Sense & Avoid for UAVs

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ABSTRACT

The German Federal Office of Defence Technology and Procurement (BWB) initiated the Wasla/HALE project in 2000 to investigate, develop and test suitable technologies for operation of UAVs in controlled airspace. The Wasla/HALE project is jointly performed by DLR, ESG GmbH, DFS and EADS Military Air Systems.
In its phase 3, the Wasla/HALE project focuses on the investigation of the "Sense & Avoid" capability in non-cooperative environments.
This paper outlines the results of the requirements analysis for a "Sense & Avoid" system for UAVs.
It summarizes customer and certification requirements and concludes technical and functional requirements. The paper defines the elements of the functional chain from first detection of an object to successful avoidance, specifies the key functions and derives an overall time budget. Special attention has been paid on the involvement of the UAV operator and the autonomous behaviour in case of data link loss or latency. It proposes a method to handle cooperative and non-cooperative objects and to derive avoidance advisories thereof. This will be complemented by a description of the design concept for an advanced avoidance subsystem operating in guided and autonomous mode. The paper summarizes the results of the technology assessment performed to identify suitable sensor systems as well as avoidance algorithms.
Finally, the paper defines the way ahead with the implementation of the experimental "Sense & Avoid" system and the proposed simulation and flight test campaigns.

BIOGRAPHY

1) Jörg Meyer studied Mechanical Engineering at the Technical University of Ilmenau, Germany. He focussed on measurement and sensor technologies and received his diploma in 1999. He joined former Dasa in 1999 and is now working on different projects related to FMS and Sense & Avoid for UAVs.

2) Dietrich Altenkirch gets his diploma in aeronautical engineering at Technical University of Braunschweig in 1977. Since then Scientific Engineer at the Institute of Flight Research of the German Aerospace Center (DLR) in the fields of flight controls, handling qualities and flight testing. Currently Manager of the UAV Demonstration Program using ATTAS.

3) René Knorr got his diploma in aeronautical engineering at Technical University of Berlin in 1989. He started his industrial experience at Eurocopter Deutschland as Development Engineer for advanced flight control laws and inceptors for helicopters. In 1993 he returned to Technical University of Berlin as a research and teaching assistant in the fields of flight simulation techniques and Human-Factors where he also got his Ph.D. in 1999. Since then he works as System Engineer and Project Manager for a variety of Technology Programmes at Elektroniksystem- und Logistik GmbH (ESG).

4) Andreas Lenz joined ESG in 2003 and is also involved in the Wasla/HALE project since then. Besides working on UAV related technology projects and studies he has experience in developing and maintaining simulation environments. He gained his knowledge in cognitive automation and assistant systems in six years working as a scientific assistant at the University of German Armed Forced in Munich. He received his diploma in Aeronautical Engineering from the RWTH Aachen in 1996. Besides his professional experience he also holds a pilots and instructor license.

5) Torsten Schattel studied Electrical Engineering at the Technical University of Dresden. He has been working at WTD 61 in various UAV projects as a Type Inspector since 1999.

Introduction

Three years ago, the project Wasla/HALE was presented on the UAV Conference in Bristol [1]. At that time, the Wasla/HALE project in its phase 2 assessed techniques and procedures required for the operation of UAVs in controlled airspace.

One big finding of this phase 2 was that the capability to "Sense & Avoid" conflicting traffic was the major question to be solved.

Consequently, the BWB launched the phase 3 of this program in 2005 to address the investigation of the "Sense & Avoid" (S&A) capability in cooperative and non-cooperative environments.

At the start of phase 3, the main focus was laid on a requirement analysis to consolidate customer and certification requirements applicable for the Sense&Avoid capability for MALE and HALE UAVs operated under IFR and to specify functional and technical requirements of a generic Sense&Avoid system.

Later in the Program, an experimental Sense&Avoid system dedicated to the assessment of critical system capabilities will be prepared and tested in simulator campaigns and using flight trials to gain experience and to validate the established requirements.

Status of the project

During the phase 2 of the UAV-demonstration project the DLR test aircraft ATTAS (Advanced Technologies Testing Aircraft System) was equipped with UAV-specific systems like control data link, communication data-link and onboard intelligent UAV-systems, see Figure 1.

