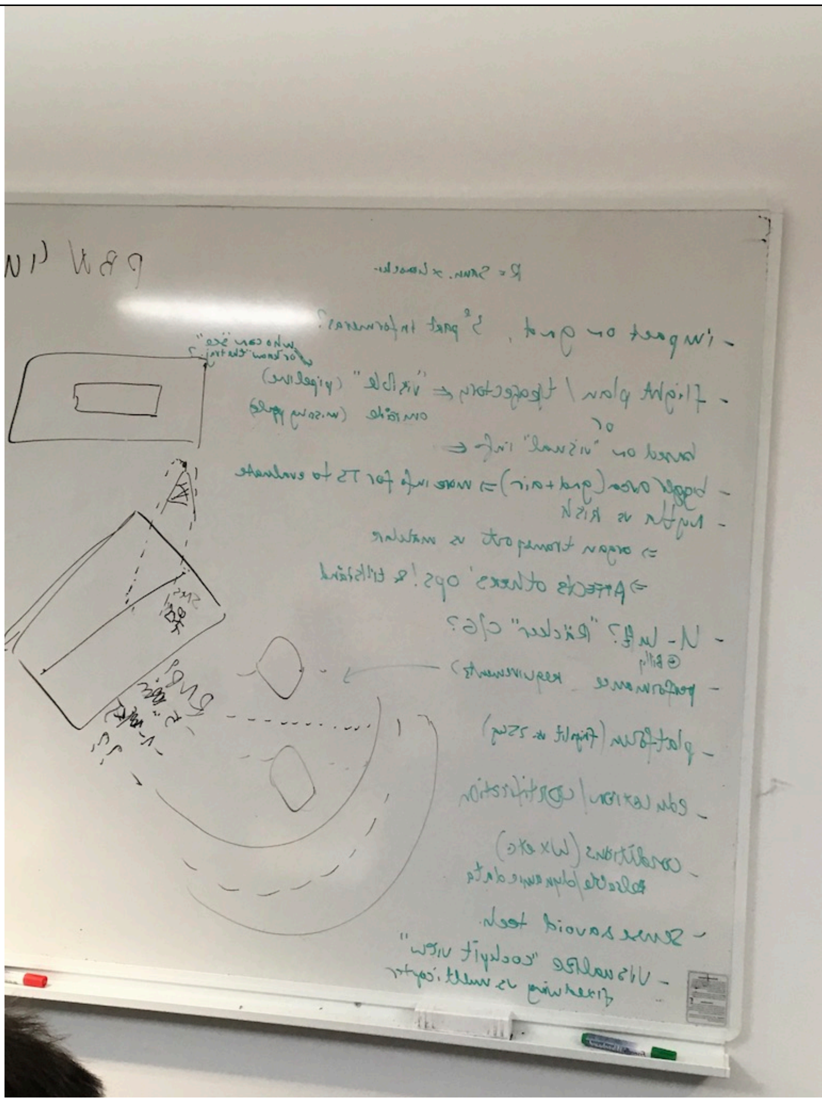

Figure 4: The second TS group view of the desired risk assessment process

The requirements for a Transportstyrelsen Approval risk assessment process

From the workshop on the 4th October, and in the synthesis meeting, a number of requirements for any risk assessment process to facilitate approvals emerged:

- Qualitative as opposed to quantitative
- A structured, formalised approach possibly checklist based that enable or builds in:
  - Redundancy (reduced use of TS team's tacit knowledge)
  - Reduces the vulnerability and exposure to risk to Transportstyrelsen
  - Enables the assessment of the operator's application risk assessment, the other drone operators and airspace users and also the societal risks Transportstyrelsen are responsible for.
  - That supports consistent decisions, is transparent and traceable Provides legal security and is perceived and seen as fair and equal
- Anna's team conduct this already and so this should be incorporated or be the basis of a method

- Helen's airspace team also contribute to the approval risk assessment and airspace requirements can be derived that involve other stakeholders – LFV, ACR, Swedish military
- There are other stakeholders and interested parties too – environment, wildlife and nature
- Some drone operating organisations do use an SMS. Some exemplars would be of value for the fourth workshop

