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# Integration and Evaluation of the Impact of Space Vehicle Operations in the European ATM

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## Abstract

Space flight activities are becoming an eminent part of flight operations in the world today. Launch and re-entry operations are expected to grow beyond state use and research purposes into a commercial space transportation business. That creates an evident need to integrate space vehicle operations into the existing air traffic management system in a safe and efficient way. The German Aerospace Center has already conducted studies which cover the operational effects of space vehicle operations on air traffic and integration of the SpaceLiner return trajectory towards a European landing site. The next level of investigations include the horizontal launch of space vehicles in the segregated and congested European airspace, assessment of the effects expressed over closure of the affected airspaces and the potential delays induced by this type of operation. Thus, we present preliminary results of our analysis in this paper, including the methodology and modeling approach used to conduct this study.

**Keywords:** *space vehicle operations, fast-time simulation, air traffic management, space traffic management*

## 1. Introduction

There is an upcoming demand for a strong and constructive cooperation between the Space Traffic Management (STM) and the Air Traffic Management (ATM) for a safe and efficient integration of space vehicle operations within regular air traffic operations. The number of launches is increasing in parallel to the increment of air traffic on a global level. Thus, there is a need of developing clear rules, agreed by all stakeholders, in order to accommodate the requirements of users in traditional airspaces, as well as space-bound vehicles travelling to and from space [5]. Here, the main accent is set on the need of new contingency planning which will include nominal and non-nominal launch and re-entry events along the whole flight track of the vehicle on its way to or from orbit, as it may cause risks for conventional airspace users, such as falling debris or space vehicle malfunctions.

Current research in the field of flight and airport operations addresses economic, operational and ecological efficiency [13, 14, 15, 19]. The propagation of delay in the air traffic network is paramount when assessing the impact of congested airspace and airports [16] [17]. This is particularly critical when estimating the resilience of the Air Traffic Management (ATM) system and the impact of different mechanisms on the expected performances variations [18]. Dynamic traffic situations emerge from traffic flow patterns across Europe and to-from intercontinental flows, military operations [20], volcanic ash eruptions [4], zones of convective weather [21], prevention of contrails [22], consideration of commercial space operations [9] and integration of new entrants [23]. Current research also considers passengers metrics as trade-offs between optimisation of flight performances might not be aligned with passengers experience.

The past space vehicle integration studies performed by German Aerospace Center (DLR) have integrated a mostly conservative approach of space vehicle operations in Europe due to the complex and saturated airspace structure. This integration study focused on the influence that a specific space

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vehicle operation (re-entry operation of a reusable hypersonic transport vehicle with a landing at a spaceport located in northern Germany) might have on the airspaces alongside the restricted areas, especially during the peak hours in the European ATM and under consideration of its current operational constraints [2]. The results have shown that using a conservative approach where the aircraft hazard areas (portion of the airspace where the space vehicle trajectory passes) are active for around 60 minutes during a peak hour in the European ATM, will cause an interaction with a large portion of flights. The effect was specifically amplified by the landing site for the space vehicle which is located in the vicinity of major European airports. To contrast this previous study, the focus in a second study was shifted towards launch operation for space vehicles using an air launch concept. The launch hazard areas as well as the first stage return hazard area will not be located in a saturated airspace and so we expect that the negative effect on the ATM system will be much smaller. Those areas are considered to be fully restricted with regard to other airspace users during the considered launch window. A less conservative approach with dynamic opening of the hazard areas is introduced as an alternative and has as well been evaluated in the simulations for this study.

## 2. Background

As mentioned earlier, space flight activities are growing on an international level, thereby creating an evident need for a safe and efficient integration of space vehicle operations into the air traffic system. For concepts like very high – speed intercontinental passenger transport via suborbital point -2 – point flights, as it is proposed by the DLR SpaceLiner, this integration issue is becoming especially relevant. As it can be seen on the graph below (Figure 1), the international drivers of commercial launch activities are USA (space x alone had 18 launches in 2017). USA has doubled their number of commercial launches from 2016 to 2017. Europe on the other side has slightly increased number of launches, but that might significantly change in future. Why is this so important? According to ICAO [6], under the Chicago Convention, each State has complete and exclusive sovereignty over the airspace above its territory. That being said, Europe has around 51 independent states, out of which 41 Member States of Eurocontrol and approximately 63 Are Control Centres (ACC). The daily operations in the European airspace vary around 30000 to 35000 flights. In comparison with the US, where there is only one national service provider and one regulator with approximately 22 ACCs, in Europe the situation looks more complicated. Each of the European countries has their own national regulators. With around 63 ACCs it creates pretty unharmonized airspace.

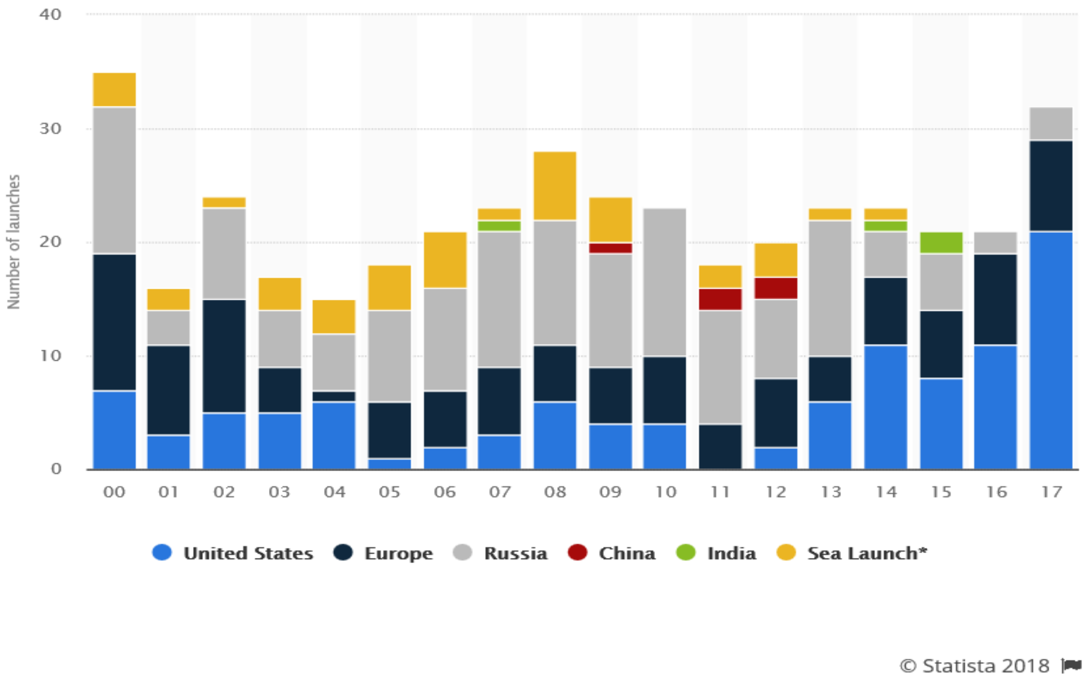


**Figure 1** Commercial space launches conducted by selected countries or regions from 2000 to 2017

 

