The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2023

Volume 26, Pages 242-253

IConTES 2023: International Conference on Technology, Engineering and Science

New Generation Space Vehicle Operations in the United Arab Emirates – An Airspace and Risk Assessment

Oliver Lehmann
Abu Dhabi University

Ramy El-Jabi
Abu Dhabi University

Kirk Webster
Abu Dhabi University

Aya Rachdi
Abu Dhabi University

Abstract: Air Transport is a highly technocentric and rapidly evolving industry. While certain legacy systems persist, more advanced technological concepts for carrying payloads and passengers further, faster, and more efficiently place this particular industry at the forefront of the most cutting-edge research and development initiatives in the fields of autonomous systems, artificial intelligence, cybersecurity, and advanced communication, navigation, surveillance applications. While drone technologies and applications have been widely and comprehensively addressed in recent years, the incipient hypersonic and suborbital commercial transport sector has received disproportionately less academic attention. Although certain suborbital passenger transport concepts such as the German Aerospace Center's SpaceLiner are proposed for the more distant future, other concepts have reached operational status. A recent addition into the foray has been Blue Origin and its vertically launched New Shepherd autonomous vehicle. The United Arab Emirates, an increasingly active spacefaring nation, has signaled its interest. Among the nation's highly ambitious short and long-term initiatives is the idea of launching space tourism flights from its own soil. Blue Origin, along with other candidates, has emerged as a contender to operate its New Shepard vehicle from a UAE-based spaceport. This paper explores how Next Generation Space Vehicle Operations (NGSVO) could impact a highly dense and compact airspace when operating from and to a UAE spaceport. Preliminary results suggest that under certain circumstances, NGSVOs may indeed affect existing Air Traffic Management (ATM) operations and pose increased safety risks while leading to higher fuel consumption and larger carbon dioxide footprints of regular air traffic. To establish a benchmark for future comparisons, the current study applies traditional airspace segregation methods to the UAE airspace to accommodate a specific type of NGSVO. Operational gains may be deduced by comparing the results of future studies applying more advanced ATM concepts to those reported in the current study.

Keywords: Space vehicle operation, Space port, Risk assessment, Air traffic management

Introduction

The approach used here includes using a simplified air traffic event model calculation to gauge how a number of UAE air traffic parameters are impacted by NGSVO; Analyzing these parameters will provide information on how many, and to what extend flights will be impacted by the space vehicle passing over and through the airspace. Elements of the UAE airspace and airway route network are used in our calculations, and space vehicle trajectories and the potential spaceport location are integrated into these. Continuing, the calculations also apply

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

the relevant hazard protection areas associated with the space vehicle in order to separate these from regular air traffic. Such hazard areas are based on recognized risk assessment methods.

Finally, such research aims to understand how today's ATM environment is going to be affected and how ATM systems and ATC controllers might deal with NGSVO, in order to achieve the intensive dynamic re-routing of the prevailing air traffic required with the lowest possible detriment.

Preliminary results have shown that it is a considerable challenge to seamlessly implement next generation space vehicles into today's ATM. However, the as part of new operating concepts demonstrated horizontal launches of space vehicles from a carrier plane are also an interesting control tool. Particularly, the navigational performance of the glider during descent, approach and landing continues to be challenging for a safe and efficient operation which does not threaten and obstruct other users of the airspace. Highly frequented air spaces such as those on which this investigation is based, this challenge applies even more to.

It had to be determined on what data basis the investigation should be founded. To make the most realistic assumptions possible, publicly available radar data was used (Flightradar24, 2022), since pure flight plan data doesn't represent the actual route flown. The considerations of this initial investigation were focused on an exemplary traffic hour. To account for a worst-case scenario, an hour with the maximum number of flights was selected. Data from the years 2019/2020 were not considered representative due to the ongoing COVID19 pandemic. After analyzing the available data, 6:00 p.m. to 7:00 p.m. from December 19th, 2018 was selected as a traffic hour with a very high number of flights within UAE airspace (peak hour) (Lehmann et al., 2022). The data used in the further course is shown in Figure 1.