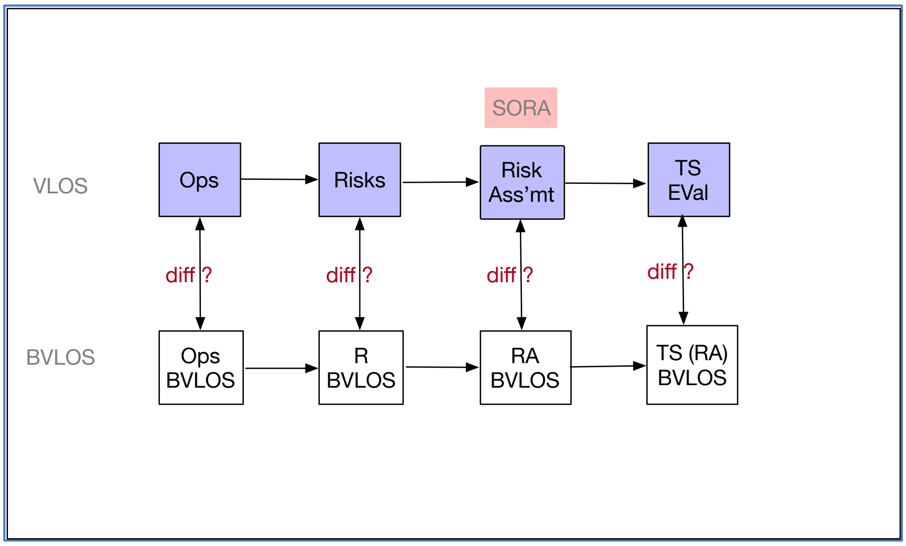

Figure 5: Basic process and flow model of the current TS approval process

A synthesis meeting was held on the 11th of October and the output of the 3rd workshop was analysed and reviewed by Dr Jonas Lundberg, Dr Anthony Smoker, LU & Dr Rogier Woltjier, FOI.

From this workshop, the Transportstyrelsen Approval and Risk Assessment Method was derived.

Figure 6: The synthesis of the 3rd workshop to TSARA

A technical note has been written that accompanies this workshop report that provides an explanation of the derivation of the TSARA method and

Workshop 4: 15th November 2018

The objective of the fourth workshop was to work with Drone operators and the TS Drone approval teams to test and explore the TSARA method with the use cases that were derived from the 2nd workshop.

The same drone operators were selected as participants and were asked to bring to the workshop an application for a use case approval. Including a risk assessment

The workshop was organised in group sessions with each group designed to have a combination of drone operators, TS Drone operation application approval team TS airspace team.

The TSARA method was introduced and the first two uses cases – forestry and powerline inspections undertaken.

It became apparent that the groups were drifting away from the intent of the task, with elements of the application being explored. In part this is because preparation for the submission of the approval application itself, the construction of the approval, plays a significant part in the risk assessment process.

This is reflected in the TSARA method in that both Drone operator and TS engage in discussions that help to define the scope and nature of the application.

For TS there is a legitimate concern about the scope and completeness of the application as the quality, completeness and scope of the risk assessment and mitigations that make up the application, as well as the other elements fulfil a role in the overall assessment of an application for an approval. To what extent should the guidance material on the submission of an application lead the applicant into a successful application? There was agreement that the application should leave some elements of an application strictly in the purview of the Drone Operator. The presence or otherwise of items that are assessed is an indication of the robustness and quality of the application and forms a part of the overall assessment

The second round of group exercises were more focused. The two groups used use case applications, principally one provided by EON and the second using railway inspections to assess an application jointly.

An essential element of TSARA is the construction of a structured argument that is, fundamentally, the TSARA output. It is in the form of a judgement. That is an argument for one of the three possible outcomes that can flow from the assessment. TSARA embraces not just the review of an application for approval, but also the specific internal TS review of airspace, ATM (in conjunction with the ANSP) and interactions with wider societal matters such as impact on the environment, noise etc. Additionally, the cost benefit of the task that approval is being sought for plays a part in any approval decision.