According to the network manager at Eurocontrol [12], the number of additional movements per day for each European State in 2024 will increase significantly compared to 2017. Western Europe will have the greatest number of extra flights per day (above 1000). The following two case studies will attempt to assess the impact of the launch of spacecraft on European aviation and how many flights could potentially be affected.

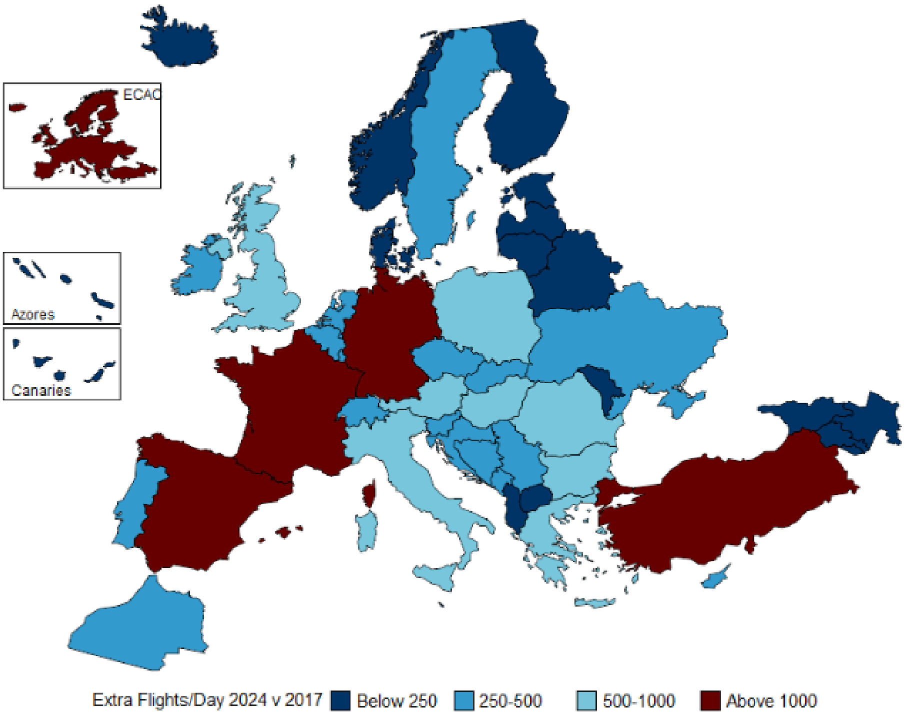


**Figure 2** Number of additional movements per day for each state, 2024 vs. 2017 (Source: Eurocontrol – Flight Movements and Service Units)

The first use case analyses the air traffic impact for a suborbital point-to point passenger transport concept involving the DLR SpaceLiner. The second use case focuses on investigations of the effects of air launch operations in a European air traffic scenario. It uses historic data based on the operations of PEGASUS XL as an example of such a category of launch vehicles. The objectives of the both use cases are to:

- Analyze the impact of Commercial Space Transportation (CST) from, to or within Europe on the air traffic system
- Evaluate concepts to minimize this impact, considering more frequent SV operation

The research questions that we tried to answer within this paper are the following:

- What kind of influence do space vehicle operations have on the airspaces alongside the restricted areas especially during peak hours in the European ATM?
- Is it possible to integrate SV operations in the current ATM?
- What kind of impact does the space flight activity have on the surrounding flights?
- How much the flight duration increase for the affected flights?

## 3. Methodology

For the purpose of modeling, simulation and analysis of air transportation concepts DLR uses model-based (fast-time) simulation tools. The simulation tool used in these studies is AirTOp, which is capable of performing gate to gate simulation of air traffic, including en-route traffic and ATC

 

modelling, 4D trajectories and air traffic flow management. AirTOp provides an open, modular and extensible environment, which allows implementing hazard areas for space vehicle air launches, as well as the hazard areas for falling debris from a spacecraft.
Although there are many other ways to perform and evaluate ATM studies and answer the above defined research questions, fast-time simulations are often used as a first and reasonable approach to cover relevant operational restrictions in the complex ATM system [4]. In particular, we want to measure the effects, which come along with different airspace modifications or integration of new entrants and how these may influence the traffic flow and capacity of the airspace. Thus, a reference scenario is defined at the beginning, which correctly or as close as possible reproduces the status-quo situation in the area of interest. Afterwards, specific traffic scenarios are simulated and modified according to the research question, in this case including the hazard areas of air launch and falling debris area. Comparing the outputs of these scenarios with the reference scenario, the impact of the changes could be assessed and will be part of detailed investigations (e.g. sensitivity analyses). The traffic scenario covers 24 hours of air traffic operations in Europe. The main evaluation day chosen for the first use case is a historical data for 30$^{th}$ of March 2015. It represents a typical day during a work week with around 25,000 flights. The second use case study includes air traffic data for 1$^{st}$ of July 2016 with around 36,000 flights. The corresponding airspace model used in the simulations is generated for the same simulation day including different sector volumes and various types of ATC sectors with the original structure, opening times and traffic volumes for that day. The airspace and traffic data is received from EUROCONTROLs Demand Data Repository (DDR2) and is used for research purposes only.

### 3.1. Applied Airspace Model

The airspace model is generated according to the chosen scenario of the respective day. It has been extracted from EUROCONTROL`s Demand Data Repository (DDR2). The airspace model is depicted in Figure 3. It contains around 6000 individual sector volumes depending on the day and airspace configuration. It contains two types of ATC sectors: collapse sectors and elementary sectors. Collapse sectors may tactically be split vertically or laterally. It is rather important to generate a most realistic airspace representation of capacitated sector volumes. This model also contains elementary sectors representing smallest capacity airspace volumes.

