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IMPROVING GERMAN AIR FORCE PILOT TRAINING BY IMPLEMENTING VIRTUAL REALITY AND AUGMENTED REALITY

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AIM

1. The aim of this service paper is to make an argument for the German Air Force (GAF) to implement Virtual Reality (VR) and Augmented Reality (AR) into various stages of pilot training and thereby modernizing and improving the current pilot training system. This service paper will show that introducing VR and AR in pilot training will have positive effects on the training and operational output.

INTRODUCTION

2. The GAF is responsible for securing the German airspace, which is ensured by air policing, among other mission sets. In addition to aircraft being ready for operations, this also requires a sufficient number of trained pilots who can operate the weapon systems. The GAF lacks a significant number of trained pilots to fully staff all squadrons. The training of pilots is demanding, lengthy and extremely expensive. While the material situation - the so-called “clear status” - has continuously improved in recent years, there is still a bottleneck in various parts of the training pipeline, which is only being reduced very slowly.[1] One reason for this is a wave of separation of experienced pilots and flight instructors, which was caused by the frustration of too few flying hours.[2] This complicates and prolongs training, as there is a lack of experienced personnel. Currently, pilot candidates and qualified pilots are trained and kept current in simulators and through live-flying. However, every training session used for initial qualification training means that the simulator or aircraft cannot be used for continuation training for current pilots. It is imperative that appropriate measures are taken to increase the capacity for training qualified pilots as well as candidates. Furthermore, live-flying hours must be utilized to the best possible extent. This can be achieved by implementing VR and AR in flight training. Overall, this will increase the operational value of the GAF.

3. The Service Paper analyzes the present use of VR and AR in training as well as emphasizes the associated efficiency and effectiveness of the utilization VR and AR in pilot training. Also, limitations of VR and AR in pilot training will be discussed.

DISCUSSION

4. VR is defined as “an artificial environment which is experienced through sensory stimuli (as sights and sounds) provided by a computer and in which one’s actions

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[1] “Traumberuf Eurofighter-Pilot: Warum der Bundeswehr trotz vieler Bewerber der Nachwuchs ausgeht,” Business Insider, accessed February 7, 2024, https://www.businessinsider.de/wirtschaft/ eurofighter-piloten-warum-der-bundeswehr-der-nachwuchs-ausgeht-2019-8/.

[2] “Schwund beim Eurofighter: Eine Pilotin erklärt ihre Kündigung,” Wiegold Thomas, accessed February 5, 2024, https://augengeradeaus.net/2018/05/schwund-beim-eurofighter-eine-pilotin-erklaert-ihre-kuendigung/.

partially determine what happens in the environment."[3] For this paper, it is understood as a digital environment, which is experienced by the user as being real. Furthermore, it allows the user to interact with the digital, three-dimensional environment.[4] In real time, sensors, which react to the movements of the user consistently alter the sight on the screen. By adding data gloves worn by the user, virtual objects can be exploited.[5]

5. AR describes a "system in which virtual objects are added to the real world in real-time during the user's experience."[6] The following three criteria are usually met by AR: virtual and real objects are combined within a real environment; this happens in real-time and interactively; AR aligns virtual and real objects with each other. Similar to VR, AR offers a high degree of feeling of reality and of presence on an emotional and cognitive level.[7] Whilst VR offers a fully synthetic world to the user without him viewing the real word, AR augments the real world by imposing virtual objects into reality.[8]

6. VR and AR applications today can be found in almost every smartphone; simple examples are programs that use the camera option to help read unknown languages.[9] There are also countless apps that support the use of VR and AR for lessons in schools today. VR and AR enhance models, diagrams and visualizations used in the natural sciences. For example, artifacts and buildings can be displayed in "real-life" and a tour of the government district and the Bundestag is possible without a trip to Berlin.[10] This means that VR and AR are already used in the everyday lives of most citizens and the young generation in particular[11], who are the target group of the GAF's recruitment. Therefore, the young generation has expectations of modern training and the use of contemporary training tools. Given that, there is no way around the implementation of VR and AR in the GAF.

