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Fast-Jet Pilot Training Modernisation Choices

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Cover image: T-38C Talon jet trainer aircraft in formation during Phase 4 / IFF sortie from Columbus Air Force Base, February 2025 / Courtesy of Justin Bronk

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Contents

Methodology

Research for this paper was conducted from August 2024 to February 2026. The paper was submitted on 5 February 2026 and approved for copy editing on 16 April 2026.

For this study, the author visited, flew with and conducted numerous interviews with instructors and unit commanders at training squadrons and OCUs in several Allied air forces, including the Royal Air Force, United States Air Force, Royal Australian Air Force, French Air and Space Force, Finnish Air Force, Republic of Korea Air Force, and Italian Air and Space Force. The author also received indepth briefings on as many of the potential options for fast-jet training-fleet modernisation as possible, including the Embraer A-29 Super Tucano, Pilatus PC-21, Leonardo M-346A and Korea Aerospace Industries TA-50 and Boeing/Saab T-7A. In addition, the author conducted type-familiarisation flights in each of these aircraft (except the T-7A), enabling their handling and performance characteristics, cockpit layout, hands-on throttle and stick (HOTAS) controls, and LVC training capabilities to be tested and compared.

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Executive Summary

NATO air forces are facing concurrent challenges of insufficient overall flight training system capacity and trainer aircraft fleet obsolescence. Despite budget challenges, modernising flight training is a non-discretionary requirement, as combat air capabilities cannot be maintained without a steady flow of enough suitably qualified fast-jet pilots.

Fast-jet pilot training consists of four phases, followed by training on the frontline aircraft type that new pilots will fly at an operational conversion unit (OCU). Phase 1 is generally flown in piston engine propellor aircraft, and Phase 2 is generally flown on turboprop aircraft. Phase 3 is traditionally flown in jet engine trainer aircraft but is now often flown in cheaper advanced turboprop trainers. Phase 4 is generally flown in advanced fast-jet trainer aircraft, but in some cases is now also being flown in advanced turboprop trainers.

During all phases, pilots will fly a mix of live training sorties in real aircraft and synthetic training sorties in a simulator. Simulator training is significantly cheaper than live flying and is very useful for initial cockpit familiarisation and procedures training before flying a new aircraft type. It can be more effective than live flying for teaching various tactical skill sets and practising how to quickly recognise technical failures and react appropriately. Simulator training can also help pilots get more benefit out of live training flights, as they can practise the tasks and learning objectives in the synthetic environment before flying. However, simulators cannot replicate the feel of live flying, especially the inner-ear senses that can lead to spatial disorientation, and how to operate under G-forces. Many skillsets that sit under the term 'airmanship' can only be built effectively by live flying training in a real aircraft.

The balance of live and synthetic training at each phase, and the aircraft types chosen to modernise obsolescent fleets, will have significant cost, and long- and short-term risk implications. Air force leaders and policymakers responsible for capability development should have a clear idea of what the different tradeoffs are, both in training new pilots to be tactically effective in modern fighter aircraft and in terms of training adequate airmanship skills.

The frontrunner aircraft options available for Phase 3 and 4 trainer-fleet modernisation for most NATO air forces are the Pilatus PC-21, Leonardo M-346A, Boeing-Saab T-7A and KAI T-50/TA-50. All have advanced fighter-like cockpits with modern live-virtual constructive (LVC) training features and are designed to work as part of a digital training system with linked part-task trainer and full-fidelity simulators and software to track and optimise an individual student's progress. The best choice for each air force will depend on how the OCU is configured for training on frontline aircraft; what class of trainer aircraft are already in use for Phases 1–2/3; and whether an air force has additional secondary requirements for a Phase 4 trainer type, such as light fighters, red air provision or companion trainers.

Introduction: The Need for Fast-Jet Pilot Training Modernisation

Crewed fighter aircraft remain the core of most air forces' combat capabilities and are likely to remain so until at least the late 2030s, even as traditional fast jets are augmented by increasing numbers of uncrewed combat aerial vehicles and collaborative combat aircraft. This paper examines the core elements of fast-jet pilot training that policymakers should consider when weighing up different options for training structures and aircraft types. It also compares the relative merits and potential downsides for different user-requirement sets of the main new aircraft types available to either national or multinational training fleets.

It typically takes between four and seven years to train fast-jet pilots, from recruitment to joining a frontline squadron. Consequently, it is not possible to increase frontline numbers rapidly while maintaining high standards of proficiency and flight safety in a fighter force. It also means that disruptions in the flight-training pipeline have unavoidable long-term effects for any given air force. Experienced pilots regularly leave the frontline as they either retire from service or are promoted into more senior ground-based staff roles. A robust, consistent and effective system for training new fast-jet aircrew is therefore critical for maintaining a healthy frontline force. Unfortunately, during successive rounds of cuts and efficiency savings since the early 1990s, trainer aircraft fleets in the UK and other NATO countries have often been targets for reductions and deferred modernisation, as they were perceived as less politically sensitive targets for reductions compared to frontline numbers.