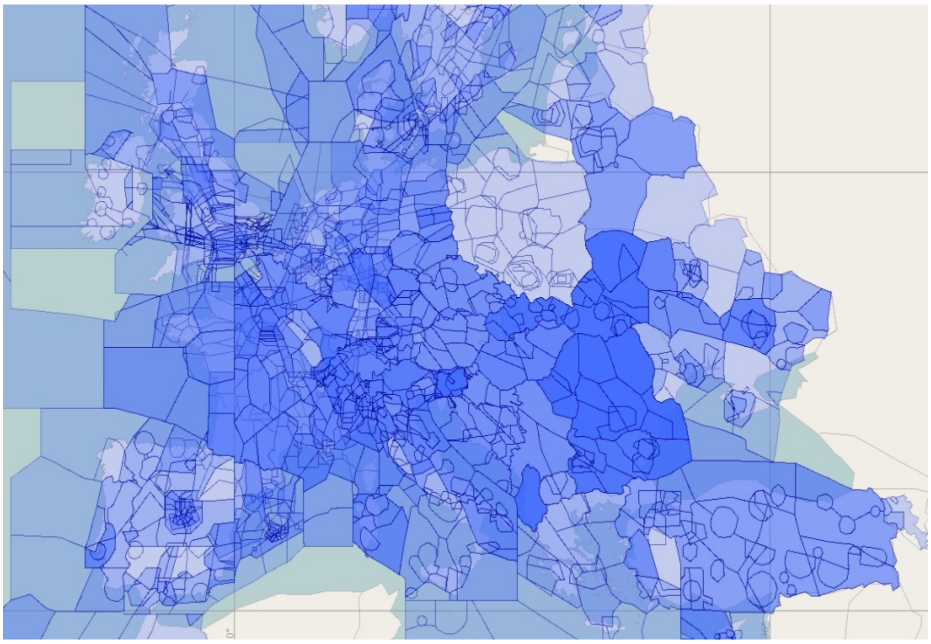

**Figure 3** Represenatation of the European airspace in AirTOp

### 3.2. Use Case Studies

For the purpose of this paper, two use cases have been developed. The first case deals with a study involving the integration of the SpaceLiner activities in the European airspace and the second use case study deals with the air launch activities in the Northern European airspace. A detailed description of both of the studies is presented below.

### 3.2.1. First Use Case: DLR SpaceLiner

The SpaceLiner has been developed by the Space Launcher Systems Analysis (SART) group of DLR and represents a very specific subset of space vehicle (SV) operation [1]. Its basic idea is to enable sustainable low-cost space transportation to orbit while at the same time revolutionizing ultra-long distance travel between different points on Earth. It is designed as rocket – propelled, two staged suborbital Reusable Launch vehicle (RLV), which can service ultra-long-haul distances like Europe-Australia in 90 minutes. Intercontinental destinations between Europe and North-West America could be reduced to flight times of slightly more than one hour. The general baseline design concept of the SpaceLiner consists of a fully reusable booster and passenger stage arranged in parallel. As described, the propelled flight phase is followed by hypersonic gliding, through which the vehicle would travel more than 1000 km almost outside of the atmosphere at very low drag. The orbiter will approach its destination entering controlled airspace at an approx. distance of 70km / 37NM with its speed below FL600 being already less then Mach 3 and will decelerate further below Mach 1 down to an altitude of approx. 36.000ft or FL360 [3]. The ambitious west-bound Australia – Europe mission (up to 17000 km) has been used as the reference case. During all phases of the spaceflight through or close above controlled airspace, separation between aircraft and the space vehicle, including its potential hazard areas in case of malfunctions, have to be assured. Most of the launch and re-entry flight trajectories require only relatively small size of restricted airspace surrounding the launch- and landing sites to remain clear of the space vehicle. Those kinds of restrictions have to be in place over the duration of the launch or re-entry operational window and cover a vertical area from the surface to an unlimited altitude. A yet much larger portion of air-space has to be managed regarding the risk of non-nominal events. This can be falling debris from an in-flight explosion or a breakup event. The debris fragments can cover a relatively large area, its size being dependent on the velocity and altitude of the vehicle during its disintegration [2].