The TS view of TSARA was that it encapsulates the processes and tacit approach that is carried out today. That is TSARA has the potential to formalise the current ways of making assessments.

The Drone operators generally agreed that TSARA was an acceptable way of assessing the risk assessments that they conduct. However, in the discussions that reviewed the exercises it was apparent that drone operators and the TS approval team have different interpretations of what application form elements. Sense and avoid being one example. This was evidenced in the EON application for a 5ategory 5C BVLOS application

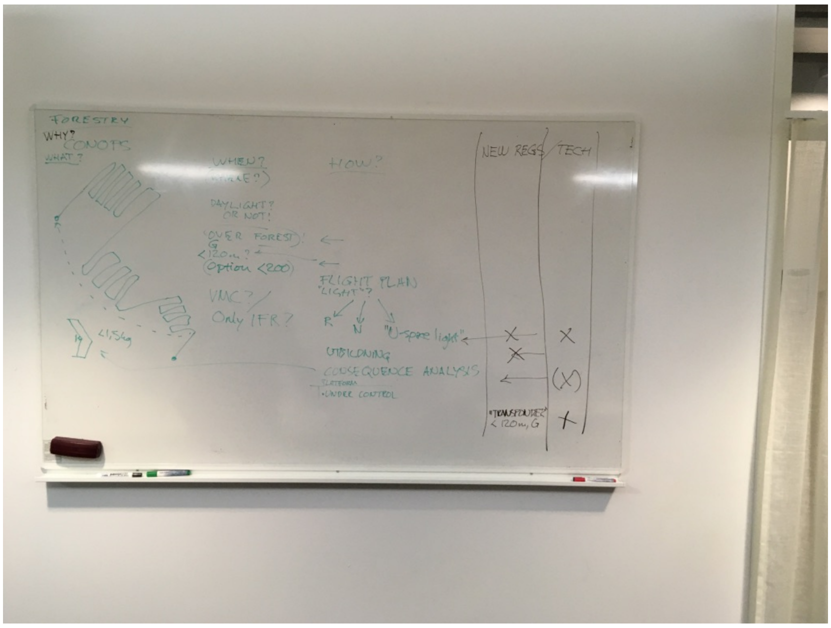

Figure 7: Afternoon Group sessions review of TSARA method

Only one dimension of TSARA was tested in this workshop. This is shown below.

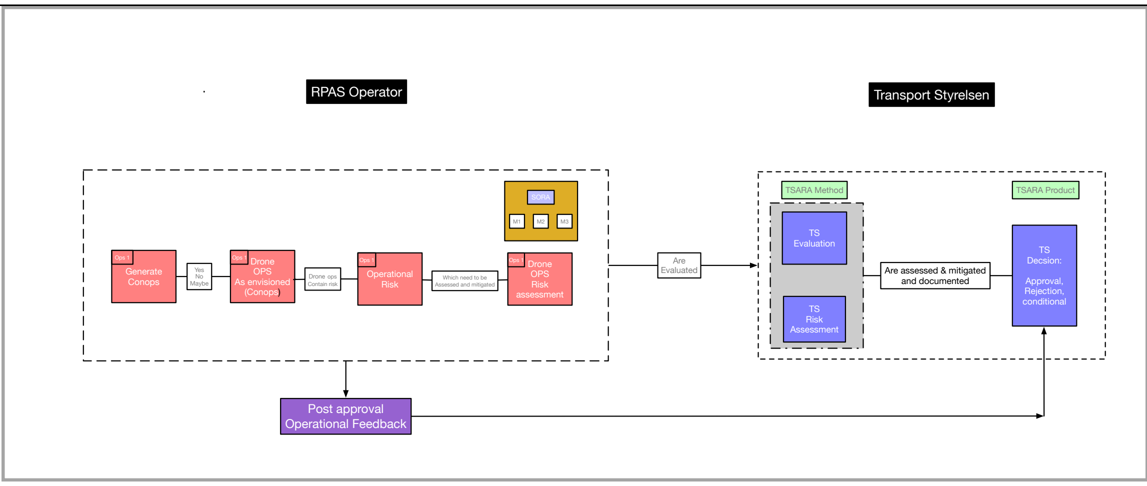

Figure 8: Basic TSARA method

The fuller set of TS Drone assessment criteria was not used. This is presented below in figure 9. Some of these items are those that would be sought in the approval process but not included in the approval application