Consequently, there is a significant shortage of fast-jet aircrew training capacity across NATO.[1] Some countries lack any national capacity to train their pilots from first flight to being combat ready, and many of those that retain the capability to do so increasingly rely on international training programmes to meet their full training requirements. The result is a heavy and increasing reliance across NATO on multinational pilot training centres, such as the long-running Euro-NATO Joint Jet Pilot Training Program at Sheppard Air Force Base in the US and the relatively new International Flying Training School at Decimomannu Air Base in Italy.[2] Multinational training approaches offer several advantages, including improved standardisation across different air forces; lower overall costs due to reduced duplication of infrastructure, compared to each country running its own training fleet; and invaluable personal connections being built from an early career stage. However, this multinational approach also currently means that countries are competing for limited spaces on training courses, there is limited ability to expand or adapt training to national priorities, and upfront costs per student are often relatively high.

In addition, many NATO air forces are currently facing significant availability and cost issues with their own trainer fleets, as advanced fast-jet trainer aircraft from the 1960s and 1970s (such as the BAE Systems Hawk T1, Dassault/Dornier Alpha Jet, Saab 105 SK-60, CASA C-101, Northrop T38C and Aermacchi MB-339) reach the end of their practical service lives. At the same time, multiple NATO air forces have announced procurement decisions to bolster frontline aircraft numbers considering the increasingly serious geopolitical threat outlook, especially in Europe. This means that they will need to train more pilots in the coming years, rather than merely sustain the existing level of training throughput. In other words, NATO air forces are having to work out how to increase their capacity to train fast-jet aircrew at the same time as their national advanced fast-jet trainer fleets are ageing out.

To solve these challenges, most NATO air forces are re-examining how they traditionally structure, run and conceptually approach flying training. Budgets, trainer-aircraft availability and instructor shortages all limit student flying hours. These pressures are mandating efforts to improve the training value that each hour of live flying can deliver for each student. There is huge potential to achieve this through modernisation of national flying training fleets, revised syllabus structures, and greater use of modern

1. Trevor Nash, 'Fast Track to Fast Jet?', European Security & Defence, 23 July 2024, <https://euro-sd.com/2024/07/articles/39449/fast-track-to-fast-jet/>, accessed 30 March 2026; Heather Penney, 'Want Combat Airpower? Then Fix the Air Force Pilot Crisis', Mitchell Institute for Aerospace Studies, 23 January 2025, <https://www.mitchellaerospacepower.org/want-combat-airpower-then-fix-the-air-force-pilot-crisis/>, accessed 30 March 2026.
2. US Air Force, 'Euro-NATO Joint Jet Pilot Training Program (ENJJPT)', updated July 2017, <https://www.sheppard.af.mil/Library/Fact-Sheets/Display/Article/367537/euro-nato-joint-jet-pilot-training-program-enjjpt/>, accessed 27 January 2025; NATO Air Command, 'A New Generation of Pilots Take Flight at Italy's International Flight Training School, Bolstering NATO's Collective Capabilities', 7 July 2025, <https://ac.nato.int/archive/2025-2/a-new-generation-of-allied-and-partner-pilots-take-flight-at-italys-international-flight-training-school--bolstering-natos-collective-capabilities>, accessed 27 January 2025.

simulators and live-virtual constructive (LVC) technologies. For example, the Pilatus PC9 and PC-21, Boeing-Saab T-7A, Korean Aerospace Industries (KAI) T-50 and Leonardo M-346A trainer aircraft are all designed to be purchased and operated as part of a comprehensive training system that combines affordable part-task training simulators, high-fidelity full-cockpit simulators and software solutions to track and optimise each student's progress throughout.[3] All offer varying degrees of in-cockpit LVC training, allowing instructors to simulate hostile and friendly aircraft, ground targets, sensors and weapons capabilities for students. This enables them to train regularly in complex scenarios that would be impossible, or at least unaffordable, to fly in with real adversary threats, weapons and sensors. The result is that students can reach a higher standard of tactical proficiency in fewer flights, and at an earlier stage in their training, while flying lessexpensive aircraft than they would have had to in the past.

Changes to traditional flight-training requirements are also being driven by a need to produce junior pilots with tactical skills that are better suited to the capabilities of the F-35 Lightning II, and that are adaptable to future next-generation aircraft types. In this respect, however, there may be less to differentiate between the trainer aircraft on offer than one might expect. The actual capabilities of the F-35 and probable next-generation combat aircraft are highly classified. So, regardless of how fifth-gen-like a trainer cockpit and avionics are made, pilots will still need significant tactical retraining once they start to fly their actual frontline aircraft and are read into its true capabilities, tactics, techniques and procedures. A great deal of this tactical training for frontline tactics in the F-35 and other advanced fighters can be, and is, conducted in specialised simulators at the operational conversion unit (OCU) stage, and therefore does not involve many expensive flight hours on the jet itself.[4] Several trainer aircraft available for advanced military flight training have – or will soon offer – a cockpit equipped with a large area display (LAD), with formatting and functionality designed to mimic that of the F-35 and the latest 4.5-generation jets.[5]

In other words, there are multiple viable options for trainer-fleet modernisation from a tactical skillsdevelopment point of view. However, the development of student pilots' airmanship is just as important as tactical skills, enabling them to safely manage the risks inherent in allweather frontline flying in fast jets. Here, there is more to choose