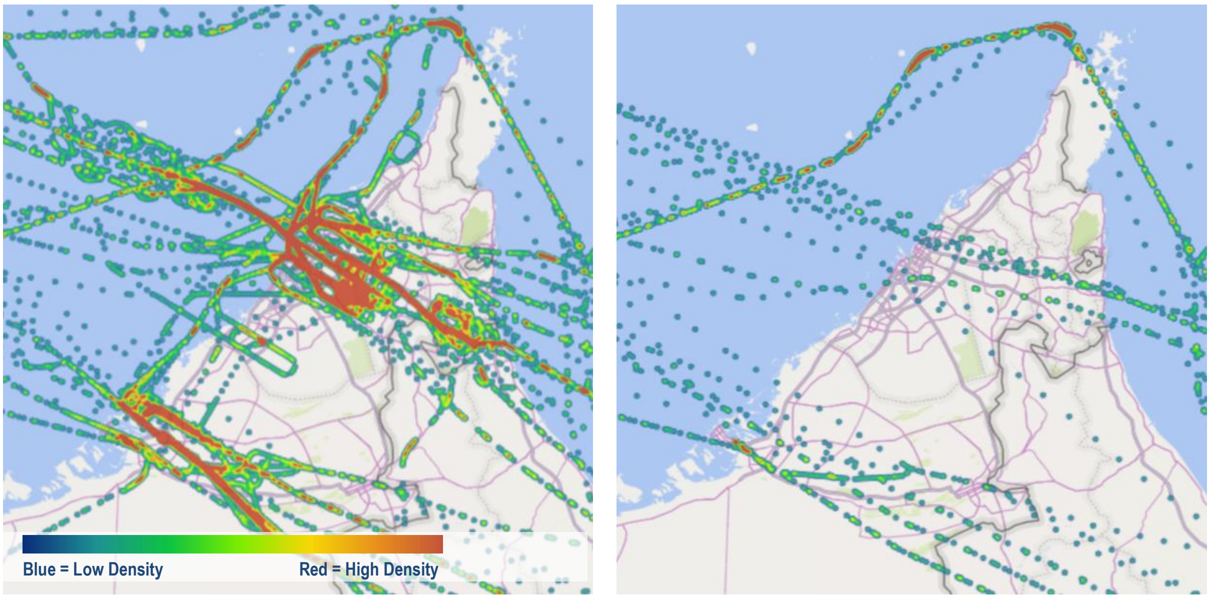

Figure 1. Heat map - Density of air traffic (Lehmann et al., 2022)

For Figure 1 unmodified position data was used. A higher density of air traffic (red color) commonly means that, among other things, higher impacts from NGSVO can be expected in this area. Further, Figure 1 shows the density of Air Traffic (qualitative) in the reference period (peak hour); All Flights (left); Only UAE Overflights (right).

In total 20,740 data sets have been evaluated, these could be assigned to in total 233 different flights within the reference hour, as well as to position data (latitude/longitude) the altitude and the direction of flight, the Callsign, the ADS-B identifier and the flight number were also included in the data.

It bears remembering that 5% to 10% of the flights which were actually conducted are not present in the data Federal Aviation Administration (2022); (Flightradar24, 2022). This may be due to missing or non-functioning or inactive ADS-B equipment of the aircraft or alternatively insufficient receiver coverage on the ground. This means that real Air Traffic in total can also be around 5% to 10% higher during any selected peak hour. For the here discussed analysis, however, this is noncritical. In the further course of the project, our database is to be expanded to include official ATC data (Lehmann et al., 2022).

Impact on Civil Aviation Airspace

Method

Model and Data

The current approach implements a simplified air traffic event model calculation to simply count the number of commercial passenger flights impacted by the temporary closure of a portion of UAE airspace. A flight is considered to be impacted if its usual passage through a portion of the airspace coincides with the closure of that airspace, forcing the flight to be rerouted, delayed, or subjected to other air traffic flow management measures. This can be considered as a simplified and accessible alternative to conducting more advanced airspace analyses using a dedicated fast time simulation platform. While future studies will make use of such resources, the current approach is suitable for the purpose of establishing a benchmark.

Historical UAE airspace flight data is provided by the Flightradar24 internet-based aircraft flight tracking service that collects data from a large ADS-B network along with other sources such as MLAT, radar data, as well as schedule and flight status data (Federal Aviation Administration, 2022). This information is combined with UAE eAIP data to derive useful flight parameters such as aircraft position, points of origin/destination, ATS routes flown, as well as bearing and distance to/from key points such as the reference spaceport location.

Two data sources provide space vehicle trajectory and flight parameters. The first is a study describing the results of a simulation campaign of nominal SS2 flights (Llanos et al., 2018), in which distance flown, altitude, and speed of simulated nominal flights are provided, among other data. The second source is the flight data recorded on Flightradar24 during SS2's test flight in California on July 11, 2021 (Flightradar24, 2022).