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[3] Jason Jerald, *The VR Book: Human-Centered Design for Virtual Reality* (San Francisco: Morgan & Claypool, 2015), 9.
[4] "Virtual Reality," Britannica, accessed January 22, 2024, https://www.britannica.com/technology/virtual-reality.
[5] Ibid.
[6] Pietro Cipresso, Irene Giglioli, Mariano Raya and Giuseppe Riva, "The Past, Present, and Future of Virtual and Augmented Reality Research: A Network and Cluster Analysis of the Literature," *Frontiers in Psychology*, no. 9 (2018): 2086.
[7] Ronald Azuma, Yohan Baillot, Reinhold Behringer, Steven Feiner, Simon Julier and Blair MacIntyre, "Recent Advances in Augmented Reality," *International Journal of Combinatorial Optimization Problems and Informatics* 3, no. 7 (2016): 34.
[8] Julie Carmigniani, Borko Furht, Marco Anisetti, Paolo Ceravolo, Ernesto Damiani and Misa Ivkovic, "Augmented Reality Technologies, Systems and Applications," *Multimedia Tools and Applications* 51, no. 1 (2011): 342.
[9] "Augmented und Virtual Reality in der Bildung," Gewerkschaft Erziehung und Wissenschaft, accessed January 21, 2024, https://www.gew.de/bildung-digital/augmented-und-virtual-reality.
[10] "Digitale Tools und Technik im Bildungsalltag. Virtual und Augmented Reality im Klassenraum? Ein Überblick bildungsrelevanter Angebote," Bundeszentrale für politische Bildung, accessed January 18, 2024, https://www.bpb.de/lernen/digitale-bildung/werkstatt/298516/virtual-und-augmented-reality-im-klassenraum-ein-ueberblick-bildungsrelevanter-angebote/.
[11] Pawel Dymora, Bartosz Kowal, Mirosław Mazurek, and Romana Śliwa, "The effects of Virtual Reality technology application in the aircraft pilot training process," *Materials Science and Engineering* 1024, no. 1 (2021): 7.

7. In the history of aviation, the use of simulation played a crucial role from the very beginning onwards. Whereas the Wright brothers used wind tunnel tests in order to collect detailed data and gain an understanding of the aircraft's perfect design,[12] the first aviation pioneers taught themselves flying via "trial and error." This, for example, was the case at the beginning of military aviation, when Lt Benjamin Foulois landed the "Wright Flyer" successfully in 1910 at Fort Sam Houston and before he set out he mentioned to take "plenty of spare parts and teach yourself to fly."[13] Soon, the use of training devices and simple aircraft simulators enhanced the effectiveness of flying training without the risk for the students losing their lives. Whilst the first flight simulators were built as wooden cockpits and only mirrowed the air plane's reactions when the student operated the stick and the pedals[14], the apparatuses improved vastly up to today's full mission simulators which also are being used for air combat exercises and the simulation of complete missions.[15] This considered, using VR and AR is the next logical step in the evolution of pilot training in a synthetic environment.

8. The average calculated costs for a GAF Eurofighter live-flying hour sums up to around 74.000 € (108.000 $ CAN) and for the GAF Tornado 43.000 € (63.000 $ CAN). This amount includes the costs of fuel, spare parts as well as resources required for operating and maintaining the respective weapon systems as well as the technical support services.[16] In contrast, the average fast jet simulator hour costs 2.000 € (2.900 $ CAN), which only is a fraction of a live flying hour.[17] Full flight simulators hereby consist of a fully modeled cockpit, including the instrumentation of the respective aircraft model, usually surrounded by a visual display system. Regularly, this is framed and mounted on a Stewart platform, the use of which supports the students feeling of being in the authentic environment. On a regular basis, the systems require large facilities which very often are climate-controlled. Usually, instructors and operators are required to provide mission oversight as well as technicians, in order to input the parameters which are required for the respective mission.[18] Also, these simulators require extensive maintenance. Whilst the costs of an average "VR-based" flying hours cannot be determined in this paper, it is clear that it will be even less compared to a simulator hour due to lower total costs. Therefore, implementing "VR and AR-based" flying training will reduce the overall costs associated with pilot training.