3. Author interviews with Pilatus and Swiss Air Force instructors and subject matter experts (SMEs), Lucerne, 24–25 August 2025; Boeing test pilots and SMEs, Washington DC, 20 January 2026; Korean Aerospace Industries SMEs and Republic of Korea Air Force instructors, Gwangju Air Base, 18 December 2025; and Leonardo and Italian Air Force instructors, International Flight Training School, Sardinia, 13–14 November 2025.
4. Author interviews with F-35 instructor pilots at RAF Marham, 20 September 2022; HMS Prince of Wales, 27 August 2025; and Leeuwarden Air Base, 18 January 2024.
5. For example, the Boeing/Saab T-7A has a large-area-display cockpit, and one is under active development and testing for the next block version of the Pilatus PC-21, and for the Leonardo M-346A Block 20. Author interviews with Boeing test pilots and SMEs, Washington DC, 20 January 2026; Pilatus and Swiss Air Force instructors and SMEs, Lucerne, 24–25 August 2025; and Leonardo and Italian Air Force instructors, International Flight Training School, Sardinia, 13–14 November 2025.

from between the various training aircraft and solutions on offer. This paper aims to examine: 1) the main fast-jet trainer-aircraft acquisition choices available to policymakers in the UK and other NATO countries; and 2) the risk factors and requirements around tactical and airmanship skills that they should be considering when choosing between different options and cost tradeoffs.

The paper first explains the stages of flight training for fast-jet pilots in NATO air forces, followed by a discussion of the respective advantages and limitations of live flying training and simulator-based synthetic training as part of this process. The third chapter explains why training airmanship skills remains vital, alongside developing tactical skills. In the fourth chapter the paper examines the characteristics, advantages and potential drawbacks of the four foremost fast-jet trainer aircraft available to air forces as modernisation options, with the fifth chapter examining the potential importance of secondary mission sets for fast-jet trainer aircraft. This chapter also considers how the presence of a national requirement for such secondary missions may affect the choice of optimal aircraft for the main trainer mission set. The paper concludes with five rules for policymakers considering options for national or collaborative multinational fast-jet trainer modernisation.

Fast-Jet Pilot Training Stages

Traditionally, in NATO- and Western-aligned air forces, fast-jet training is divided between four 'phases'.[6] After Phase 4, new pilots will proceed to an OCU, also known as an operational training unit or 'B-Course', to learn how to operate the specific type of frontline aircraft that they will subsequently fly in their first operational squadron. The four phases differ subtly between air forces but can be broadly summarised as follows.

- **Phase 1: Elementary flying training**: Learn to fly an aircraft safely, including basic manoeuvres, aerobatics, radio procedures, and flying theory and regulations. Generally flown in piston-engine propellor aircraft with speeds of up to 120 knots (kts).
- **Phase 2: Basic flying training**: Learn military flying procedures, navigation, formation flying, the basics of combat manoeuvring, night flying, bad-weather flying, low-level flying, mission planning, pre-flight briefing and post-flight debriefing. Generally flown in turboprop engine aircraft with speeds of up to 280 kts.
- **Phase 3: Advanced flying training**: Learn to fly and operate jet aircraft, including how to conduct all the previously learned procedures (navigation, formation flying, and low-level, bad-weather and night flying) in heavier, faster aircraft with higher fuel consumption and greater sortie complexity. Initial introduction to fast-jet tactics and dogfighting. Traditionally flown in turbofan engine (jet) aircraft with speeds of up to 550–750 kts but increasingly flown in advanced turboprop engine aircraft with speeds of up to 370 kts.
- **Phase 4: Lead-in fighter training**: Learn basic frontline tactics; how to safely and effectively employ simulated air-to-air and air-to-ground weapons; and complex mission planning and debriefing, including weapons employment evaluation, and the basics of datalink and radar use. Generally flown in turbofan engine (jet) aircraft with speeds of up to 550–750 kts.

6. Nash, 'Fast Track to Fast Jet?'.

In any air force, students are constantly assessed and graded against rigorous standards throughout this process. They also learn the core skill sets at the heart of all capable Western-style air forces: mission planning, briefing and debriefing. Mission planning and briefing involve the student and instructor pilot going through every phase of an upcoming sortie. This includes discussing the planned route; weather; airfield and airspace issues; training rules and safety procedures in place at every stage of the flight; various reversionary courses of action if things go wrong or do not proceed as expected; and what tasks, responsibilities, tactics and radio communications are expected from them at each stage. Even for a relatively simple sortie, this process can take an hour or more and requires student pilots to absorb a huge amount of information and decide, ahead of time, what they will do in various planned or potential situations.[7]

Once they have flown a sortie, the student(s) and instructor(s) will debrief. This often means reviewing key phases of the flight in second-by-second detail using voice and video recordings of the cockpit displays of all aircraft, and usually a 3D digital recreation of the sortie using data from each aircraft and external instruments. Each decision and action taken by the student, and any others taking part in the sortie, will be questioned and assessed in forensic detail. For more complex flights, this can take several hours, and students are expected to absorb and learn from all feedback given – with improvements expected on subsequent flights, even as new training objectives and tasks are given in each mission.[8] This process of mission planning and debriefing is the same, regardless of whether the sortie itself is flown live in an actual aircraft or virtually in a high-fidelity simulator. However, there are, of course, various benefits and limitations to both live flying and simulator training, so all modern air forces use both in conjunction to train pilots.