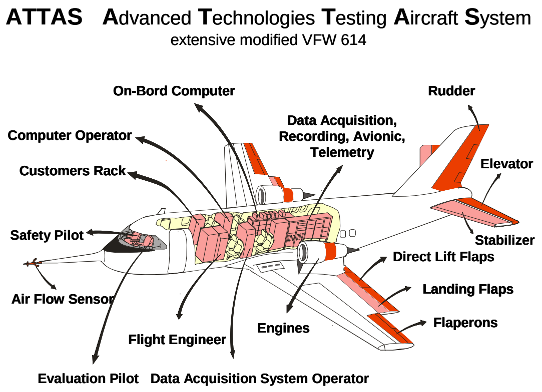

Figure 1: Experimental UAV-System ATTAS

The experimental UAV-system was completed by two UAV ground control stations, one located at Braunschweig, the homebase of the ATTAS aircraft, and the other at the Federal Armed Forces Flight Test Center at Manching in the southern part of Germany. With this configuration several flights from Braunschweig to Manching and inverse as well as special flights from Manching demonstrating emergency procedures like guidance data link loss, TCAS-event and rerouting because of adverse weather were performed, using the general German airspace while controlled from one of the ground control stations, see Figure 2.

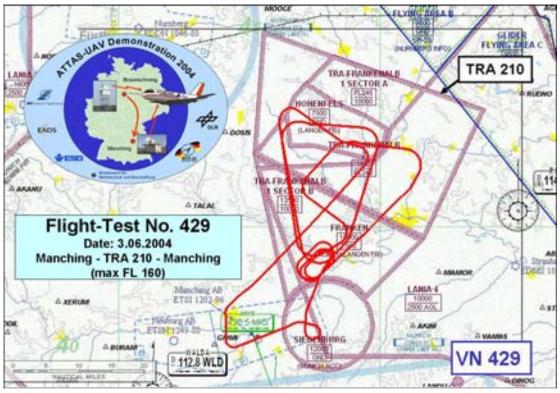

Figure 2: UAV Test flights using ATTAS

For phase 3 of the demonstration project, one major point of interest is the so far not solved Sense & Avoid problem of UAV's. For the best performance of such a system it is essential to have one ore more sensors with the maximum detection range, high resolution and reliability and minimum weight and costs. Depending on the physical principle the possible candidates for sensing have advantages and disadvantages. Figure 3 shows the characteristics of possible sensor types.

	LADAR	RADAR	TV	IR
Detection range	small	very large	large	moderate
Size/mass	heavy	heavy	light	light
Adverse weather	moderate	good	very bad	bad
Electrical power	high	high	small	small
Kind of information	high	high	small	small
Complexity	high	high	small	moderate
Detection by others	yes (active)	yes (active)	no (passive)	no (passive)
Use during night	yes	yes	no/yes	yes
Costs	?	?	?	?

Figure 3: Characteristics of possible sensors

The characteristics of all sensors were weighted in the sense of the overall performance of the complete system. The system must be commercial of the shelf, because new developments of sensors were not the aim of the project. It was decided to use a combination of an optical and a radar sensor, because both sensors complement one another in their characteristics for instance the radar systems needs a lot of power and the TV-systems needs less. Figure 4 is showing the installation of both sensors below a modified radom of the ATTAS aircraft.

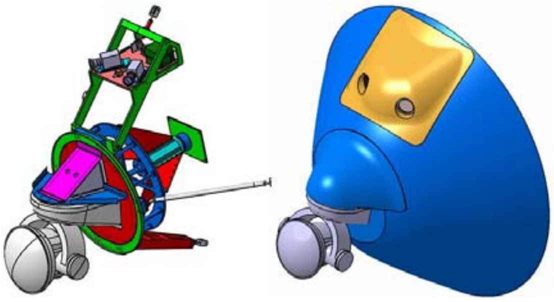

Figure 4: Sense & Avoid Sensor Integration

These sensors will be tested in three flight test campaigns in 2007 with real flight conflicts generated by a non cooperative test aircraft.

Sense&Avoid Requirements Analysis

The definition of certification requirements applicable for UAV operation as a whole and for Sense & Avoid in particular has been a key issue since the benefits of operating UAVs were identified. This chapter summarizes the most important certification requirements applicable to a S&A system.

„… regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft …“ ("FAR Part 91.113 – „Right of Way Rules“)

In controlled airspace, the separation to other objects is ensured by compliance with ATC instructions or consideration of ATC provided traffic information.
The S&A system shall be used as an independent means to detect conflicting traffic and against non-equipped VFR objects that are not controlled by ATC.