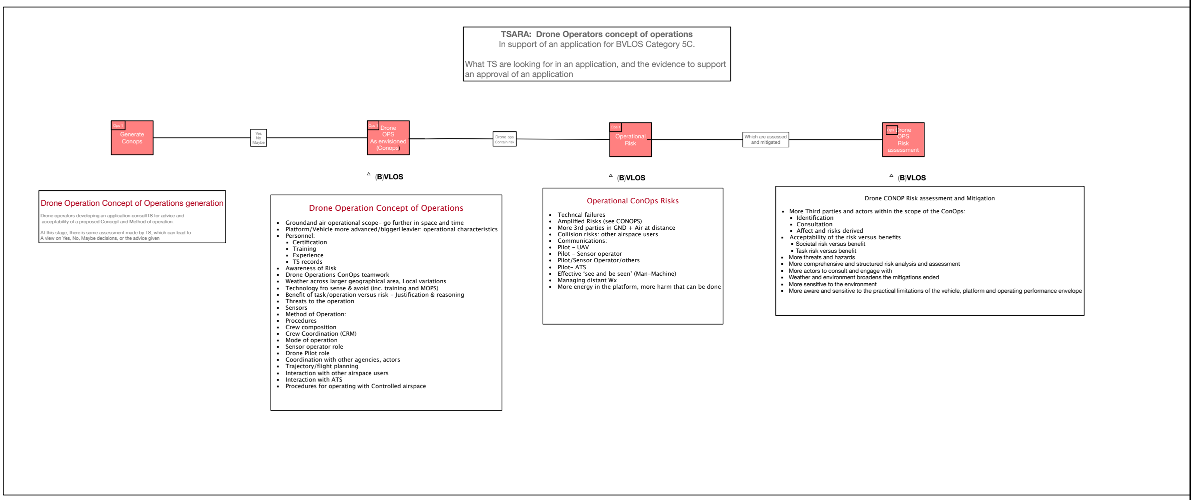

Figure 9: TS Approval factors, CONOPS based

The workshop was successful and confirmed that the general approach to the risk assessment of BVLOS 5C drone operations, with the output from workshop 4 shaping the approach to the assessment generally holds good.

A number of amendments were identified to strengthen TSARA.

The use of A SORA style SOAN was not included, but its value was recognised.

Overall, there was confidence from workshop 4 that TSARA can be developed to provide initial 5C BVLOS risk assessments in the approval process.

Workshop 5: December 7th 2018

Workshop 5 built on what was learnt in workshop 4 and was a second iteration of testing TSARA with use cases.

Included in Workshop 5 is the Low density/Urban city case that once again used the LiU visualisation table.

Before the workshop. LU met with TS and reviewed all elements of TSARA in detail.

Once again, this conformed the broad consensus that formalising the current approval process that the knowledge elicited from TS incorporated, Basic checklist, that represent the algorithm part of the TSARA method were discussed and developed further. From the meeting, additional flows of information into the TSARA method itself were also identified

An initial set of checklists/flow process diagrams were presented and reviewed. These were developed further for the workshop, it being an objective of the workshop to see if they can indeed support the TSARA risk assessment and decision tasks.