7. Author observation from in-person site visit and participation in Phase 3 and 4 multi-aircraft training briefings, sorties and debriefing processes at Jyväskylä–Tikkakoski Air Base, 2 October 2024; Columbus Air Force Base, 7 February 2025; and Royal Australian Air Force (RAAF) Williamtown, 26 March 2025.
8. *Ibid*.

Balancing Live Flying and Simulator Training

As a rule, the synthetic training available in a high-fidelity simulator is excellent for practising tactics, cockpit procedures, and responses to simulated emergencies and equipment failures regularly, cheaply and safely. In a real aircraft, there are many pressing time constraints, such as time slots in training airspace, fuel availability, transit time to and from training airspace, and taxiing and traffic delays in the pattern at the airbase during departure and arrival. This means that not only is flying time inherently limited in each live sortie, but a significant proportion of the time available is spent on ground operations, air traffic control procedures, departure and arrival procedures in the pattern, and transits. While this is all useful training, it is of little use for learning tactics or complex manoeuvres, which must be flown in dedicated training airspace.

By contrast, a modern simulator can be set up so that students and instructor pilots start in the air. They can then repeat multiple training sets in quick succession to practise, experiment and correct mistakes without having to worry unduly about fuel, airspace restrictions or timings. At later stages, such as Phase 4, they can also practise tactics and weapons use that would otherwise require specialist firing ranges and large training airspace to train live. For example, in a simulator, pilots can accelerate to supersonic speeds at any altitude, jettison external fuel tanks and fire long-range weapons as required by the tactical scenario – all of which are heavily restricted or prohibited actions in most over-land training airspace.

However, there are many important skills in military flying training that can only be practised in a real aircraft. Simulators generally struggle to provide a sufficiently realistic perception of relative distance and closure speed and lack the feel that enables students to reliably and safely manage aircraft performance while conducting other tasks. This makes them unsuitable for teaching close-formation flying skills, safe basic fighter manoeuvre (BFM) tactics and safe rejoin manoeuvres.

Another obvious example is getting comfortable with flying, maintaining situational awareness, and continuing to work sensors and systems while under the G-forces created by manoeuvring an aircraft at speed. Simulators cannot produce G-forces, but even relatively gentle turns at 300–400 kts in a fighter aircraft can easily place pilots under 3–4 Gs. 1 G is a measurement of acceleration equal to normal felt gravity when stationary on Earth. Common frontline air combat manoeuvres and defensive manoeuvres to evade incoming missiles frequently produce 7–9 Gs, in some cases for sustained periods and/or repeatedly in quick succession.[9] These forces cause significant physical discomfort, disorientation, airsickness and rapid G-induced loss of consciousness (G-LOC), unless pilots are 'G-fit' and practise the appropriate muscle-strain and pressure-breathing techniques. Even under seven to nine times the felt force of gravity in a hard turn, pilots must continue to fly the aircraft precisely to maximise its performance and gain tactical advantage, operate sensors and weapons, communicate with the other pilots in their formation and maintain situational awareness. If pilots do not fly live sorties regularly, they simply cannot practise this skill set, and 'G-fitness' degrades rapidly even once acquired if they do not fly at least once or twice a week.[10] No amount of simulator training can prepare students for the effects of rapid-onset and sustained heavy G-forces – that can only be done during live flying in aircraft with sufficiently high performance to generate high G-forces during representative manoeuvres.

Another core skill set is the ability to fly, navigate, maintain close formation and land safely in bad weather conditions and/or at night. In conditions where visibility is too poor for safe visual navigation and deconfliction – known as instrument meteorological conditions (IMC) – pilots must fly according to their instrument readings and pre-planned navigation information, in coordination with air traffic control or military airspace battle managers when available. Although this sounds relatively simple, when flying, the inner ear plays tricks on a pilot's perception of acceleration, direction and even gravity once the eyes can no longer provide a reliable picture.[11] What this means in practice is that in IMC, pilots must often ignore their instincts. Especially after hard manoeuvres, pilots can feel like they are upside down, turning hard to one side or other, climbing or descending even though the aircraft is in level flight, and vice versa. In technical terms, pilots risk having an 'erroneous sense of the magnitude or direction of any of the aircraft control and performance flight parameters'.[12] This is known as 'spatial

9. Author observation in numerous fast-jet sorties including Tucson Air Force Base, 29 January 2025; Kingsley Field Air Force Base, 4 and 5 June 2025; Tactical Air Base 22, Malbork, 29 July 2025; Torrenjon Air Base, 11 September 2025; and Nancy-Ochey Air Base, 3 February 2026.
10. Author interviews with multiple fast-jet instructor pilots in frontline and training squadrons, including Columbus Air Force Base, 7 February 2025; RAAF Williamtown, 26 March 2025; Kingsley Field Air Force Base, 5–6 June 2025; Torrejon Air Base, 11 September 2025; International Flight Training School, Decimomannu Air Base, 14 November 2025; and Nancy-Ochey Airbase, 3–4 February 2026.
11. *Ibid.*; Todd E Heinle and William R Ercoline, 'Spatial Disorientation: Causes, Consequences and Countermeasures for the USAF', Defense Technical Information Center Compilation Part Notice ADP013861, <https://apps.dtic.mil/sti/tr/pdf/ADP013861.pdf>, accessed 30 March 2026.
12. Heinle and Ercoline, 'Spatial Disorientation'.