„Approvals for ROA operations should require the proponent to provide the ROA with a method that provides an equivalent level of safety, comparable to see-and-avoid requirements for manned aircraft.“ (FAA order 7610.4J, Chapter 12, Section 9; July 2001)

Unfortunately, the terminology "equivalent level of safety" (ELOS) is not clearly defined. In principal, there are two methods to ensure ELOS, a capability based approach and a safety based approach. The capability based method ensures safety by requiring capabilities similar to the human pilot. Since UAVs will be operated from a remote ground control station (GCS), and given the transmission delays applicable to the invoked data link connections as well as the limited situational awareness of the UAV operator, it becomes obvious, that the situation controlling a UAV is not comparable to the human pilot situation and that the capabilities derived from a human pilot might not be sufficient for a UAV.
In contrast, the statistical approach is purely based on an evaluation of Mid-Air and Near Mid Air Collisions caused by manned A/C. Using such an evaluation, a safety requirement can be derived. It has been found, that the level of safety for human pilots corresponds to $8{,}57 \cdot 10^{-6}$/FH (AOPA Air Safety Foundation). This value would be applicable to UAVs as well when requiring an ELOS.

"Where a UAV pilot-in-command is responsible for separation, he should, except for airfield operations, maintain a minimum distance of 0.5nm laterally and 500ft vertically between his UAV and other airspace users, regardless of how the conflicting traffic was detected and irrespective of whether or not he was prompted by a S&A system." (Eurocontrol OAT Task Force, [2])

This requirement already establishes separation requirements applicable for UAV operation and has therefore a direct impact on system design of the S&A system. It should be noted that these values are applicable whenever the UAV operator is responsible for separation. In such situations, the UAV might experience non-transponder equipped traffic under VFR, but also transponder equipped traffic under IFR.

Involvement of the UAV Operator

The Eurocontrol UAV OAT Task Force established requirements for the operation of UAVs under ATC control. One key finding is that the UAV shall be primarily operated under operator control and shall act autonomously only in conditions with data link failure or latency.

“For ATM purposes, the primary mode of operation of a UAV should entail oversight by the pilot-in command.” (Eurocontrol OAT Task Force,[2])

„A back-up mode of operation should enable the UAV to revert to autonomous flight in the event of

total loss of control data-link between the pilot-in-command and the UAV. This back-up mode of operation should ensure the safety of other airspace users." (Eurocontrol OAT Task Force,[2])

These requirements have to be taken into account also for the Sense & Avoid capability, leading to the need to inform the operator about the Sense & Avoid conflict situation, possible resolution advisories as well as the transmission and execution of operator commands in a timely manner.

Due to the nature of the data link connections, a fall-back mode of operation will be required for the UAV to react autonomously on traffic conflicts in conditions with data link loss or latency.

Capability Assessment & Functional Break Down

A "Sense & Avoid" system is characterised through its sub-capabilities "Sense" and "Avoid". For a functional breakdown each of these sub-capabilities were analysed to identify its key capabilities according to Figure 5

The "Sense" sub-capability is build of its key capabilities "object detection", "object tracking" and "object consolidation" whereas the "Avoid" sub-capability is build of its key capabilities "conflict detection" and "conflict solution".

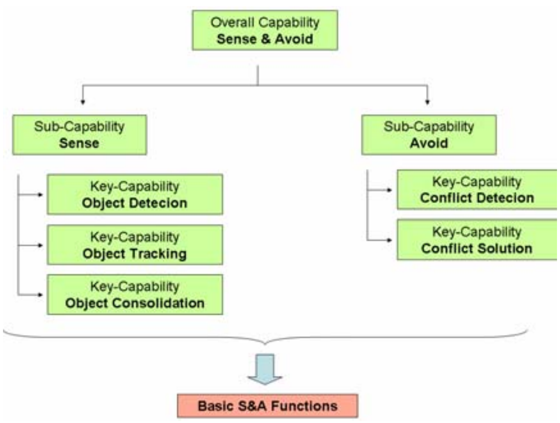

Figure 5: "Sense & Avoid" capabilities

The sub-capabilities may only be achieved, if the corresponding system functions are realised. Consequently, a functional break down of basic and secondary S&A system functions has been generated. Here, basic S&A functions are understood as principle functions which in manned aircrafts are provided by the pilot whereas in unmanned aircrafts operating autonomously they have to be totally provided by an onboard system.

Secondary S&A functions are evolving in the case of allocating particular S&A capabilities between a S&A system onboard the UAV and a remote pilot in a Ground Control Station (GCS).

Figure 6 illustrates the functional break down of the "Sense" and "Avoid" capabilities. The basic functions are divided into the functions "Sense" and "Avoid".