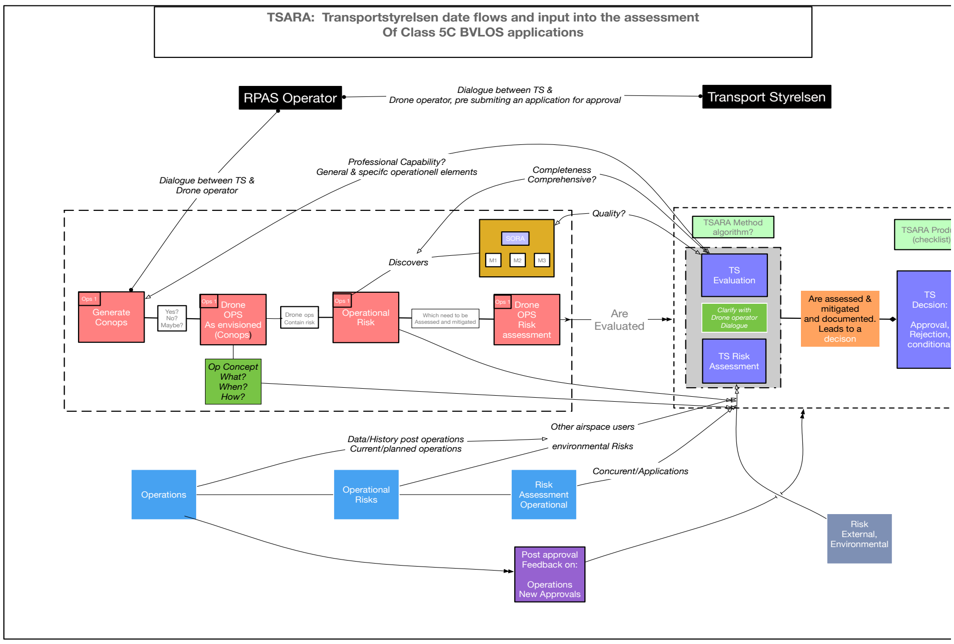

Figure 10: TSARA flows and inputs into the method

The workshop drew upon four Drone operators who participated in the second workshop as participants for this review of TSARA and were asked to prepare and bring a Category 5C BVLOS application for approval. These participants fulfilled the request admirably.

Once again, after a review of the TSARA Method, the workshop was divided into two groups. In the morning session, one group explored the powerline application whilst the other group worked with the low density Urban/city case for which LiU/Lund provided the basis for an application. This was influenced by the application of BVLOS drone deliveries of food and other goods in Reykjavik.

In the afternoon, the groups changed with the morning pipeline group changing to the Urban/city use case and the other group using a SSRS SAR Use case application to test TSARA.

The Urban/City use case evolved into sessions where what was needed to be included in an application for approval was the focus. This is the 'Left Hand Side' of Figure 10.

The overall impression of the two Urban/City use cases was that this is much more involved and complicated than first imagined. The nature of the concept of operations are not well understood or defined. However, as a key input into any TSARA determination is the concept of operations, then further research is required into this aspect of the use case.

The two other use cases that were explored and to test TSARA were able, on the basis of the evidence presented in the application, found that the TSARA checklists are a suitable way to proceed a number of additional elements need to be included. The addition of a SORA/SAIL style quantification of risk is worthwhile pursuing, in further research

Using the checklists provided the means to structure the data collection that would provide the input into the Claim/Argument/Evidence structure of decisions. It was emphasised that these decisions needed to be transparent and reasoned.

Smartplanes, one of the participating drone operators introduced a quantitative approach to risk assessment that is straightforward once established. This risk model included parameters for population density and values for the probability of harm to humans involved in collisions with drones, for which Sailplanes worked with Uppsala University to develop.

Summary and conclusions

In developing a risk assessment method for Transportstyrelsen to conduct assessment of applications for Category 5C BVLOS drone operations, an exercise in knowledge elicitation was conducted in three workshops. This was followed by two workshops that examined a risk assessment method that is tailored to the Transportstyrelsen approval of drone applications process.

The knowledge elicitation workshops drew on participants from the agency as well as the drone operating community. The value of these workshops was greatly enhanced by having these two sets of actors working together. This led to the TS use cases to be revised and the revised set were used in subsequent workshops

The current approval process was explored and captured and formed the basis of a method, known as TSARA – Transportstyrelsen Approval and Risk Assessment method.

To the basic understanding of how the approval is undertaken, including all of the interested stakeholders and involved parties, was added the view of the drone operator and their domain knowledge of how BVLOS 5C drone operations would be undertaken. From this, the workshop was able to gain an understanding of the differences between VLOS and EVLOS operations.

Through a risk workshop, the basis of the Transportstyrelsen needs for a risk assessment method were derived that were built into a new candidate method.