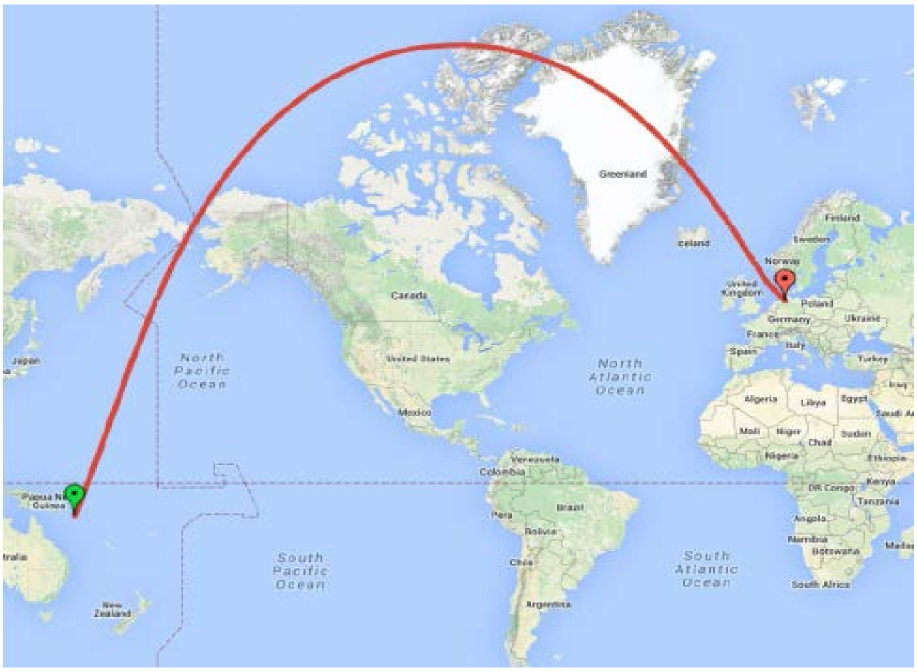


**Figure 4** West bound Australia – Europe mission trajectory

As a result, Hazard Areas have been introduced to extend the area protecting surrounding aircraft beyond the pure space vehicle separation area or operating zone. Their size is calculated by a debris dispersion prediction against an acceptable risk threshold (which is related to public safety standards). A hazard areas lateral extension is accordingly determined, using a fragmentation model specific to the individual space vehicle. The vertical extension of the hazard area typically reaches from ground to FL600 (and beyond) throughout regular airspace. The top ceiling might be reduced, e.g. for a reentering space vehicle when it already has reached lower altitudes. Hazard areas are also limited in time, which means that they are active at the actual position of the space vehicle on its trajectory, while they have to be as well considered for air traffic planning and control significantly before the actual flight event. The effective period of a given Hazard Area extends from the time that the first fragment of hazardous debris will enter the Area, to the time that the last fragment of hazardous debris will exit the bottom of it. To ensure the safety of airspace users during space vehicle operation, airspace restrictions have to be put in place. As size and duration of the hazard area is significant for the effect of space vehicle operation on the air traffic, their impact has to be determined carefully. It will be directly related to the applied operational concept for space and air traffic integration, which defines for example the activation / cancelation of hazard areas and if a hazard area gets closed for other aircraft or remains open with measures for timely evacuation in place. The following analysis will consider the interaction of air traffic with those hazard areas for the selected SpaceLiner use case [4].

**Figure 5** Landing trajectory of the SpaceLiner to the Nordholz airport (left) and SpaceLiner model (right)

### 3.2.2. Second Use Case: Air Launch

The second use case, which slightly differs from the first one not only with the concept of the aircraft, but also the launch concept, will be described in this section. This use case focuses on the effects of Air Launch Operations on a European air traffic scenario [10]. The starting point is the commercialization of space travel where the cost of transporting people and payload could be significantly reduced. The dynamics of this process is reflected in a rapidly growing number of commercial launches, as shown in the introduction part. All this leads to the need for new concepts for the launch and landing locations of spacecraft, new mission profiles and concepts for the increased demand in this type of operations. An air launch is a method of delivering a payload by rocket from the air into space. Typically, air launch rockets are able to deliver payloads of up to 500 kg into low earth orbit (LEO). What is special with this type of method is that the rocket launches are carried out horizontally from a carrier aircraft. The advantages of this type of launch operation are its flexible launch position (in the air) and reduced launch related requirements at the spaceport – the airport used to prepare carrier aircraft and launch vehicle before its flight. Air launch operations provide a rather high flexibility and independence from specifically installed ground infrastructures. In the context of this work an air launch of a Pegasus XL rocket from a carrier aircraft will be used to represent a realistic example of such an operational type. In the use case scenario, the carrier aircraft departs from a potential spaceport at Nordholz. Historical data from a Pegasus launch of the IRIS research satellite on June 28$^{th}$, 2013 over the Pacific Ocean off the coast of California has been used. The launch targeted a sun-synchronous orbit with an inclination of 97.8°. This orbit has a high relevance for this use case because it represents a very high commercial demand, e.g. for satellite constellation and remote sensing missions. We here examined how the implementation of such a launch within the European airspace and the associated airspace restrictions affect the surrounding air traffic.

For the creation of the restricted airspace, historical flight restriction areas are used as a reference [5]. The data has been acquired from a published NOTAM from the named Pegasus ISIS launch. The launch corridor is mirrored from the US Pacific Ocean (Figure 6 left-hand side) to the North Sea (Figure 6 middle). The location in Europe is very attractive because it is close to the production of potential payload, from satellite manufacturers in the northern part of Germany, which saves time and money for transport. Launch in the polar orbit from Europe is relatively easy to implement, considering a launch corridor over large inhabited areas in north-south direction, e.g. the North Sea. Figure 6 on the left shows the historic flight restriction areas associated with the launch of ISIS (black rimmed areas). The two red outlined areas are the flight restriction zones for the data received from the NOTAM. The northernmost of the four areas is the drop launch area of the rocket. The start runs in the southern direction. The next two areas are reserved for the first stage burnout and second stage burnout, which fall back into the sea.

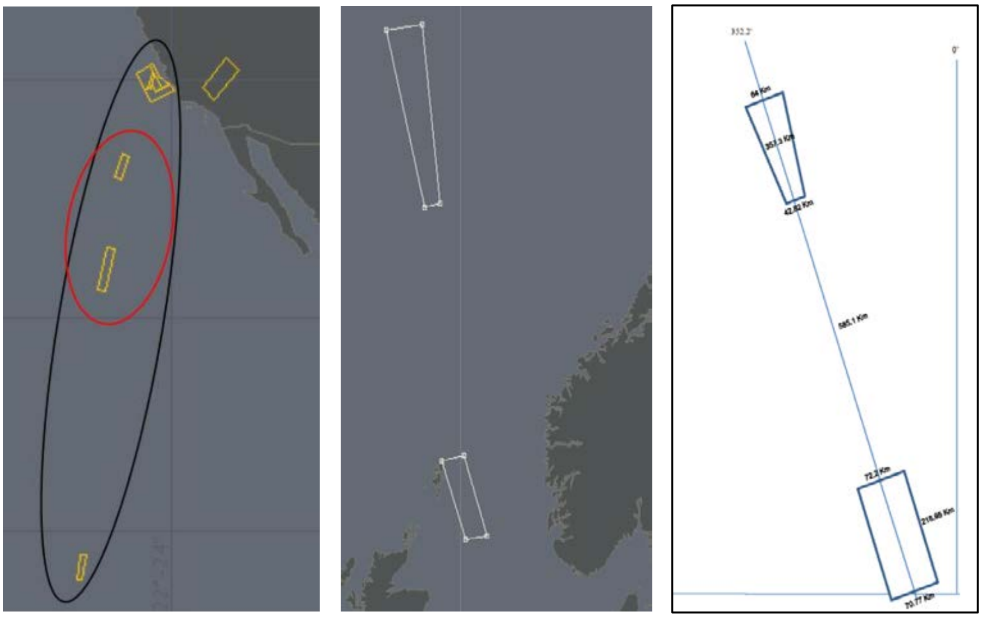

**Figure 6** Air launch polygons – US Pacific Ocean (left), North Sea (middle), Mirroring the baring angle (right)

As it was already described in our case study, a military area near the departure airport exists. Since this is already considered to be a temporary restricted airspace, there are no other restrictions to be applied on the airspace. Also the fourth restricted area from the example is not further investigated in our use case because it does not belong to European airspace. So the main two polygons where the stage burnout and drop takes place are considered and calculated.