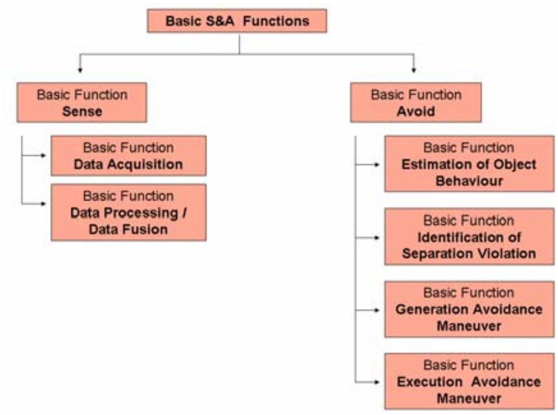

Figure 6: Functional Break Down of "Sense & Avoid" capabilities

The basic function "Sense" consists of the functions "Data Acquisition" and "Data Processing / Data Fusion". The basic function "Avoid" consists of the functions "Estimation of Object Behaviour", "Identification of Separation Violation", "Generation of Avoidance Manoeuvre" and "Execution of Avoidance Manoeuvre".

In the case where the S&A capabilities are distributed between the UAV and the operator on the ground the following secondary S&A functions can be derived as "Data Transfer between UAV and GCS", "Information Presentation & Interaction" and "Functions- & System Status Test" which is illustrated in Figure 7.

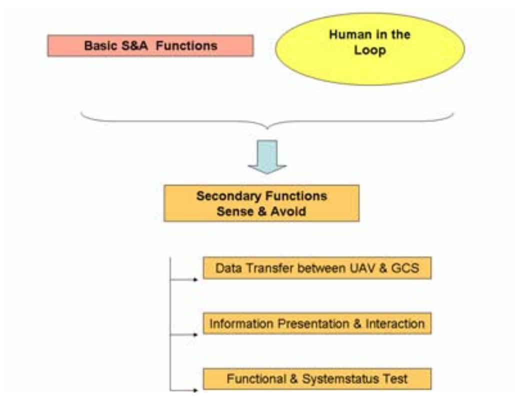

Figure 7: Secondary Functions

This approach assures that all UAV system functions relevant to provide S&A capabilities are considered.

Functional Allocation and System Concept

Figure 8 illustrates a system concept and the allocation of the identified system functions for a Sense & Avoid system.

The overall system consists of the S&A core system for the basic sense and avoid functions and dedicated sub functions that are used to transmit the information and to provide a HMI to the UAV operator and to execute the avoidance manoeuvre with the FMS/Autopilot.

The S&A core system contains a "Sense" component and the "Avoid" component. The "Sense" component has to be able to detect both, cooperative (e.g. using TCAS II) and non-cooperative objects (using forward looking sensor).

It is envisaged to consolidate the detected objects of both, cooperative and non-cooperative sense components and to use this consolidated situational picture as an input for the avoidance function to elaborate a resolution advisory.

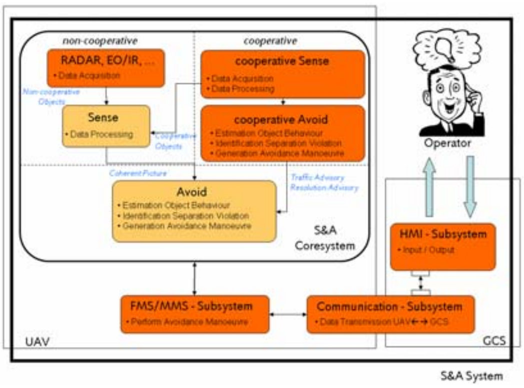

Figure 8: Functional Allocation and System Concept

Since a HALE/MALE UAV with a MTOW > 5700kg will have to be equipped with TCAS II, one has to take into account the handling of TCAS Traffic/Resolution Advisories (TA/RA). Since TCAS II can only consider Transponder equipped A/C, its RA has to be validated for safety against non-Transponder equipped objects. This validation will have to be done in a common „Avoid“ block as illustrated in Figure 8. As for the pilot operating an A/C, this common Avoid block must have to ability to overrule the TCAS RA, if the TCAS RA would lead to a follow-on conflict with a non-Transponder equipped A/C. In such conditions, the avoidance logic must not execute the TCAS RA (because the non-Transponder equipped A/C would be endangered) nor act against it (because of the conflict with the Transponder equipped A/C that originally triggered the RA). A reasonable solution would be to avoid laterally or to stay at level.