disorientation' and can easily become a major safety risk if pilots start to manoeuvre according to their instincts rather than what the instruments are telling them.[13]

Furthermore, when deployed, fast-jet pilots often operate in unfamiliar and complex airspace while carrying heavy external payloads. These factors further increase the challenges that military pilots face in recovering safely from spatial disorientation in IMC. The physical sensations that contribute to spatial disorientation, as well as several potentially misleading lighting and visual distortion phenomena that can occur in specific bad weather and/or nighttime conditions, cannot be replicated in a simulator. Nor can the instinctive fear that a pilot feels when lost and disorientated in a heavy, fast aircraft that is low on fuel in blind conditions.

Spatial disorientation is the leading killer of Western-trained fighter pilots, since it can rapidly lead to lethal situations in such fast, manoeuvrable aircraft. For example, US Air Force (USAF) records show that six of its pilots were killed flying fighter aircraft in the decade from the start of 2014 to the end of 2023.[14] Four of these fatal crashes occurred in IMC – three of them at night – and investigations concluded that spatial disorientation was the cause.[15] One of the others involved G-LOC, and the final one was due to incapacitation of the pilot due to unknown causes during a transit flight.[16] The picture is also similar across fighter aviation in the US Navy and US Marine Corps: the majority of fatal crashes over the past decade occurred in IMC, with spatial disorientation suspected or confirmed as a major factor.[17] In other words, statistically, fighter pilots are at greater risk of accidents during tactical training in IMC, and while flying to and from combat areas, than they are during active combat operations – especially if they have relatively limited live flying experience in IMC.

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13. Robert J Poisson III and Michael E Miller, 'Spatial Disorientation Mishap Trends in the U.S. Air Force 1993–2013', *Aviation, Space, and Environmental Medicine* (Vol. 85, No. 9, September 2014), pp. 919–24.
14. US Air Force Safety Center, 'Aviation Statistics', <https://www.safety.af.mil/Divisions/Aviation-Safety-Division/Aviation-Statistics/>, accessed 30 March 2026. The source provides statistics by aircraft for F-15, F-16, F-22 and F-35 from FY2014 to FY2023, which is the last year displayed at time of writing.
15. Brian Everstine, 'USAF: Rapid Descent Caused Fatal F-16 Crash in December', *Air Force Times*, 13 July 2015, <https://www.airforcetimes.com/news/your-air-force/2015/07/13/usaf-rapid-descent-caused-fatal-f-16-crash-in-december/>, accessed 30 March 2026; United States Air Force Aircraft Accident Investigation Board Report, 'F-16C, T/N 86-0317', 8 December 2020, <https://www.afjag.af.mil/Portals/77/AIB-Reports/2020/8DEC20%20ACC%20F-16%20Michigan%20AIB%20Report.pdf>, accessed 30 March 2026; United States Air Force Accident Investigation Board Report, 'F-15C, T/N 86-0176', 15 June 2020, <https://www.afjag.af.mil/Portals/77/AIB-Reports/2020/15JUN20%20F-15C%20TN%2086-0176%20AIB%20Report.pdf>, accessed 30 March 2026; Air Combat Command, 'ACC Releases Accident Investigation Board Report for F-16 Crash at Shaw AFB', 9 November 2020, <https://www.acc.af.mil/News/Article-Display/Article/2409430/acc-releases-accident-investigation-board-report-for-f-16-crash-at-shaw-afb/>, accessed 30 March 2026.
16. Air Combat Command, 'F-16CM Thunderbird Accident Investigation Released', 16 October 2018, <https://www.acc.af.mil/News/Article-Display/Article/1663212/f-16cm-thunderbird-accident-investigation-released/>, accessed 30 March 2026; United States Air Force Accident Investigation Board Report, 'F-15C, Tail Number 86-0157', 27 August 2014, <https://www.airandspaceforces.com/PDF/DRArchive/Documents/2015/July%202015/082714_F15C_VA.pdf>, accessed 30 March 2026.
17. Author interview with the commanding officer of the 49th Fighter Training Squadron in charge of the Introduction to Fighter Fundamentals training, Columbus Air Force Base, 7 February 2025.

The increasingly common incorporation of automatic aircraft-collision avoidance systems and ground-collision avoidance systems in fifth-generation aircraft – and some advanced fourth-generation aircraft, such as the F-16, Gripen and Rafale – reduces the dangers, but does not eliminate them completely.[18] Training pilots well enough to manage these dangers is a core responsibility of any military flight-training system.