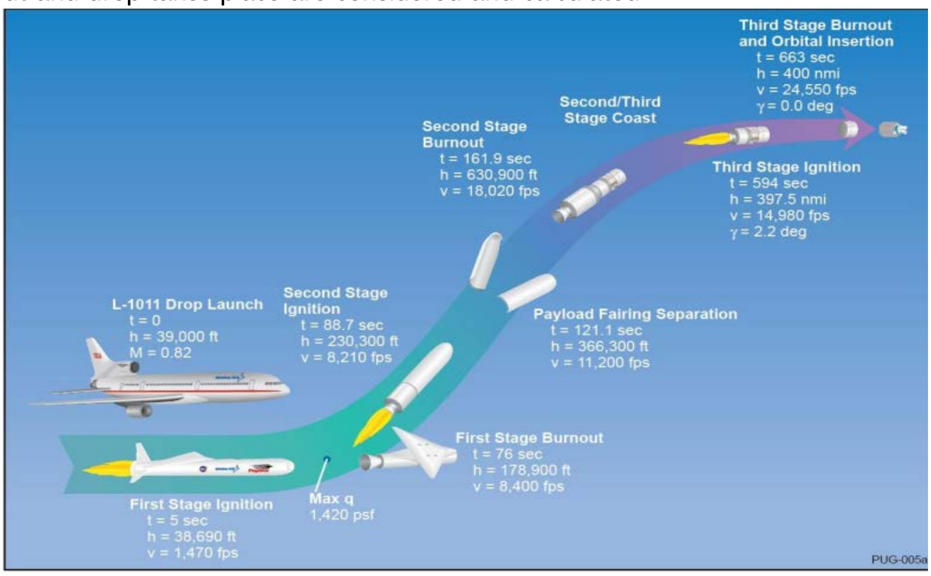


**Figure 7** Phases of the rocket launch of Pegasus XL (Source: Northrop Grumman)

 

The simulation for this case study consist of three scenarios: baseline scenario which represents the status quo situation in the air, scenario two with air launch polygons active during minimum air traffic movements and scenario three, where the air launch polygons are active during peak hours. On Figure 7, the phases of the rocket launch of Pegasus Xl are depicted. The used air launch polygons are based on this flight profile.

## 4. Results

The results in the first use case study have shown a large number of flights affected by the landing of the space vehicle on European landing site [2]. This was mainly due to the conservative assumptions and limitations in the operational scenarios. Therefore, the cautious approach of simulating the space vehicle trajectory with the hazard areas activated for a relatively long period of time. In the second use case, the hazard areas or air launch polygons have been opened according to the air launch operation activities.

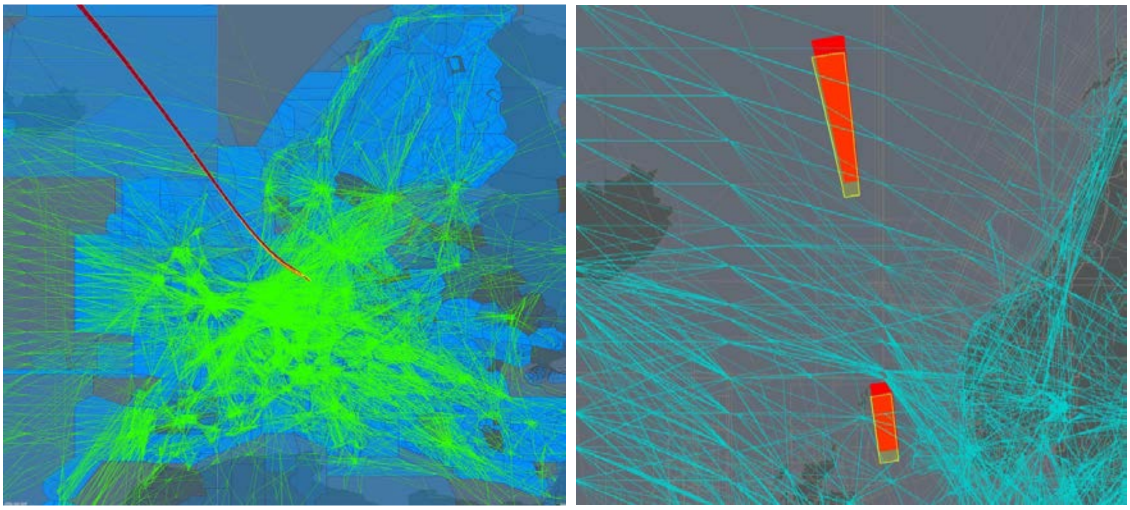

**Figure 8** Screenshot of the landing space vehicle trajectory in the European airspace (left) and space vehicle air launch integration in the European airspace (right)

### 4.1. First Use Case Results

This graph represents the number of aircraft that have entered the hazard areas during the rolling hour of the simulation for all 3 scenarios. The peak hours of traffic are also in the morning between 08:45 until 09:45 and for the afternoon they spread in the period between 15:00 and 16:00. This is a good indicator for planning the start and landing times of the space vehicle in the European ATM. The avoidance of peak hours of traffic for the scheduled flights will result in less possible encounters with the hazard areas and less flights that might be affected during a space vehicle operation in the European ATM. The considerations at this point have been limited to the analysis of only the entry number of aircraft. Similar results were received also for the other investigated parameters which corresponds to the fact that the chosen SpaceLiner trajectory and its related hazard areas are interacting with routes connecting several hub airports in Europe. They are also in a close vicinity to the entry and exit points of the North Atlantic traffic. The numbers obtained from the simulation helps to further develop and plan follow up research on SpaceLiner flight route planning and measures minimizing its interaction with other airspace users. After conducting this initial study, several fast time simulations with different historic traffic samples have been performed, leading to an overview of the possibility of integration of these type of operations. It has to be mentioned that the use cases of the simulation scenarios have a relatively conservative approach. The hazard areas are assumed to be active during the complete timeframe of the SpaceLiner flying through European airspace plus an additional 30 minutes of buffer time, meaning a large portion of European airspace has been "affected" for about 60 minutes. The amount of traffic that has an encounter with the hazard areas during this time is relatively large and it varies between 350 and 400 aircraft for the peak hour operations.