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[12] "1901 Wind Tunnel Tests," National Aeronautics and Space Administration, accessed January 16, 2024, https://www.grc.nasa.gov/www/k-12/airplane/wrights/test1901.html

[13] Thomas Manning, *History of Air Education and Training Command 1942-2002* (Randolph Air Force Base Texas: Office of History and Research, 2005), 28.

[14] James Killgore, "The Planes that never leave the Ground," *American Heritage of Invention & Technology* 4, no. 3 (1989): 58.

[15] "Training im Tiefstflug. Flugsimulatoren der Bundeswehr," Flug Revue, accessed January 16, 2024, https://www.flugrevue.de/flugsimulatoren-der-bundeswehr-training-im-tiefstflug/.

[16] "Fast 74.000 Euro. Teure Flugstunde des Eurofighter," NTV, accessed January 19, 2024, https://www.n-tv.de/incoming/Teure-Flugstunde-des-Eurofighter-article1374061.html.

[17] "Catch-22 für Eurofighterpiloten: Weniger Flugstunden, weniger Simulator (Nachtrag: Luftwaffe)," Augen Geradeaus, accessed January 17, 2024, https://augengeradeaus.net/2018/04/catch-22-fuer-eurofighter-piloten-weniger-flugstunden-weniger-simulator/.

[18] "U.S. Air Force Pilot Training Transformation," Congressional Research Service, accessed January 23, 2024, https://crsreports.congress.gov/product/pdf/IF/IF12257/2.

9. VR and AR are also already being used within training in the GAF. For example, AR-systems are being used for A400M maintenance training. With that, maintenance and repair personnel can be trained in a highly realistic environment without the need for an actual aircraft. The entire system consists of training rigs, which are detailed replicas of several parts of the aircraft as well as a supplementary AR-system, with is integrated. Maintenance procedures can be practiced as if the personnel were working on the real A400M. Consequently, the maintenance and repair personnel training does not negatively affect the A400M's fleet availability and readiness.[19] In flight training, however, VR has so far only been used at the GAF Training School. In preparation for the gliding training phase, which every officer cadet has to undergo, practical elements have been trained in a VR gliding simulator since 2019 in addition to the theoretical basics such as aviation, navigation and aerodynamics.[20] As a result, the practical preliminary training at the gliding school has been reduced and the trainees can start the actual training with a higher level of experience. The VR simulator thus increases the flight time at the gliding school significantly.

10. The GAF is pursuing a digitalization strategy with the aim of improving the effectiveness and efficiency of the GAF's mission fulfilment now and in the future.[21] The aim is to recognize the potential of new digital technologies and incorporate them into the further development of air warfare for increased operational effectiveness. The requirement for digital technologies is that these applications and programs enable flexible, individualized and cost-efficient knowledge acquisition, regardless of time and place. They also facilitate individualized learning.[22] The implementation of VR and AR in flight training meets all the criteria of the digitalization strategy and it is therefore logical to utilize VR and AR in flight training. The further digital transformation of the GAF must be continued consistently, closely linked to the Luftwaffe's innovation management.

11. Since its formation, the Luftwaffe always has been working together in a multinational environment closely linked to allies and international organizations.[23] Therefore, it is important to acknowledge that the United States Air Force (USAF) is already experimenting with VR and AR. In order to train more pilots in less time whilst reducing the overall costs of training, the so-called "Pilot Training Next" (PTN) was launched by the Air Education and Training Command (AETC) in 2018. Within this