Space Vehicle Trajectory

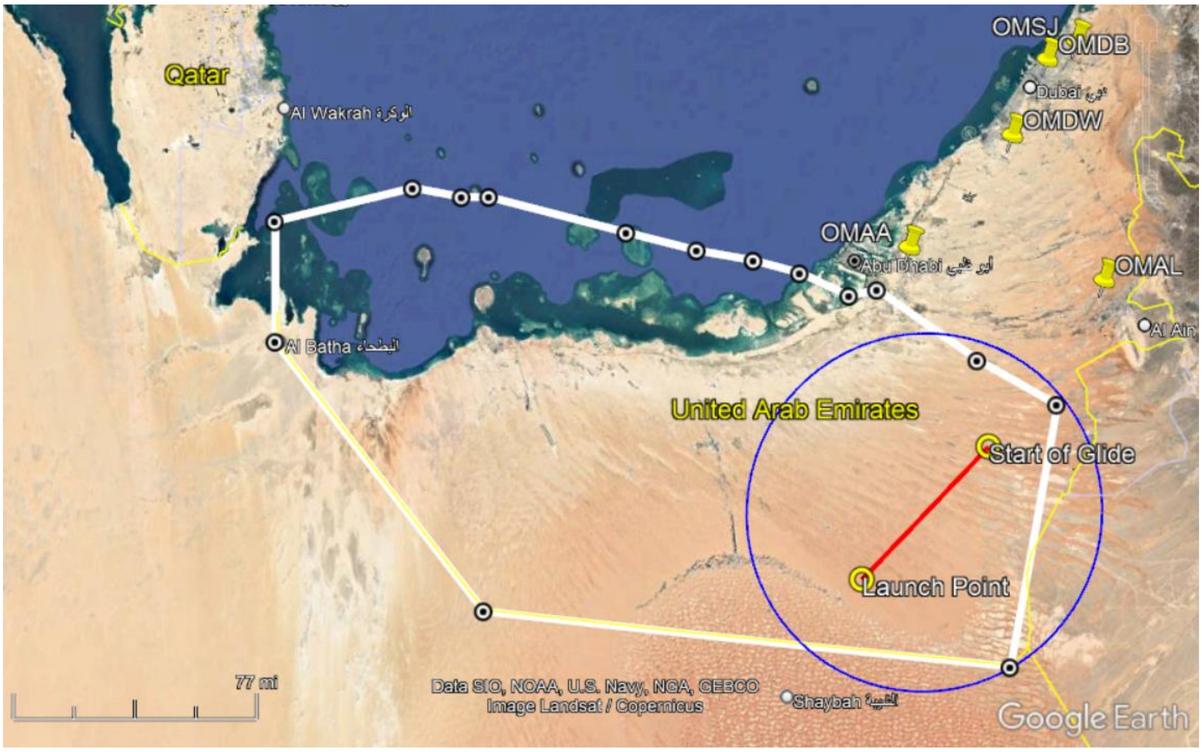

Figure 2. Proposed SS2 trajectory (red) and related assessment area (blue)

For the current hypothetical use case, the following scenario will be considered: SS2 will be transported by the carrier aircraft from the future Al Ain Spaceport to a launch point around 100 NM southwest of the spaceport, within the OMR 54 restricted area, and will be released above 40,000 feet for the secondary launch. Upon its return, SS2 will enter the glide phase at around 49 NM from the launch point, and around 50 NM from the Spaceport. The distance of 49 NM represents the maximum distance flown by the SS2 between the launch point and the top of glide during a simulation campaign in one study (Llanos et al., 2017). SS2 will then return to the Spaceport as a glider. Figure 2 shows the proposed SS2 trajectory (red segment), OMR 54 restricted airspace (white trapezoid), along with the airspace closure (blue circle) as defined further below.

Large portions of airspace have been historically blocked to protect civil aviation traffic from the passage of space vehicles, from slightly before until slightly after the planned time of operations (Tinoco et al., 20210; Young et al., 2017). The dimensions of the temporary airspace closure typically depend on the flight characteristics of the specific type of space vehicle and the nature of the operation. More specifically, the temporary airspace closure must be large enough to account for off-nominal events such as the inflight breakup or explosion of the space vehicle, leading to a debris field spanning relatively large areas. Since a debris dispersal model for SS2 was not available for the current study, the approach taken in Lehmann et al. (2022) is applied: a circular airspace closure is defined having a similar surface area of a trapezoidal operating range near the Cecil Spaceport in Florida (USA), as defined in Llanos et al. (2017).

As explained in Lehmann et al. (2022), the application of a debris dispersal model based on a known inflight breakup, namely the Space Shuttle Columbia accident, is not appropriate in this case. The proposed circular area is centered at the mid-point of SS2's trajectory (between the secondary launch from the carrier aircraft and the top of glide). The hypothetical horizontal launch corridor between the Al Ain Spaceport and the launch and reentry operating area in OMR 54 will be excluded from the impact analysis based on the same rational presented in Llanos et al. (2017) and Lehmann et al. (2022). This serves as an adequate approximation for the UAE scenario and allows to derive some preliminary insights. Figure 2 shows the airspace closure (blue circle), the OMR 54 restricted airspace (white trapezoid), along with the proposed SS2 trajectory (red segment) as defined further above.

Results and Discussion

Assessment Results

Prior to identifying affected flights, it would be useful to present overall traffic data in the UAE Airspace. The following figures provide an overview of traffic demand and controller workload during the defined peak hour. A total of 233 fights were counted in the UAE airspace during the defined peak hour. This includes 61 overflights through the UAE airspace, 78 departures from UAE airports, and 94 arrivals into UAE airports. Here, "UAE airports" refers to Abu Dhabi International Airport (OMAA), Dubai International Airport (OMDB), Al Maktoum International Airport (OMDW), and Sharjah International Airport (OMSJ) only.

Premilitary insights on the number of potentially impacted flights may be derived by analyzing the traffic demand within the defined assessment area. 12 flights passed through the assessment area during the peak hour, all of which were overflights passing through the UAE airspace. None of these flights were departing from or arriving to UAE airports. This may indicate the need to implement common relevant air traffic flow management measures such as rerouting of overflights. While such measures would not be required for UAE terminal traffic in this specific case, other scenarios involving SVO flight trajectories closer to major UAE airports would most likely have an impact on terminal traffic as well. Table 1 shows the affected flights.