Figure 9 illustrates the time budget of the sub functions in the overall S&A process. The major contribution is caused by the execution of the avoidance manoeuvre itself, with approx. 30s duration for a turn manoeuvre (bank angle limited to 15deg, conservative approach) and approx. 27s for a TCAS II compliant climb manoeuvre (0.25g, 1500ft/min).

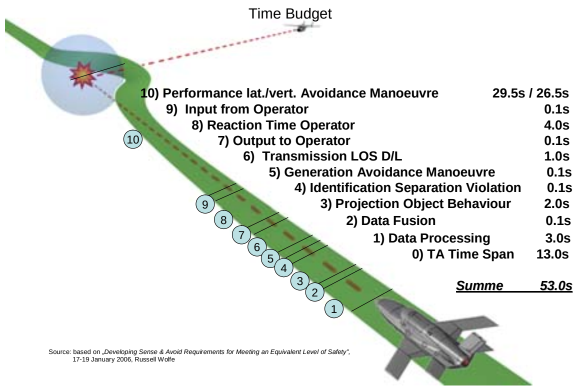

Figure 9: S&A Time Budget

The time budget might be split in three parts.

The UAV operator must be given sufficient time in advance to get aware of the potential conflict and to avoid conflicting traffic using standard means of piloting an UAV before the conflict becomes an emergency situation. This time span (element 0) corresponds with the time span between the issue of a traffic advisory (TA) and the issue of a resolution advisory (RA) in TCAS II.

Part 2 (elements 1 – 9) contains all elements necessary to inform the UAV operator of the conflict, to suggest a resolution advisory and to wait for the authorisation of the RA by the operator.

Part 3 (element 10) consists of the time needed for the execution of the avoidance manoeuvre until achievement of separation.

Data Acquisition

Figure 10 illustrates the conflict geometry applicable to a Sense & Avoid system. The future behaviour of both A/C is defined by their velocity vectors. In case of a crash, the objects will approach each other using the "collision angle" defined below. In contrast, the angle relevant to the "Sense" system is the "viewing angle". This angle defines the angle, under which the conflicting traffic can be seen by the UAV relative to the A/C X-axis and corresponds to the native coordinate system of the "Sense" components. The range vector defines the current separation to the object and can be used to derive the closing speed between the two objects.

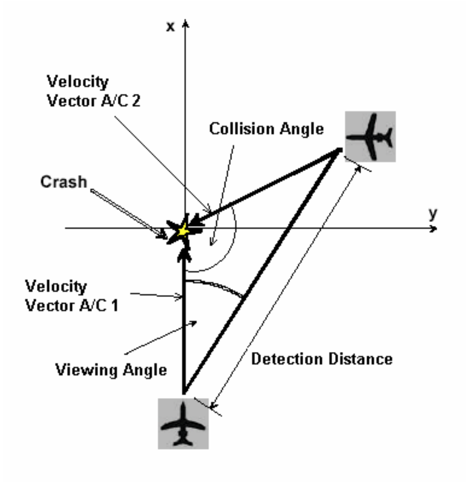

Figure 10: Conflict Geometry and Viewing Angle

For the Field of View, a requirement for the azimuth range has been defined in ICAO Annex 2 to be at least ±110°. Although this requirement was originally stated for manned A/C, it has been found sufficient for UAVs as well.

For the elevation, no requirement has been defined by certification authorities. However, a value of ±10° has been found sufficient for manned A/C. Again, this value will be used for UAVs as well with a design objective of ±15°.

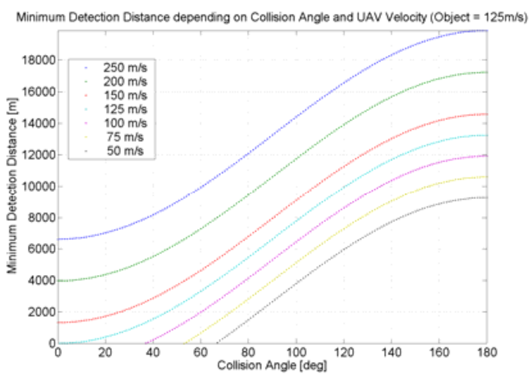

Figure 11: Minimum Detection Distance

Figure 11 illustrates the required minimum detection range for a sensor to achieve the time budget defined above depending on collision angle. The picture has been generated for an assumed object ground speed of 125m/s (maximum allowed under VFR). The speed of the UAV itself has been varied between 50m/s and 250m/s (exception for state A/C), field-of-view restrictions have been neglected.