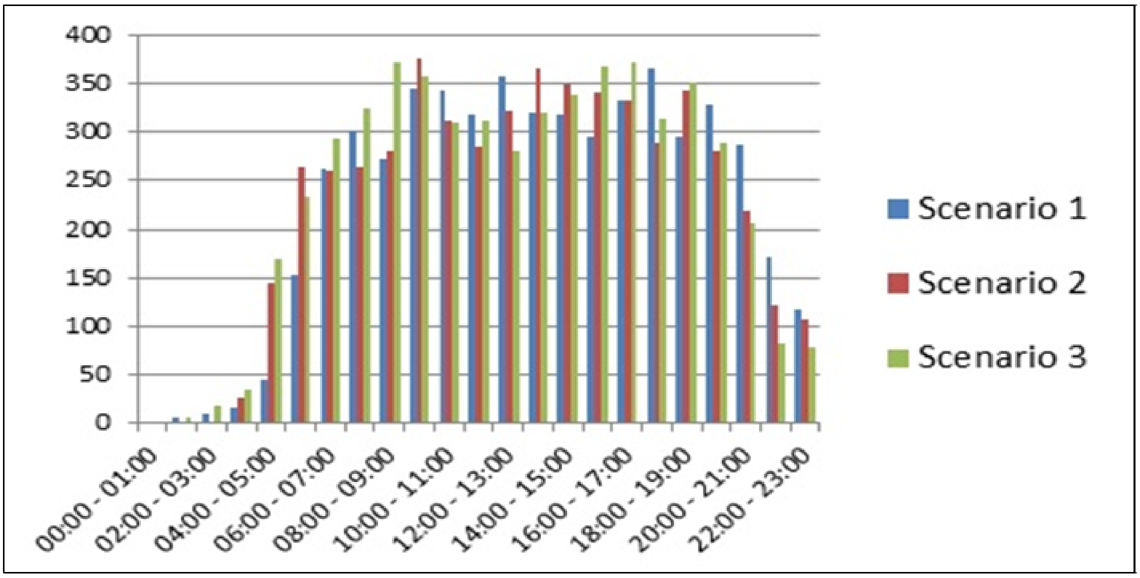


**Figure 9** Entry counts in the hazard areas for all three scenarios

The implications on the affected flights which have been identified to pass through the calculated hazard areas now depend on the way these hazard areas are handled. When considering a high risk scenario, like for first test flights of a new vehicle, a complete closure of the hazard areas could be an option. The amount of affected flights then equals the numbers described above in chapter 4.3. This approach would be comparable with the measures first considered during the Space Shuttle return to flight procedures, for which a pre-emptively closure of an airspace corridor of a width of 20 to 50 miles below the re-entry trajectory for a duration of 35 to 60 minutes was first suggested [10]. It would mean that the already complex and saturated European airspace has to cope with reduced flight efficiency because of the rerouting of the affected flights. That also would affect the flying time of the aircraft, as well as the fuel burned (which have not yet been determined but can be accessed using the same simulation setup which has been used within this initial study). For the ATC capacity of the surrounding airspaces in the vicinity of the hazard area, the rerouting would result in an increased number of flights and potential conflicts that need to be resolved, as well as significant increment of the controller workload for the affected airspaces. With such expected massive effects on the European air traffic system, this approach does not seem to be realistic. Adopting the general approach to keep the airspace of hazard areas open for aircrafts passing below the space vehicle, while implementing procedures to ensure timely evacuation of aircrafts from those areas in case of a mishap, the effects on the air traffic system should be significantly limited. Assuming for example a closure of only the hazard areas within the final part of the SpaceLiner approach, at which the orbiter is flying through controlled airspace below FL600, the maximum number of directly affected flights in the chosen use case scenarios will drop significantly. This for still following a conservative approach of activating hazard areas and flight restriction areas not only during the direct passing of the SpaceLiner, which lasts approx. 8 minutes but for an amount of 45 minutes, taking into account launch time uncertainties and time buffers for activating and deactivating these regions. It has to be considered though, that the vast amount of aircraft trajectories crossing the SpaceLiner trajectory and passing through its hazard areas are located towards the later phases of flight close to the space port (see Figure 11).

In total, the results of this first set of fast-time simulation use cases give an overview on the current ATM performance and the possibility for integrating SpaceLiner operations in it. To reduce the described effects, a more advanced concept needs to be considered and one of those concepts includes dynamic hazard areas. This concept proposes that the portions of hazard areas will be activated and deactivated with the movement of the SpaceLiner along its trajectory, which means that each hazard area will be only active for several minutes. This would prevent the closure of large amounts of ATC sectors as well as closure of airport operations in the vicinity of the SpaceLiner trajectory. Another approach is to optimize the shapes and volumes of hazard areas, along with their dynamic activation, to further limit the necessary interaction with the adjacent air traffic. There have already been several studies performed [7][8], which results will be taken into account for future work.

### 4.2. Second Use Case Results

The simulation of the base scenario with 36,097 flights over 24 hours and active polygons, provides around 68 flights that would have a potential conflict with the polygons. The entire daily operation is divided then in time frames of 60 minutes (duration of the potential closure of restricted flight areas). These times frames are spaced apart in 10 minutes intervals, adding up the number of flights that would fly through the restricted areas within those frames. The maximum total occupancy within the two polygons is 17 flights. This period with the highest traffic within the polygons is from 11: 50-12: 50. In contrast, the results also show several hours with no or only little traffic flows through the polygons during the observation period. In particular, periods of daylight are of importance, as good visibility conditions most likely will be required when performing the launch. Therefore, the simulation time between 13:40 – 14:40 is of a special interest for our study.

Table 1 represents some of the parameters for the time frame with the highest number of affected flights. Further analysis has been performed to identify the potential impact of an operation being performed at exactly this “worst case” launch window. The parameters in this table contain the output data for the 17 flights which have been rerouted around the air launch areas. Those are: the total distance flown in the baseline scenario, total distance flown in scenario 3 (re-routing), the difference of the distance flown between both scenarios and the delay in minutes.