Table 1. Flights affected by the proposed airspace closure

Operator	Call Sign	Aircraft	From	To
Air India	AIC975	A320	GOI	KWI
Air India Express	AXB321	B738	CCJ	RUH
Air India Express	AXB773	B738	CNN	DOH
Jet Airways	JAI524	B738	BOM	RUH
Jet Airways	JAI552	B738	BOM	DOH
Jet Airways	JAI560	B738	BOM	DOH
Jet Airways	JAI566	B738	TRV	DMM
Oman Air	OMA673	B788	MCT	JED
Oman Air	OMA677	B738	MCT	MED
Saudi Arabian Airlines	SVA3759	A332	DEL	JED
Saudi Arabian Airlines	SVA705	B772	KHI	JED
Saudi Arabian Airlines	SVA773	A333	BOM	JED

Table 2 below lists the ATS routes that intersect the assessment area:

Table 2. Affected ATS routes

Affected ATS Routes	Affected
LUDID-M628-RIGIL-M628-PEKEM	AXB321 OMA673 SVA3759
M628-RIGIL-M628-PEKEM	SVA705 SVA773
RIGIL-M628-PEKEM	JAI524
SODEX-ELUDA-N563-NOBTO-N563-PARED-SIGMO-N563-TAPTO-N563-VUXOD-N563-KUGTO-N563-BOSEV-L565-UKUVO-G462-OXARI-G462-PURLI-G462	AIC975
SODEX-N563-ELUDA-N563-NOBTO-N563-PARED-N563-SIGMO-N563-VUXOD-N563-P899-LAGVU-P899-MEKRI-P899-VATIG-P899-KUMSI	AXB773
SODEX-N563-ELUDA-N563-NOBTO-N563-PARED-N563-SIGMO-N563-VUXOD-N563-RUKOS-P899-LAGVU-P899-MEKRI-P899-VATIG-P899-KUMSI-MEKMA	JAI552
SODEX-N563-ELUDA-N563-NOBTO-N563-PARED-SIGMO-PUVUT-N563-VUXOD-N563-ORMID	JAI566
SODEX-N563-ELUDIA-N563-SIGMO-N563-VUXOD-N563-P899-LAGUV-P899-VATIG-P899-KUMSI-P899-MEKMA	JAI560

Discussion of Results

The above analysis assumes that the entire assessment area would be closed to regular air traffic during the peak hour. This implies that appropriate ATFM measures (mostly rerouting) would need to be applied to all 12 flights identified above. On the other hand, the launch point location and the flight direction were chosen strategically to ensure that most of the assessment area falls within the OMR 54 restricted airspace. This is categorized as a permanent restriction from ground level to unlimited, for military purposes. Although civil aviation aircraft are occasionally permitted to transit through OMR 54 on pre-agreed ATS routes, it wouldn't be unusual for these routes to become unavailable on occasion, forcing aircraft to adopt alternate routes.

It's worth noting that while the proposed assessment area somewhat overlaps the airspaces of Oman and Saudi Arabia, this situation may be dealt with either through agreements between the concerned parties or by adjusting the location of the launch point and the direction of flight in order to contain the assessment area entirely within UAE airspace. The latter approach would potentially lead to higher levels of impact, as described in Lehmann et al. (2022).

Furthermore, while the assessment area considered in the current study assumes that OMR 54 would be made available for such SVOs, it is certainly not a forgone conclusion. Hence, while the current specific scenario may not represent a significant impact on traffic movements and controller workload, the actual flight trajectory could potentially be much closer to major UAE airports, in which case the impact on both overflights and arriving/departing aircraft would likely be significant. In such circumstances, NGSVOs may indeed affect existing Air Traffic Management (ATM) operations and pose increased safety risks while leading to higher fuel consumption and larger carbon dioxide footprints of regular air traffic.

Impact on Flight Safety

Risk Assessment Methodology

With continued enhancements in not only navigating regulations but also exploring gaps within the systems associated with space operations, governments across the globe have been working with industry to find solutions that will make this new commercial endeavor safe and viable for the public. Since Blue Origin and Virgin Galactic have done successful commercial passenger launches, and with SpaceX continued launches to the international space station, these government entities have relaxed some of the regulation pertaining to such launches but still requires that these companies maintain detailed records associated with these launches. Technology is also aiding in better identifying gaps that could potentially harm the system but with constant revamping of safety measures, these launch systems are poised to carry passengers to the edge of space and back to earth safely.

Table 3. Adopted Risk Assessment Process

Prosedure	Task
1. Identify the Threats, Vulnerabilities, Hazards/Risks	• SS2 takeoff to predetermined altitude and separation process. • SS2 does not separate from the transport vehicle. • SS2 does not ignite for the next phase of flight due to computer glitch. • Separation is outside normal parameters/or identified launch area. • Loss of one or both aircrafts • Equipment functional failures • Structural failures and Human errors
2. Understand the impact of these threats, vulnerabilities, and risks on the organization	• Loss of occupants of both aircrafts • Colliding with another aircraft during the separation and return phase of orbiter. • Debris field beyond containment area • Civilian harm or injury below • Legal matter associated with the loss of the vehicle and occupants. • Possible environmental contamination due to flammable/explosive fuel leakage or wreckage • Environment (or external) events, such as Orbital Debris impacts dispersion
3. Create or use a model for risk analysis	• Bow-tie Analysis • Failure Mode and Effect Analysis (FMEA) • Decision Tree Analysis • Fault Tree Analysis (FTA)
4. Sample the model to understand the threats, vulnerabilities, and risks more fully	• Ensure manual control of ignition system if necessary. • Automate the drag system to reduce human error. • Coordinate with ATC to facilitate the liftoff and separation process • Review Flight Data to include trajectory and speed • Internal monitoring of the flight crew during the entire flight process • Analyze Cockpit Voice Recorder (CVR) • Review deviations from flight path if any
5. Analyze the results obtained from the above steps	• Results of Analysis • Review of Flight Data
6. Implement a risk management plan to manage the threats, vulnerabilities and risks based on the results of the risk analysis	• Mitigation plan to reduce likelihood of hazardous activities • Redesign of parts or activities if necessary as deemed by the analyzed data
7. Review and Revise	• Review current plans and update as required