The small collision angles on the left hand side correspond to situations, where the UAV is overtaken by another object (UAV speed < object speed) or where the UAV is overtaking another object (UAV speed > object speed). The conditions on the right hand side correspond to a head-to-head conflict, in which the closing speeds between both A/C reach their maximum values.

As expected, the required detection range is defined by the head-to-head conflict with a collision angle of 180°. Under this condition, the closing speed between both objects will maximize. The required detection distance of approx. 20km can be found easily by multiplying the worst-case closing speed with the required time budget of 53s.

Data Fusion

The availability of redundant sensor measurements (TCAS II transponder fixes and non-cooperative sensor measurements) leads to the need to consolidate the different fixes. The result will be more reliable object data that will allow a reduction of false alarm rate and an improvement of collision avoidance reliability. However, it should be noted that the TCAS will only observe transponder equipped A/C, hence a consolidation of non-cooperative A/C will not be possible without further sensor information. Figure 12 illustrates the different observation volumes for TCAS and non-cooperative sensor.

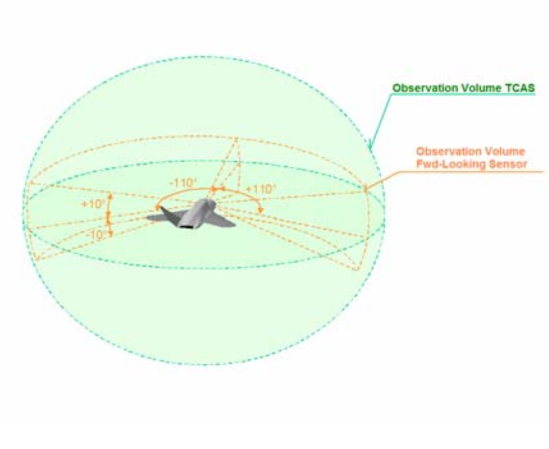

Figure 12: Observation Volume and Consolidation

Estimation of Object Behaviour

There are two methods to estimate the object behaviour, which have been assessed. This first method is called “nominal method”. It is based on the assumption that the object will continue its current behaviour in future. Due to its simple principle, this method is easier to implement. The fact that the vast majority of objects indeed act according to this behaviour model resulted in the implementation of this model in the TCAS system. However, this approach will require further measures to account for objects with rapidly changing behaviour, as might be experienced for instance with circling gliders.

Another method would be to allocate a safe volume around each identified object and to scale this volume depending on the dynamic capabilities of the object and the remaining time. This would mean that the safe volume covers all positions the object could reach within the remaining time span, even when considering worst-case aggressive behaviour (i.e. ramming attacks). This means that the worst-case method is inherently safe. Unfortunately, common objects do not behave this way. As a consequence, the worst-case method would result in an increased amount of false alarms.
Since the size of the observation volume depends on object agility, this approach would also require the classification of the object into a category (i.e. balloon, glider, fighter A/C, etc.). This in turn would lead to an increase in the required detection accuracy.

As a consequence, the nominal method has been chosen to estimate the object behaviour. The implementation of the method and the measures to account for rapid changes in object behaviour will be defined in the next chapter.

Identification of Separation Violation

With the preposition that a UAV has to be equipped with TCAS II, it is assumed that the overall S&A system functions have to refer and to be compatible with the existing ACAS Standard.

This leads to the application of the TCAS method to classify separation violations as illustrated in Figure 13. A conflict can escalate into 3 categories:

- "Traffic Advisory" (TA) category

If an object enters this outermost category, a traffic advisory will be given to the UAV operator. The aim of this TA category is to allow the UAV operator to identify and to perform suitable measures to prevent a further escalation of the conflict.

- "Resolution Advisory" (RA) category

An object entering this middle category will trigger the generation and the issue of an avoidance manoeuvre to avoid the conflicting traffic. The selected avoidance manoeuvre will be transmitted to the UAV operator for authorisation and will be executed once the authorisation is received by the onboard system.

- "Autonomous Avoidance" (AA) category

If an object enters this innermost category without the authorisation by the UAV operator to execute an avoidance action, the selected avoidance manoeuvre is executed autonomously to prevent a mid air collision. This category shall be used in case of data-link loss or latency and is considered a fallback category.