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[19] "Rheinmetall supplying German Air Force with training rigs and augmented reality systems for A400M maintenance training," Air Recognition, accessed January 23, 2024, https://www.airrecognition.com/index.php/news/defense-aviation-news/2022-news-aviation-aerospace/may/8379-rheinmetall-supplying-german-air-force-with-training-rigs-and-augmented-reality-systems-for-a400m-maintenance-training.html.
[20] "Die digitale Zukunft hat schon längst begonnen," Luftwaffe, accessed January 23, 2024, https://www.bundeswehr.de/de/organisation/luftwaffe/aktuelles/die-digitale-zukunft-hat-schon-laengst-begonnen-157638.
[21] "Air Power Connected: Digitalisierung konkret, eine Luftwaffen-Perspektive," Armed Forces Communications and Electronics Association, accessed February 8, 2024, https://www.bundeswehr.de/resource/blob/253844/aa4f60a38a05a3482746176751ea03c8/digitalisierung-afcea-data.pdf.
[22] Luftwaffe, *Strategie Digitalisierung Luftwaffe* (Berlin: Kommando Luftwaffe, 2021), 5-10.
[23] "The German Air Force in Transformation – Fit for the Future," Bundeswehr, accessed February 8, 2024, https://www.bundeswehr.de/en/the-german-air-force-in-transformation-fit-for-the-future-5067196.

project, new technologies and innovations in flight instruction are being explored.[24] In order to train on required fundamental aviation skills for future fifth-generation fighter pilots, VR and AR is being used. The implementation was evaluated and came to the result, that students who were exposed to VR and AR training tools were on top of the class in the following specialized training modules such as the type rating courses.[25] The Luftwaffe therefore should build up on the USAF's experiences. Furthermore, this allows another opportunity for close allied cooperation, especially because the GAF will purchase F-35A combat aircraft in the very near future. The introduction of the fifth-generation fighter jet will fundamentally change the training requirements for respective pilots, more heavily relying on synthetic training compared to fourth-generation fighter jets.[26] VR and AR will be a suitable enhancement to the current simulator-based training.

12. Although synthetic flight training is extremely helpful in teaching numerous skills and enable to train required competencies in a safe and controlled environment, clearly it also has its limitations. A certain skillset cannot be trained and some experiences cannot be replicated within a synthetic environment.[27] On a physical side for example, the different G-forces which affect the pilot when accelerating cannot be replicated. Also, the training of soft skills is affected. While real-life distraction can be trained to a certain degree, in a simulator it will never be to the same degree as in the air. More pertinent, managing stress and fear is even less trainable, because the synthetic environment goes along with a certain level of known safety.[28] Nevertheless, it has to be noted that recent research confirms that pilots who were trained using VR perform on the same level and with the same competencies as pilots trained within the usual training pipeline.[29] Therefore, it is important to assess which competencies and skills can be trained by using VR and AR technology.

13. While the use of VR cannot be a substitute for live-flying hours and although VR technology reflects an artificially created reality, there is also a significant difference compared to using a modern full flight simulator. As simulator training cannot substitute live-flying, the usage of VR-technology cannot fully substitute simulator training. Nevertheless, teaching basics by using cutting-edge VR will free up simulator hours and prepare future pilots when they progress to get trained on their weapon system.[30] In addition to requiring fewer specialized staff to maintain and operate, VR systems will

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[24] Congressional Research Service, "U.S. Air Force Pilot Training Transformation".
[25] "The Air Force's Virtual Reality Fighter Training Is Working Best for 5th-Gen Pilots," Military, accessed February 7, 2024, https://www.military.com/daily-news/2021/03/26/air-forces-virtual-reality-fighter-training-working-best-5th-gen-pilots.html.
[26] "DOD pursuing next-gen virtual training for fighter pilots," Defense Scoop, accessed February 7, 2024, https://defensescoop.com/2023/01/17/dod-pursuing-next-gen-virtual-training-for-fighter-pilots/.
[27] Alfred Lee, *Flight Simulation. Virtual Environments in Aviation* (Burlington: Ashgate Publishing Limited, 2005), 100.
[28] Ibid, 105.
[29] Ylli Dalladaku, Jacob Kelley, Brycen Lacey, James Mitchiner, Braden Welsh, and Matthew Beigh, "Assessing the Effectiveness of Virtual Reality in the Training of Army Aviators*," Proceedings of the 2020 Annual General Donald R. Keith Memorial Capstone Conference*, no. 1 (2020), 40.
[30] Military, "The Air Force's Virtual Reality Fighter Training Is Working Best for 5th-Gen Pilots."

become cheaper to procure as they proliferate, thereby lowering implementation costs relative to full motion simulators.