It is the operations of these SVO and their integration into the current airspace system that creates risks that must be understood and mitigated. The process of integration is a complex one and requires input from industry as well as using system engineering to design safety measures for the system itself. System engineering is defined as “a methodology that supports the containment of the life cycle cost of a system. System engineering can be viewed as the art and science of developing an operable system capable of meeting requirements within often opposed constraints” (NASA, 2007). The process must be flexible and should demand recurring evaluations to ensure that benchmarks are met and that they satisfy the evolution of these vehicles as well as growth in the surrounding areas of the launch site.

Risk cannot be eliminated altogether but can be mitigated through risk controls using system engineering (during the design phase), along with other risk analysis tools and methods. These methods tend to follow a step function in which the risk is constant until changes in the design, process, or operation are addressed. Conventional theory suggests that risk can increase when trading safety margin for perceived gains such as increased performance which ultimately increases the risk for the underlying areas of the launch vehicle. Utilizing a system engineering approach can reduce the chance and effects of failures that could be inherent to the design of the system which ultimately could place the vehicle and operation at risk.

Before further reviewing some of the risks associated with high-risk recreational activities, we must first define risk. Risk is the chance or probability of a hazardous situation that may lead to harm to a person, users, environment, property, equipment loss, or harmful effects on the environment (Canadian Centre for Occupational Health and Safety, 2021). The hazardous situation may also be called a failure mode, and it is triggered by a failure cause. The risk itself is assessed by the severity of the harm and the probability of the harm happening.

The risk assessment process includes:

1. Identify threats, vulnerabilities, and risks.
2. Understand the impact of these threats, vulnerabilities, and risks on the organization.
3. Create or use a model for risk analysis.
4. Sample the model to understand the threats, vulnerabilities, and risks more fully.
5. Analyze the results obtained from the above steps.
6. Implement a risk management plan to manage the threats, vulnerabilities and risks based on the results of the risk analysis.
7. Review and revise.

Although Failure Mode and Effects Analysis FMEA will not be used in this paper, it should be noted that when FMEA and Risk Analysis are completed in harmony, with their key differences, attributes and interconnected relationship considered, risk management process stands to benefit in terms of efficiency and effectiveness, saving both time and resources (Congenius, 2021). Further guidance on risk assessment methodology can also be found in the ICAO Safety Management Manual Doc 9859 (2018).

Adopted Approach for SpaceShip Two

In the case of SS2, the assessment is as shown in Table 3. Below (Figure 3) is an example of risk impact/probability chart that consists of varying degrees of risk probability and risk impact:

Risk Assessment Matrix		**Impact**			
		Minor 1	**Moderate 2**	**Major 3**	**Critical 4**
Likelihood	**76% -100% 4**	**4 Medium**	**8 High**	**12 Very High**	**16 Extreme**
	51% - 75% 3	**3 Medium**	**6 High**	**9 High**	**12 Very High**
	26% - 50% 2	**2 Low**	**4 Medium**	**6 High**	**8 High**
	0% - 25% 1	**1 Very Low**	**2 Low**	**3 Medium**	**4 Medium**

Figure 3. Adopted risk assessment matrix

The corners of the risk impact/probability matrix show varying extremes that typically have the most actionable items and will shed light on the possibilities of inherent risks:

- **Low probability/ low impact:** Risks in this area are both low probability and low impact, so no attention is needed.
- **High probability/ low impact:** Risks poses a moderate threat to operations. Although risk should be minimized, in this corner, it can be easily managed if it occurs.

- **Low probability/ high impact:** Risks will have a high impact on operations, but the probability of the event materializing is unlikely. Preventative steps should already be in place should an event occur. Contingency plans should also be in place to minimize the severity of the impact should the risk manifest.
- **High probability/ high impact:** Risks in this category represent the highest-priority risks and should be given the most attention because they have a higher probability of occurring which would have a negative impact on operations (Indeed, 2022).

With the use of Temporary Flight Restrictions (TFRs), SpaceShip Two could be segregated from other arriving or departing traffic, ensuring that there is a slight modification to the flight structure to protect both spaceship two and the overlying traffic. As suggested for future studies, the dynamic opening and closing of the surrounding airspace might be a temporary but viable solution for the future growth of SVO. Any integration solution must include characteristics associated with the suborbital launch platform. Some of the characteristics identified includes, launch system reliability, timing, and trajectory (Unverzagt, 2020).