To manage these risks in a flying training system, student pilots must learn to recognise the symptoms of spatial disorientation, control and manage fear, and recover safely through extensive and realistic IMC flying. This is unpopular with many pilots, because IMC navigation and recovery procedures are comparatively boring to fly – at least until something goes wrong – as they involve flying without looking outside of the aircraft and generally require more complex flight planning and concentration than flying in visual flight rules. Flying hours are expensive, and familiarity and practice sets involving relatively standard administrative flying (such as navigation, approach and pattern work), in real or simulated IMC, takes up flying time that might otherwise be used for tactical training. Tactical training in IMC at fighter speeds is also critical, generally far from boring, and often even more challenging to master safely than IMC navigation and recovery procedures.[19]

One option is to give students more instrument flight rules (IFR) flying time in cheap piston-engined or turboprop-engined aircraft, either as part of Phase 1 or 2 training, or with contracted civilian flight schools, which is better than nothing. But another key facet of frontline jet flying is the speed at which things happen. One aspect that instructor pilots consistently emphasised during the research for this paper is that it is not uncommon for students to be perfectly good IFR pilots at two miles per minute at 100 kts in a pistonengined aircraft, but then really struggle to be safe and build IFR proficiency at 6–7.5 miles per minute in a fast jet cruising at 300–400 kts.[20] The same can be true of the ability to judge and respond to adverse weather during critical phases of flight, and to manage closing speed and energy states during dynamic phases of flight while under task load.[21] Prior experience in slower aircraft is a useful foundation. But a key metric for assessing whether flight safety risks on the frontline are being unwittingly accepted in flight training should be how many flying hours new pilots have spent training in real IMC, and at night, at representative jet speeds.

18. Aaron M U Church, ‘The Science of Avoidance’, *Air Force Magazine*, February 2016, <https://www.airandspaceforces.com/PDF/MagazineArchive/Documents/2016/February%202016/0216avoidance.pdf>, accessed 30 March 2026; Stefano D’Urso, ‘Upgraded Rafale F3-R Achieves Initial Operational Capability with the French Air Force’, *The Aviationist*, 16 December 2019, <https://theaviationist.com>, accessed 30 March 2026.
19. Author interviews with French Air and Space Force instructor pilots, Nancy-Ochey Air Base, 3–4 February 2026.
20. Author interviews with: RAAF Fighter Weapons Instructor pilots, RAAF Amberley, 15–16 September 2025; US Air Force Fighter Weapons Instructor pilots, Columbus Air Force Base, 7 February 2025; French Air and Space Force instructor pilots, Nancy-Ochey Air Base, 3–4 February 2026.
21. *Ibid*.

The Continuing Importance of Airmanship

The abilities, described above, to fly precisely and operate safely in IMC at high speeds, maintain good G-fitness and techniques, and other key skills such as air traffic control and airspace interactions in busy areas, are skillsets that fall under the generic term 'airmanship'. Broadly, airmanship refers to the capability to safely and precisely control the aircraft, navigate, communicate, and make good decisions quickly and calmly, especially when things start to go wrong. Airmanship skills can be thought of as separate from tactical skills such as sensor and weapon management, tactical manoeuvring and maintaining situational awareness in complex situations. Good fighter pilots require both. Tactical skills are generally easier to train efficiently in a synthetic environment with good simulators, especially if they are linked, to enable multiple pilots to train together in a single virtual scenario. Airmanship skills are generally heavily tied to the amount of high-quality live-flying training hours that students receive. One additional, notable exception is that recognition, diagnosis and recovery procedures for technical failures or predictable emergency scenarios are practised regularly in simulators.

However, assessments of the risks and opportunities involved in various tradeoffs for modernisation options too often focus primarily on the efficiency with which tactical skills can be trained and exclude or downplay airmanship. The balance between live flying and simulator training is one area where this can introduce risk. Equally, debate on the merits of using cheaper turboprop trainers (such as the Pilatus PC-21 or Embraer A-29 Super Tucano) to replace legacy advanced jet trainers (such as the Hawk and Alpha Jet) in Phase 4 flying training tends to focus on the tactical complexity that can be created for student pilots using synthetic sensors, weapons and other in-cockpit aids.[22] This is an important factor to evaluate: can tactical skills be taught adequately enough in a modern turboprop trainer to efficiently generate pilots who can then

22. Fighter-trainer manufacturer presentations and accompanying panel discussions at the International Fighter Conference, Rome, 4–5 November 2025, and the International Flight Training Conference, Lucerne, 31 March 2026–2 April 2026.

quickly learn to operate the radar, weapons and other tactical systems on a frontline jet at the OCU? The answer is, in many cases, yes. However, there is another question that should be considered, which is to what extent airmanship skills can be sufficiently trained in turboprop trainer aircraft to allow pilots to reliably operate far faster, heavier, jet-powered frontline aircraft safely, especially in difficult conditions (such as when low on fuel in unfamiliar airspace in IMC).

One argument in favour of using advanced turboprop trainers for Phase 3, and even Phase 4, is that they are several times cheaper to operate per hour than an advanced jet trainer. Pilots can therefore get more live flying hours out of any given training budget, enabling them to build better core airmanship and basic tactical skills before they get to the frontline.[23] More cynically, the same number of live-flying training hours as can be flown in a jet trainer can be flown for significantly less money in an advanced turboprop. The performance, G-forces and LVC training capabilities are good enough in high-end turboprop trainers to allow most pilots who reach the end of Phase 4 to quickly transition to far heavier and faster frontline jets. Several air forces (including the French Air and Space Force, Swiss Air Force, Emirati Air Force and Qatari Air Force) all now conduct Phase 3 and 4 training in the PC-21, before student pilots proceed straight to the OCU for F/A-18, Rafale, Mirage 2000 or F-16.[24] The Chilean Air Force and Portuguese Air Force do the same with the A-29 for students destined for the F-16.[25] Notably, however, these air forces all operate significant numbers of twin-seat fighters in their OCU squadrons. This means that instructor pilots can take over at any point if there are issues during initial conversion sorties and avoids the risks inherent in student pilots going straight from a PC-21 or A-29 to a single-seat frontline jet.