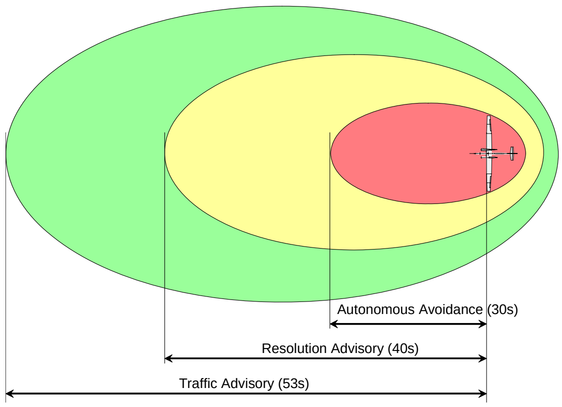

Figure 13: Classification of Separation Violation

The associated time values correspond to the “time-to-closest-approach” as known from the TCAS system.

The identification of a separation violation is accomplished using a range test and an altitude test.

For the range test, the estimated time to closest approach of the objects is derived using Equation 1.

$$t_a = \frac{\left(r^2 - m_a{}^2\right)}{-r \cdot \dot{r}} \qquad (1)$$

with: r - consolidated range

	m_a	- lateral dist. to closest approach
	t_a	- time to closest approach

It has to be further investigated, if this equation might be used for accelerated movement of objects as well or if further measures have to be identified. In order to account for slowly approaching objects, a second range test is performed to ensure that no object penetrates a safety volume around the own A/C laterally. The estimated lateral distance to closest approach is derived using Equation 2.

$$m_a = \sqrt{\left(r^2 - \frac{r^2}{1 + \frac{r \cdot \ddot{r}}{\dot{r}^2}} \right)} \qquad (2)$$

In addition to the range test, an altitude test is performed as well. Equation 3 defines the estimated time to co-altitude of the conflicting objects.

$$t_v = -\operatorname{sgn}(a) \frac{a}{\dot{a}} \qquad (3)$$

with:	t_v	- time to co-altitude
	a	- consolidated altitude separation
	v_m	- minimum vertical distance

As with the range test, a further geometric test has been implemented to ensure that slowly approaching objects will not penetrate the safe volume around the own A/C. Equation 4 defines the estimated minimum vertical distance between the objects.

$$v_m = a + \dot{a} \cdot t_a \qquad (4)$$

A separation violation is identified, when the following criteria are fulfilled:

- t_a < Lateral Time Threshold
- m_a < Lateral Range Threshold
- $\dot{r}$ < 0 and v_m < Altitude Range Threshold
- $\dot{r}$ < 0, t_v < Lateral Time Threshold and t_v < Altitude Time Threshold

The values for the lateral and vertical thresholds (both time and range) are scheduled depending on conflict category („Traffic Advisory“, „Resolution Advisory“, „Autonomous Avoidance“). Furthermore, these thresholds have to be adapted according to

- The UAV performance data to ensure the required avoidance capability
- The aspect that a lateral avoidance will change the relative speed between UAV and conflicting object
- The consideration of additional time rates required for the data transfer in remote guidance.

Another aspect to be considered is the occurrence of multiple collision conflicts. For this purpose a prioritisation of the potential collision objects has to be performed with respect to the predicted shortest time of encounter. Therefore all potential threats must be taken into account within a time frame. Otherwise a purely sequential solution of the conflicts can lead to tightening a particular conflict.

Generation of Avoidance Manoeuvre

The aim of the Sense & Avoid system is to provide sufficient separation to other airspace users. This is assured, if a minimum separation of 500ft vertically or 0.5 NM laterally [2] can be guaranteed at all times.

The various traffic conflicts can be grouped into 4 categories:

- conflict with a single TCAS equipped A/C

Since the UAV has to be equipped with TCAS II, a TCAS RA has to be followed by the UAV. TCAS II separation minima shall be achieved.

- conflict with a single non-transponder equipped A/C

In this conflict, the UAV has to avoid the object with the option to perform a vertical avoidance manoeuvre according to the TCAS II standard or a lateral manoeuvre compliant with the right-of-way rules.

- conflict with multiple non-transponder equipped A/C

According to the priority of the potential conflicting objects an avoidance manoeuvre in both vertical and lateral direction has to be calculated. For this purpose a 3D avoidance space will be spanned which has to be cut down to reasonable areas by using a heuristical approach considering the current flight phase/flight state of the UAV, its worst case dynamic performance and the conformity to the right-of-way rules. The computation of a band of 3D-avoidance trajectories fitting with the available avoidance area are generated in a stepwise process. First vertical manoeuvres using TCAS II algorithms are calculated. In a second step vertical trajectories will be superimposed by lateral manoeuvres which will be parameterized via required heading changes with maximum bank and roll rate. From the available avoidance manoeuvre candidates, this trajectory manoeuvre will be selected, which provides the highest safety distance to the surrounding objects and the minimal deviation from the original flight path.