Refinement of Assessment Scenario

To better understand the status of the airspace in Al Ain and the surrounding areas within the UAE, we must first look at the uses of the current airspace. By reviewing the flight data available which includes takeoffs and landing as well as overflights, points the project in a direction that will provide the data necessary to aid in the integration of SVO. Mitigation strategies must be incorporated to ensure that in the event of an unforeseen catastrophic failures, the debris field will be contained within the specified NM buffer zone on either side of the launch trajectory but could be expanded as needed. During liftoff from the designated spaceport the mated aircraft will be under the guidance of air traffic control and will follow the established procedures as it attempts to get to its designated altitude for separation above 50,000 ft.

During the initial ascent, there should be no other commercial traffic above Spaceship two ignition altitude, where the aircraft would have no problems getting to its position to begin the weightlessness phase before its return. During the return phase of Spaceship two, the craft should still follow the same parameters to return once below 50,000 ft. Although now a glider, it should be able to circumnavigate whatever aircraft might be in the vicinity with the help of Air Traffic Control (ATC) to get back to its landing position at Al Ain Spaceport. This can only be done through coordinated information sharing between managers of the airspace and launch providers. The authors are aware that the current effective airspace rules, do not recognize the type of glider described here (see ICAO Annex 2; Chapter 3.2.2). As a result, suitable supplements, preferably at the ICAO level, must be defined. The aviation law issue to be derived from this is not part of this technical paper and will be examined separately.

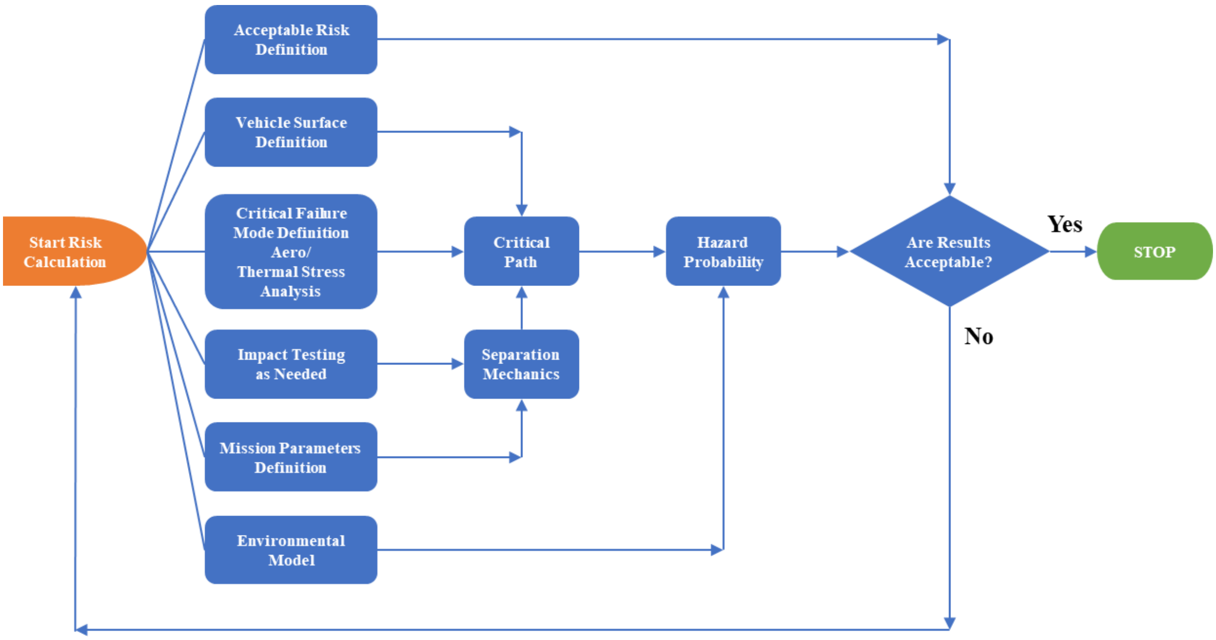

Figure 4. On-orbit impact analysis methodology
Committee on Space Shuttle Meteoroid/Debris Risk Management (1997)

In a recent white paper submitted by Air Line Pilot Association (ALPA) to one of their annual conferences, "the challenge to date has been to develop a data-exchange mechanism to pass this information to the other parties involved. The FAA's space data integrator (SDI) under development is a move in this direction and would serve as a testbed for what could potentially be used in the UAE to facilitate suborbital space launches in and around the region. According to reports, SDI would provide controllers and traffic managers with situational awareness of a spaceflight mission through real time data on vehicle state and operational status, calculate the location and extent of potential hazard areas, and provide visibility into mission progress. SDI will afford the capability for FAA and, by extension, other airspace users to benefit from a detailed level of knowledge of a space mission as it progresses through shared airspace. In addition, the real-time, detailed view provided by SDI allows alert and execution of contingencies if off-nominal events occur" (Air Line Pilots Association, 2020).

There are multiple risk assessment strategies to choose from across varying industries. The risk assessment associated with spaceship two and the transport aircraft comes from a complex set of systems that if not implemented correctly, would affect not only other users within the airspace, but could negatively impact the surrounding environment.