The main argument against this approach is that student pilots training exclusively on turboprop aircraft can only be exposed to cruise speeds approaching 300 kts; very brief spikes of around 7 Gs when turning hard after a dive to reach maximum speed; and sustained forces of around 4 Gs during manoeuvres. They therefore face a huge jump in the acceleration, speeds, and resulting G-onset rates and sustained G-forces that they will routinely experience during their OCU conversion course on a frontline jet fighter such as a Typhoon, Rafale or F-16. For student pilots coming straight from a turboprop, it can be a major challenge to safely and precisely manage the power, weight and therefore far higher closure speeds, greater acceleration and slower deceleration in a frontline jet during formation flying, rejoin manoeuvres and early BFM sorties. Resultant mistakes by student pilots during early fast-jet sorties can present serious flight safety risks for both students and instructors, even in twin-seat jets. There was a strong consensus among instructors interviewed for this study that flight safety incidents were noticeably more common in student pilots who had come

23. Author interviews with Embraer SMEs, Lisbon, 14 August 2024; and Pilatus SMEs, Lucerne, 24–25 August 2025.
24. Author interviews with Pilatus SMEs at the Pilatus factory, Switzerland, 25 August 2025.
25. Author familiarisation flight in an A-29 Super Tucano, Portugal, 14 August 2024; author interviews with Chilean Air Force instructor pilots, Iquique Air Base, 9 October 2024.

straight from turboprops in Phase 4, despite the real benefits that such students had often received from greater access to synthetic training than previous generations.[26]

Synthetic training is particularly vital for the increasing number of air forces that operate only singleseater frontline aircraft like the F-35 and F-22. It is also vital for the RAF, whose Typhoon fleet has only a few twin-seat airframes remaining in service with the OCU.[27] While advanced simulators cannot simulate G-forces, they enable student pilots to learn the cockpit procedures, and experience the handling characteristics and performance of their new frontline type in great detail, in a virtual setting, before they ever actually fly it. This apparently works well in single-seat OCUs, with few issues arising among pilots conducting their first solo sorties in a single-seat frontline jet after extensive simulator-based type-familiarisation training.[28] However, all of the air forces that currently operate single-seat only OCU squadrons use advanced jet trainers, such as the T-38C, Hawk T2 or M-346A, for their Phase 4 flying training, rather than turboprop trainers.

26. Author discussions with instructor pilots at OCU and Phase 4 squadrons at Columbus Air Force Base, 7 February 2025; RAAF Williamtown, 26 March 2025; Kingsley Field Air Force Base, 5–6 June 2025; and Nancy-Ochey Airbase, 3–4 February 2026.
27. Ministry of Defence figures from November 2019 showed three Typhoon T3 twin seat aircraft remaining on strength with 29 Squadron, and only two other T3 aircraft in the rest of the Royal Air Force Typhoon fleet. See HM Government, 'Information Regarding a Full List of Tail Codes and Tail Numbers about UK Military Aircraft (Annex A)', 15 November 2019, <https://assets.publishing.service.gov.uk/media/5dce8cc5e5274a076734209a/Aircraft-Tail-Numbers-Annex-10288.pdf>, accessed 30 April 2026.
28. Author discussions with instructor pilots in OCU squadrons at RAF Coningsby, 21 March 2024, and RAAF Williamtown, 26 March 2025; and with RAF/Royal Navy instructor pilots on HMS Prince of Wales, 28–29 August 2025.

Future Trainer Aircraft Options and Flight Training Approaches

The training aircraft currently available to air forces looking to replace the legacy fast-jet trainer types used in Phase 3 and 4 training all have different strengths, costs and limitations, which are explored below.

The turboprop-powered Pilatus PC-21, and jet-powered Leonardo M-346A, Boeing/Saab T-7A, KAI T-50 and TA-50, are the most obvious options for most Western air forces. A fairly new entrant to the market is the Turkish Aerospace Industries Hürjet, which is being developed for the Turkish Air Force and has also been ordered by the Spanish Air Force.[29] Another turboprop option is the Embraer A-29 Super Tucano, which is primarily configured as a light-attack aircraft, but is also used as a Phase 3 and 4 trainer in several countries, including Portugal and Chile.[30]

The PC-21 offers considerable savings in terms of operating costs compared to jet-powered alternatives such as the M-346A, T-7A or T/TA-50.[31] The cockpit is comparable to those found in frontline fighters such as the F-16 and F/A-18, and includes multifunction displays (MFDs), a headsup display (HUD), HOTAS controls, ejection seats, the ability to simulate radar, some datalink functions, a targeting pod, and generic air-to-air and air-to-ground weapons. Its lightweight, powerful turboprop engine and comparatively high wing loading, coupled with a yaw-compensation