**Table 1.** Simulation results for the rerouted flights

| Callsign | Total distance flown Baseline scenario (NM) | Total distance flown scenario 3 (NM) | Difference of the distance flown (NM) | Delay (Min) |
|---|---|---|---|---|
| QTR739 | 7426,5 | 7508,4 | 81,9 | 10:04 |
| UAE201 | 6141,8 | 6148,9 | 7,1 | 00:54 |
| UAE237 | 01:23 | 5994,1 | 7 | 00:53 |
| SAS935 | 4834 | 4844,5 | 10,5 | 01:23 |
| QTR725 | 6363,2 | 6386,1 | 22,9 | 02:52 |
| QTR743 | 5914,9 | 5922 | 7,1 | 00:52 |
| QTR707 | 6278,8 | 6330,3 | 51,5 | 06:31 |
| QTR701 | 6109,9 | 6161,4 | 51,5 | 06:34 |
| UAE235 | 6406,9 | 6429,8 | 22,9 | 02:53 |
| QTR763 | 5853,1 | 5904,5 | 51,4 | 06:33 |
| NAX7067 | 4686,2 | 4739,7 | 53,5 | 06:36 |
| DAL9960 | 1199,1 | 1241,5 | 42,4 | 05:36 |
| DLH410 | 3829,6 | 3848 | 18,4 | 02:21 |
| DLH446 | 4513,1 | 4537,7 | 24,6 | 02:48 |

 

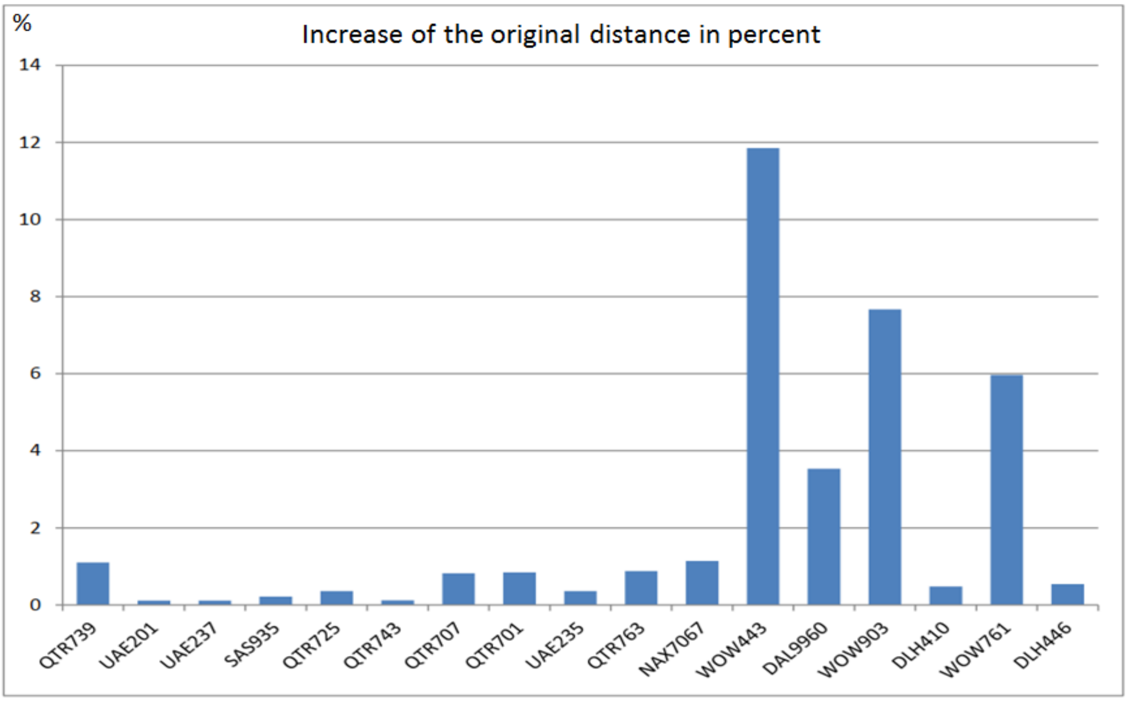


**Figure 10** Increase of the original distance flown in percentage

In order to better illustrate the findings on the total distance travelled, the percentage increment in the distance flown is calculated. For this purpose, first the difference between the total flight path of the base scenario and the total flight route of scenario 3 is formed. Subsequently, the difference between the distances traveled and the percentage increase is calculated. The results are given in Figure 10.

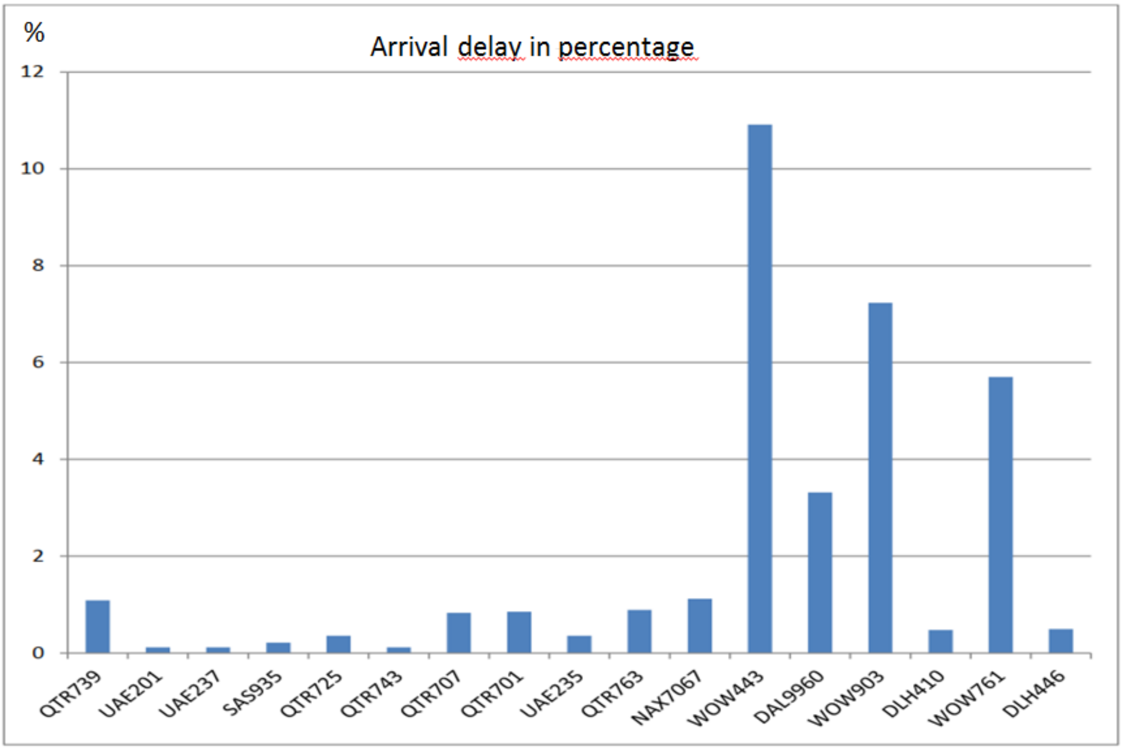


**Figure 11** Arrival delay expressed in percentage

 