Launch & reentry operation window as short as possible –

- Avoid peak traffic times
- Optimize launch & reentry trajectories as far as possible
- Optimize air space usage alongside restricted areas which could include military operation areas (MOA).
- Ensure real time monitoring and direct communication, connecting all involved stakeholders with ANSP managers and ATC facilities (Kaltenhaeuser et al., 2015)

Analysis and optimization of SVO scenarios and concepts regarding air traffic impacts as suggested by Kaltenhaeuser et al., 2015 can be seen below:

- Improved ATC procedure design
- Support of Spaceport site evaluation
- Integration of SVO Mission management and ATM
- Improved SVO implementation into AIM (e.g. System Wide Information Management)
- Provision of adequate evaluation and validation capabilities

Conclusion

Further study will require more precise definition of the space vehicle's 4D trajectory within the surrounding airspace in the region, as well as a more precise definition of flight restriction areas along the SV trajectory. After reviewing the latest dataset, it was recognized there were slight deviations from prescribed flight path in terms of vehicle heading. An investigation into the cause of these deviations is warranted to further define both the prescribed trajectory as well as define the hazard protection areas. Such restriction areas would be based on traffic separation criteria for such high-risk operations as well as hazard areas relating to abnormal events such as the inflight breakup or explosion of the space vehicle, leading to a debris field spanning relatively large areas. The primary objective during this next stage is the application of a more accurate debris dispersal model to define more precise hazard protection areas, allowing for a less conservative approach, possibly leading to reduced impacts on regular air traffic within the UAE airspace and beyond.

The risk assessment methodology presented in our initial research was further expanded to incorporate analyses of both internal and external risks relating to NGSVO within UAE airspace (Lehmann et al., 2021). This paper was updated to review other possible solutions to this burgeoning problem to finally integrate SVO traffic with normal commercial traffic into the UAE airspace. As the problem is further researched, the hope is that it will present a more concrete solution that will solve the issue once and for all.

Outlook

Future research will involve the use of a fast-time simulation platform and a more comprehensive dataset allowing for a more detailed analysis of the UAE, Oman, Saudi and surrounding airspaces, and the impact of inserting NGSVO trajectories. We will then be able to consider how modern and emerging ATM concepts such as Trajectory Based Operation (TBO), Advanced Flexible Use of Airspace (AFUA), dynamic sectorization, and the role of aircraft-ground datalink requirements could support the situation. The impact of re-routings on overall fuel consumption and CO2 emissions of the air traffic in airspaces across the region will be expanded and investigated.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the authors.

Acknowledgement

*This article was presented as an oral/poster presentation at the International Conference on Technology, Engineering and Science (www.icontes.net) held in Antalya/Turkey on November 16-19, 2023.

*This project was supported and funded by the Abu Dhabi Department of Education and Knowledge (ADEK) Award for Research Excellence (AARE) 2018.

References

Air Line Pilots Association. (2020). *ALPA white paper: Safe integration of commercial space operations into the U.S. national airspace system and beyond*. Retrieved from https://www.alpa.org/-/media/ALPA/Files/pdfs/news-events

Canadian Centre for Occupational Health and Safety (2021). *Hazard and risk*. Retrieved from: https://www.ccohs.ca/oshanswers/hsprograms/hazard_risk.html

Committee on Space Shuttle Meteoroid/Debris Risk Management (1997); *Protecting the space shuttle from meteoroids and orbital debris*. Washington, D.C.: National Academy Press, Sciences, Engineering, Medicine.

Congenius. (September 23, 2020). Risk analysis vs FMEA: How knowing the difference benefits your risk management. Retrieved from https://congenius.ch/

Cooke, B., & Williams, P. (2004). *Construction planning, programming and control*. Oxford: Blackwell Publishing. Retrieved from: https://www.stakeholdermap.com/risk/risk-assessment.html#cooke

Federal Aviation Administration. (2014). *Management of space vehicle operations in the national airspace System concept of operations*. Retrieved from https://www.faa.gov

Federal Aviation Administration. (2022). Air traffic technology Retrieved from: https://www.faa.gov/air_traffic/technology/equipadsb/research/airspace/

Flightradar24. (2022). Commercial data services. Retrieved from https://www.flightradar24.com/commercial-services/data-services

Health and Safety Executive. (2016). Risk management online. Retrieved from: https://www.hse.gov.uk/risk/index.htm

Air Line Pilots Association (2018). *Addressing the challenges to aviation from evolving space transportation*

ICAO. (2021) – *Rules of the air – Annex 2* (10th ed.). Amendment.

ICAO. (2018). *Safety management manual doc 9859* (4th ed.).

Indeed, (October 12, 2022). *How to use a risk assessment matrix*. Retrieved from indeed.com

Industry High Level Group (2019). *Aviation benefits report 2019* Retrieved from: https://www.icao.int/sustainability/Documents.pdf

Kaltenhaeuser, S., Luchkova, T., Klay, N., & Ang, R. (2019). Assessment of the impact of air launch operations on air traffic in Europe. *5th Annual Space Traffic Management Conference.* Austin, Texas

Kaltenhaeuser, S., Morlang, F., Hampe J., & Schmitt, D. (2015). Air traffic management and space transportation: System wide information management and integration into European airspace. *ICAO/ UNOOSA Aerospace Symposium*

Lehmann, O., El-Jabi, R., Webster, K., & Rachdi, A. (2021). Integration of space vehicle operations into the United Arab Emirates air traffic management – An impact analysis. Proceedings of the *32nd ICAS Congress.* Shanghai, China

Lehmann, O., El-Jabi, R., Webster, K., & Rachdi, A. (2022): New generation space vehicle operations in the United Arab Emirates – An airspace and risk assessment. Proceedings of the *33rd ICAS Congress*. Stockholm; Sweden

Llanos, P. J., & Seedhouse, E. (2017). Integrating spaceship two into the national airspace system. In *AIAA SPACE and Astronautics Forum and Exposition* (p. 5358).