14. The implementation of AR can also be implemented to maximize the effectiveness of live-flying training. Because AR, by definition, is the enrichment of reality with virtual images and therefore "completes the real world with new imagines or information",[31] AR can be used during live-flying training in order to increase training options. For example, AR can be used to simulate enemy aircraft and provide a realistic synthetic environment to train fighting against near-peer adversaries.[32] This would enable pilots to train to more complex mission sets against synthetic adversaries during live-flying training and obviate the need to produce additional sorties for airborne aircraft to serve as so-called "red air."

CONCLUSION

15. The use of VR and AR in various sections of basic and advanced flight training increases the operational value of the GAF and modernizes the current training system. This is a further step towards the digitalization of the Luftwaffe and therefore meets the expectations of the younger generation for modern training. Costs can also be reduced as fewer resources are required and the training itself can be more individualized and flexible to customized requirements.

16. Pilots are sometimes resistant to the implementation of VR and AR, especially when flying hours are concurrently reduced. Rather, it is important to use VR and AR at the right stage in flight training in order to achieve a maximum operational output. The use of VR mainly supports the learning of basic flying skills in particular. AR is to be implemented in conjunction with live-flying lessons, for example when training complex full missions, in order to achieve a better depth of training. During the testing and implementation phase of VR and AR, it is important to closely monitor the process through quality management and evaluation in order to highlight the success of the measures and provide scientific evidence.

RECOMMENDATION

17. Identification. Suitable sections of pilot training for the implementation of VR and AR must be identified. For VR, these are parts of training that teach the basics of aviation. For AR, these are sections of live-flying training or exercises that involve complex missions and in which the quality of training is enhanced by the use of AR, for example by the simulation of "red air". Suitable civilian partners for cooperation and rapid implementation must be identified in accordance with the GAF's digitalization strategy.

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[31] Dymora, Kowal, Mazurek, and Śliwa, "The effects of Virtual Reality technology application in the aircraft pilot training process," 2.

[32] "BAE Systems and Red 6 augment Hawk trainer jet's reality," Shephard Media, accessed February 5, 2024, https://www.shephardmedia.com/news/training-simulation/bae-systems-partners-with-red-6-on-augmented-reality-training-for-hawk-fast-jet/.

18. Test phase. Once suitable training courses have been identified, the use of VR and AR must be tested. It must be ensured that the quality of the training remains at least the same or is improved. This is crucial, as there must be no gaps in airspace security. Furthermore, any risk of accidents must be ruled out. In order to guarantee this, the results must be compared with the previous training results.

19. Evaluation. The implementation of VR and AR in flight training must be evaluated in a standardized manner in all phases right from the beginning. This will ensure that the quality of the training does not decline and that the training continues to achieve the desired objectives. Furthermore, standardized evaluation ensures comparability. This is a factor that has not yet been implemented in current programs of allied partners.[33] As positive effects are expected in terms of training success based on current scientific findings,[34] a standardized evaluation also contributes to the acceptance of the implementation, as the positive effects are measurable and comprehensible.

20. Implementation. Where training success is at least consistent, VR and AR should be implemented across the board in pilot training. This must continuously be evaluated in order to ensure a high quality of training in the future.

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[33] Military, "The Air Force's Virtual Reality Fighter Training Is Working Best for 5th-Gen Pilots."
[34] Ryan Guthridge, and Virginia Clinton-Lisell, "Evaluating the Efficiancy of Virtual Reality (VR) Training Devices for Pilot Training," *Journal of Aviation Technology and Engineering* 12, no. 2 (2023): 5.

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