Figure 11 depicts the arrival delay for the rerouted flights in scenario 3 compared to the baseline scenario. It can be noticed that all the flights except for WOW443, WOW903 and WOW761 have a delay which is less than 4% compared to the baseline scenario. For these 3 flights, considerable extra distance amounting up to 12% more was travelled due to rerouting. This was attributed to the fact that during the full simulation, with reasons unknown at the moment, these 3 flights did not abide by the manual rerouting implemented but instead, created an automatic rerouting.

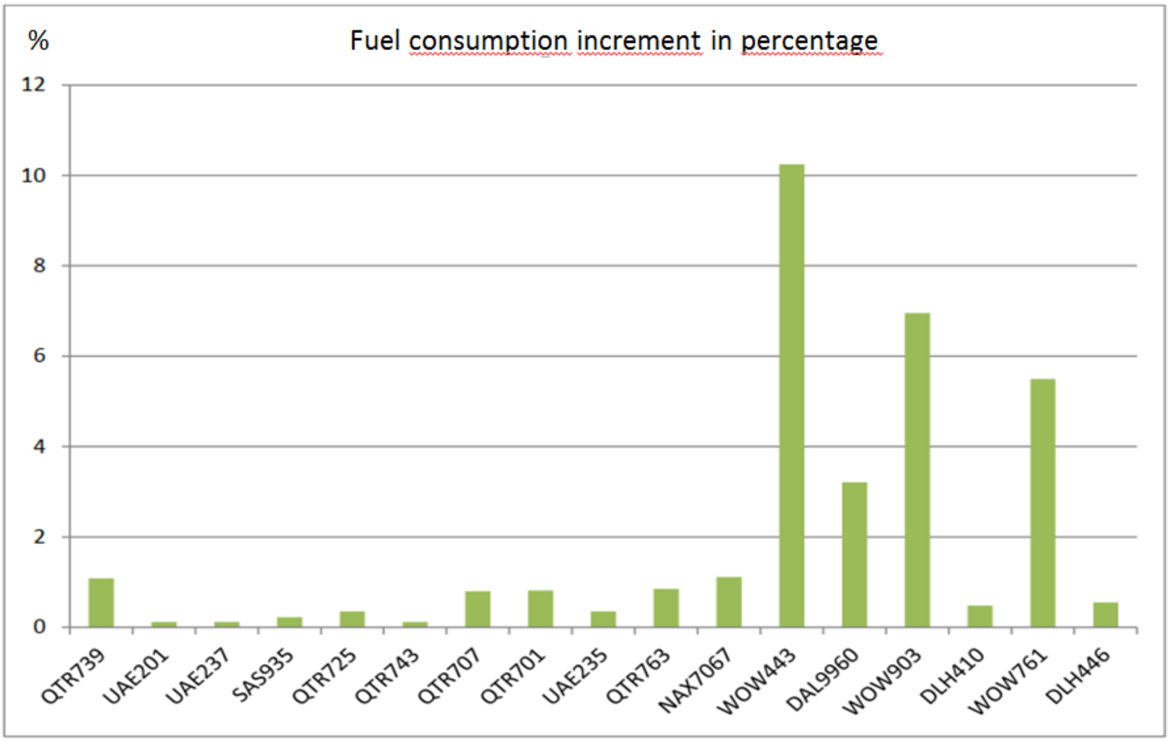


**Figure 12** Fuel consumption difference

Finally, the related potential increase in fuel consumption has been assessed for the high impact launch window. It is based on comparison of the fuel consumption within the two simulated scenarios. The excess consumption of fuel is shown as a percentage in the diagram in Figure 12. The fuel consumption model stored in AirTOp does not allow a sufficiently realistic indication of the absolute fuel consumption. Therefore, only the percentage increase in fuel consumption is determined in this analysis.

## 5. Conclusion and outlook

To sum up the content of this paper, an overview on the performed studies and use cases has been given. The first use case study covered the integration of the landing trajectory of a SpaceLiner, a vehicle designed by DLR, in the northern European airspace. The landing space port in this case is Nordholz in the northern part of Germany. The use case scenario contains only historic traffic data. It is a conservative scenario because of the limitations that had to be considered in the first run. The hazard areas were active during the complete rolling hours and no dynamic opening and closure was performed. The controller workload was also not included in the analysis. No weather or atmospheric data was included as well. Conflicts were not resolved, but they are reduced to a minimum by using historical traffic data.

In the second use case study, some of the assumptions and limitations mentioned above apply too. Additionally, only 2 out of 3 launch polygons were modelled, because in our simulation scenario the third polygon was not in the European airspace. While the rerouting of affected flights has not been performed with optimal rerouting criteria and no alternative measures have been taken to avoid rerouting like ATFM rules, the results show that air launch operation in the chosen area can be performed with only limited impact on European air traffic operation.

In order to further improve integration concepts and the detail level of related air traffic impact analysis, several measures will be taken into future studies. First of all, the integration of air traffic flow management (ATFM) is planned for the future studies and simulations. Two possible methods will be tested: holding at gate and airspeed control, where applicable, in order to reduce costs and flying time. Dynamic airspace as well as dynamic opening of the hazard areas will be implemented. This is expected to lead to a further reduced impact of space vehicle operations on the surrounding airspaces and flights. The dynamic hazard areas will be activated and deactivated with the movement of the space vehicle trajectory. It will prevent closure of large amounts of ATC sectors for unnecessary long periods of time and limit the necessary amount of rerouting of scheduled traffic.

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