- conflict with multiple objects (TCAS equipped A/C + non-transponder equipped A/C)

In case of availability of a TCAS RA, the avoidance logic has to incorporate this partial solution within the computation of the overall solution space as described in the previous way.

This will ensure that the generated avoidance manoeuvre is not in contradiction with the TCAS II logic which is an essential step, because the TCAS equipped platform might not be aware of the non-transponder equipped A/C at all.

Performance of Avoidance Manoeuvre

In the following some general considerations concerning the computation of lateral and vertical avoidance and its underlying flight dynamics are given.

Figure 14 illustrates the ground track of lateral avoidance manoeuvres depending on bank angle. A local-geodetic coordinate system has been used to assess the time duration to achieve separation.

The upright axis labelled "X" points towards the conflicting object, here in an assumed frontal conflict. The orthogonal axis labelled "Y" shows the direction, in which the A/C has to turn in order to avoid the conflict. The red line is the separation, which has to be passed rightwards to continue the flight safely.

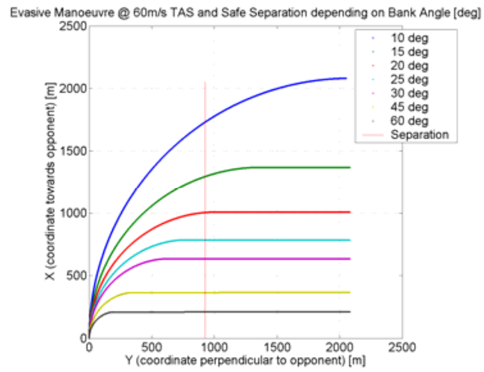

Figure 14: Lateral Avoidance Manoeuvre

It should be noted that for the lateral avoidance manoeuvre, the time to achievement of separation is almost independent on turn radius and on TAS. The main dependency is the bank angle used to perform the turn manoeuvre. Unfortunately, the bank angle is a critical value when the availability of LOS data link connection is important. Hence, a bank angle of 15° has been used to identify the time needed to achieve separation.

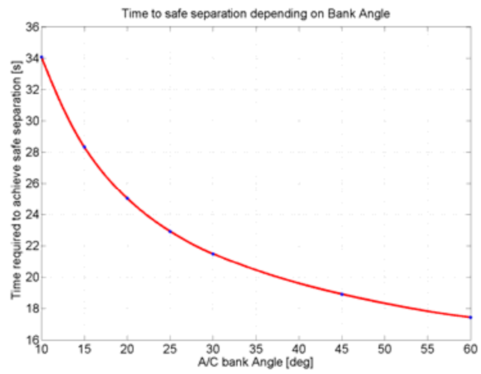

Figure 15: Time required for Lateral Avoidance Manoeuvre

Similarly, the time to separation has been assessed for a vertical avoidance manoeuvre (climb or descend). Since such a manoeuvre can be commanded by the TCAS, a TCAS II compliant climb manoeuvre (0.25g, 1500ft/min, [3]) has been assessed.

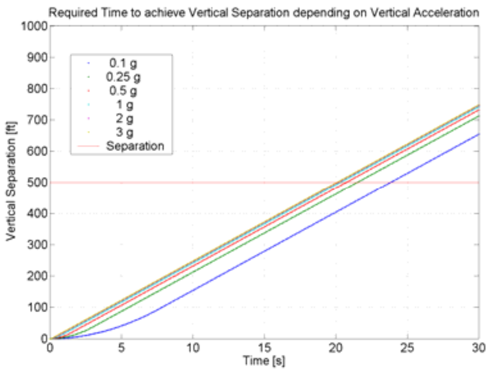

Figure 16: TCAS II compliant Vertical Avoidance Manoeuvre

It becomes obvious, that the time to separation is limited by the vertical climb rate. An increase of the vertical acceleration would not necessarily improve the time duration any further.

Resume

This paper defines preliminary functional and technical requirements for the development of a Sense & Avoid system applicable for UAVs. These requirements form a baseline for the development of an experimental "Sense & Avoid" system with limited capabilities to assess the identified critical system functions.

With the experience gained during the upcoming simulation and flight test campaigns, the currently available requirements will be critically re-assessed and re-worked where necessary.

This re-assessment shall take into account the results of the demonstration campaigns as well as the on-going development of the certification regulations for S&A systems.

At the end of Wasla/HALE phase 3 the re-worked requirements shall allow to design a UAV S&A system minimising the risk for mid-air collisions to a level equal or less high than for manned aircrafts.

References

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