Llanos, P., Seedhouse, E., & Hays, C. (2018). Nominal spaceship two flights conducted by scientist-astronaut candidates in a suborbital space flight simulator. *4th Annual Space Traffic Management Conference*. Daytona Beach, Florida

Luchkova, T., Kaltenhaeuser, S., & Morlang, F. (2016). Air traffic impact analysis design for a suborbital point-to-point passenger transport concept. *3rd Annual Space Traffic Management Conference*. Daytona Beach, Florida

Martin, J.N. (1997) *Systems engineering handbook: A process for developing Systems and Products*. (Lucent Technologies.

Millard, S. (2010). Over-flight risk considerations for the launch of an ELV rocket to an ISS inclination. *AIAA Atmospheric and Space Environments Conference.* Federal Aviation Administration

NASA. (2007) *Systems engineering handbook*. Washington, D.C.: NASA Headquarters. Retrieved from https://soma.larc.nasa.gov/mmx/pdf_files

National Research Council (1997). *Protecting the space shuttle from meteoroids and orbital debris*. Boeing North American Inc. Retrieved from https://www.nap.edu

Tinoco, J. K., Yu, C., Firmo, R., Castro, C. A., Moallemi, M., & Babb, R. (2021). Sharing airspace: Simulation of commercial space horizontal launch impacts on airlines and finding solutions. *Journal of Space Safety Engineering, 8*(1), 35-46.

Turner, R. (2000). *Gower handbook of project management* (4 th ed.). Aldershot: Gower.

Unverzagt, R. M. (2020). *Airspace integration in an era of growing launch operations*. *Center for space Policy and strategy*. Retrieved from https://aerospace.org/sites/default/files/2020-10/Unverzagt_AirspaceIntegration_20200929.pdf

Wolf, C. (1978). *A theory of "non-market failure": Framework for implementation analysis.* Santa Monica, CA: The Rand Corporation.

Young, J. E., Kee, M. G., & Young, C. M. (2017). *Effects of future launch and reentry operations on the national airspace system. Journal of Air Transportation, 25*(1), 8-16.

Annex 1.Abbreviations

ADEK...........Abu Dhabi Department of Education and Knowledge (UAE)
ADS-B..........Automatic Dependent Surveillance – Broadcast
AFUA ....Advanced Flexible Use of Airspace
AIP................Aeronautical Information Publication
ALPA............Air Line Pilot Association
ANSP............Air Navigation Service Provider
ATC..............Air Traffic Control
ATFM...........Air Traffic Flow Management
ATM.............Air Traffic Management
CCOHS.........Canadian Center for Occupational Health and Safety
FAA..............Federal Aviation Authority
ICAO............International Civil Aviation Organization
MBRSC........Mohammed Bin Rashid Space Centre
MLAT...........pseudo-range Multilateration
MOU.............Memorandum of understanding
NGSVO........New Generation Space Vehicle Operations
NM................Nautical Miles
OMAA..........Abu Dhabi International Airport
OMAL..........Al Ain International Airport
OMSJ............Sharjah International Airport
SDI................Space Data Integrator
SS2................Scaled Composites Model 339 SpaceShip Two (The Spaceship Company)
SV.................Space Vehicle
SVO..............Space Vehicle Operations
TBO..............Trajectory Based Operation
TFR...............Temporary Flight Restrictions
UAE..............United Arab Emirates

Annex2. Definition

"Dwell time" means the period during which a launch vehicle's instantaneous impact point is over a populated or other protected area.

"Launch vehicle" means:
a) a vehicle built to operate in, or place a payload or human beings in, outer space; and
b) a suborbital rocket.

"Protected area" means an area of land not controlled by a launch operator that is a populated area, is environmentally sensitive or contains a vital national asset.

"Suborbital trajectory" means the intentional flight path of a launch vehicle, reentry vehicle, or any portion thereof, whose vacuum instantaneous impact point does not leave the surface of the Earth.

"Suborbital rocket" means a vehicle, rocket-propelled in whole or in part, intended for flight on a suborbital trajectory, and the thrust of which is greater than its lift for most of the rocket-powered portion of its ascent.

"United Arab Emirates" means the seven Emirates of the United Arab Emirates.

Author Information

Oliver Lehmann
Abu Dhabi University
P.O. Box 59911
Abu Dhabi, United Arab Emirates

Ramy El-Jabi
Abu Dhabi University
P.O. Box 59911
Abu Dhabi, United Arab Emirates
Contact e-mail: *ramy.el-jabi@adu.ac.ae*

Kirk Webster
Abu Dhabi University
P.O. Box 59911
Abu Dhabi, United Arab Emirates

Aya Rachdi
Abu Dhabi University
P.O. Box 59911
Abu Dhabi, United Arab Emirates

To cite this article:

Lehmann, O., El-Jabi, R., Webster, K., & Rachdi, A. (2023). New generation space vehicle operations in the United Arab Emirates – An airspace and risk assessment. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 26,* 242-253.