The TSARA candidate method was examined using participants from the drone community and Transportstyrelsen teams.

A number of conclusions were made:

- The approval application process can be interpreted differently by TS and by the drone community
- The approval application form needs revising
- There is a dearth of safety and incident data to draw upon from UAS operations
- An iterative approach to risk assessment of 5C BVLOS drone operations is preferable
- Evolution to a qualitative approach, but always with a narrative around which the approval decision can be made
- The SORA SAIL, and its approach, is felt to be a way of merging a qualitative and quantitative methods
- The current, and future risk assessments will make significant use of the interactions with TS approval team and the applicants
- Transportstyrelsen BVLOS assessments involve a number of internal actors with vested interests
- The risk landscape that Transportstyrelsen engages with in considering and approving 5C BVLOS is significantly wider than that of the drone operator
- This is exacerbated by the different operating characteristics of BVLOS drone platforms that mean that there are new risks to consider, different parties to engage with and a wider societal need to fulfil.
- The concept of operation of a BVLOS drone operation is the essential means by which common understanding of the risk landscape can be derived

References

Joint Authorities Rulemaking of Unmanned Systems, (2012). *JARUS guidelines on specific operations risk assessment (SORA)*. JARUS: Brussels

Glossary

ACR	Aviation Capacity Resources AB
ATS	Air Traffic Services
BULOS	
BVLOS	Beyond visual line of sight
EASA	European Aviation Safety Agency
EVLOS	Extended line of sight
FOI	Totalförsvarets forskningsintitut
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
LFV	Luftfartsverket
LiU	Linköping University
LU	Lund University
LUSA	Lund University School of Aviation
SORA -SAIL	JARUS Specific Operations Risk Assessment -Safety level
SSRS	Sjöräddnings Sällskapet
TS	Transportstyrelsen
TSARA	Transportstyrelsen Approval and Risk Assessment method
UAV	Unmanned Aerial Vehicle

Participants to the five workshops undertaken in 2018

		Workshops					
Participant Name	Affiliation	Pre-Meeting May 29th	1 Aug. 14th	2 Aug. 28th	3 Oct. 4th	4 Nov. 15th	5 Dec. 7th
Charlotte Billgren	Transportstyrelsen	✓	✓	✓	✓	✓	-
Jörgen Andersson	Transportstyrelsen	✓	✓	✓	✓p	✓p	✓
Helen Ingerdotter	Transportstyrelsen	✓	✓	✓	✓	✓	✓
Lars-Erik Blad	Transportstyrelsen	✓	✓			-	✓
Per Fredriksson	Transportstyrelsen	-	✓	-	✓	✓	-
Anna Ahlberg	Transportstyrelsen	-	✓	✓	✓	✓	✓
Erik Jangren	Transportstyrelsen	-	-	✓	✓		✓
Carl Stålberg	Transportstyrelsen	-	-			✓	✓
Remi Vesvre	Transportstyrelsen	-	✓	✓	-	✓	✓
Billy Joseffson	LFV	-	✓	-	✓	✓	
Roger LI	LFV	-	✓	-	-	-	✓
Lothar Meyer	LFV	-	✓	-	-	-	-
Anders Klimt	LFV	-	✓	-	-	-	-
Jonas Lundberg	LiU	✓	✓	✓	-	✓	✓
Amy Rankin	LiU	✓	-	-	-	-	-
Johan Bergstrom	Lund University LTH/TFHS	✓	-	-	-	-	-
Anthony Smoker	Lund University LTH/TFHS	✓	✓	✓	✓	✓	✓
Rikard Tylstrom	Lund University LTH/TFHS		-	✓	✓	-	-
Rogier Woltjier		-	-	-	✓	-	✓
Fredrik Falkman	SSRS	-	-	✓	✓	✓	✓
Nicklas Fredriksson	Swedish Army	-	-	✓	-		-
Rickard Henningsson	Swedish Police	-	-	✓	-	✓	-
Per Sundqvist	EON	-	-	✓		✓	✓
Peter Melander	Swedish Rail SJ	-	-	-	-	✓	-