29. Stefano D'Urso, 'First Look at the Full-Size Model of the Hurjet in Spanish Air Force Markings', *The Aviationist*, 11 May 2025, <https://theaviationist.com>, accessed 1 February 2026; Dominic Perry, 'Spain Signs for 30 TAI Hurjet Trainers with Deliveries to Begin in 2028', *Flight Global*, 30 December 2025, <https://www.flightglobal.com>, accessed 1 February 2026.
30. Author familiarisation flight in an A-29 Super Tucano, Portugal, 14 August 2024; author discussions with Chilean Air Force instructor pilots, Iquique Air Base, 9 October 2024.
31. While exact cost comparisons will vary between types and air forces, Pilatus claims that customers have reported a cost reduction of over 50% compared to jet trainers. However, it should be noted that this is stated in a marketing statement by the aircraft manufacturer. See Pilatus, 'The French Air Force Buys Another Nine PC-21', media release, 16 July 2021, <https://www.pilatus-aircraft.com/en/news/the-french-air-force-buys-another-nine-pc-21>, accessed 30 March 2025.

system, mean that it can reach 300 kts in a cruise and, at those speeds, has a very jet-like feel with little propellor-vibration or yaw effects felt in turns.[32]

Figure 1: Pilatus PC-21 Pilatus HB-HZC

Source: Carlos Menendez San Juan / Wikimedia Commons

These characteristics allow air forces that use the PC-21 for Phase 3, and even Phase 4, training to simulate the pace at which trainee fast-jet pilots will need to work in frontline fast jets during many tasks. For example, a low-level navigation route can be flown at 300 kts, with a pop-up to acquire a pre-planned target with a targeting pod and strike it with a simulated guided weapon delivery. The length of each part of the route is shortened proportionally so that, at 300 kts, each course change and required action occurs at a time interval similar to what it would be if flying the same task in a faster jet-powered trainer or fighter at 450–500 kts, giving them a realistic task load and timelines.[33] Similarly, as many frontline fast jets generally fly at 300–350 kts as an 'admin speed' when not actually performing combat manoeuvres, the PC-21 can cruise fast enough to provide a semirepresentative working pace for student pilots performing IFR navigation procedures and pattern work.

In theory, an air force that chooses to purchase the PC-21 instead of a new advanced jet trainer could give its student pilots significantly more live flying time during Phases 3 and 4 for the same budget, due to its lower operating costs. This could help reduce the risks associated with pilots entering the frontline with far less live flying experience at

32. Author familiarisation flight in a PC-21, Switzerland, 25 August 2025.
33. Author interviews with a Swiss Air Force PC-21 instructor pilot with prior experience as a frontline F/A-18C/D instructor pilot, Lucerne, 25 August 2025.

representative jet speeds than in previous generations. In particular, student pilots could get more live IFR flying experience in real and simulated IMC at around 300 kts, before they have to do the same thing in heavier, faster frontline jets. However, it unavoidably means a significantly greater jump when moving from Phase 4 training to an OCU. With a turboprop-powered trainer in Phase 4, pilots at an OCU are not only learning to fly and operate the systems and tactics on their specific frontline jet – they also must learn how to fly a jet turbofanpowered aircraft for the first time. This means more time spent learning relatively basic jethandling and systems-management skills, while flying frontline aircraft that are very expensive to operate. This also entails flying additional hours on fighter airframes that are manufactured with a finite fatigue life, which will consequently run out of flying hours sooner than if student pilots did jet conversion on a jet trainer before coming to the OCU. The requirement for more sorties for each student pilot at the OCU also means that more qualified instructor pilots must be assigned to teach them, rather than serving in operational fighter squadrons.

For air forces such as the Swiss Air Force, and the French Air and Space Force, which operate considerable numbers of twin-seater variants of their frontline fighters, this trade off can be justified. Cost savings made at the Phase 3 and 4 training stages from not having to operate a more expensive jet trainer aircraft probably outweigh the resulting additional costs accrued on frontline aircraft at the OCU. As tactical skill sets can be sufficiently trained in a PC-21, there are rarely any issues that prevent student pilots who come directly from that aircraft from achieving the required tactical standards at the OCU – even if it takes some additional type-familiarisation flights to get there.[34]

From an airmanship point of view, safety risks are managed by instructors guiding students through the considerable jump from PC-21 to F/A-18D or Rafale B in a twin-seat aircraft for the first few flights, enabling them to take over at any point if required. This mitigates, but does not eliminate, flight safety risks that are inherently accepted when students come to the OCU straight from a turboprop trainer aircraft in Phase 4. However, for air forces that operate fighters with no twin-seat variant (such as the F-35), the jump from even a high-performance turboprop like the PC-21 straight to a first solo sortie in a frontline fighter involves significantly more risk, even with the benefit of extensive preparation beforehand in a modern simulator. While it can reach greater G-forces during manoeuvres and operate at higher speeds than other turboprop trainers (such as the PC-9/T-6 Texan II, PC-7 and A-29 Super Tucano), even the PC-21 has to be flown specifically with the intent to generate short periods of high G-forces, which cannot then be sustained like a fighter or jet trainer. Pilots at the OCU will therefore be accustomed to inherently less energetic and more predictable G-onset and acceleration characteristics than if they did their Phase 3 and/or 4 training in an advanced jet trainer.

34. Author interviews with a Swiss Air Force PC-21 instructor pilot with prior experience as a frontline F/A-18C/D instructor pilot, Lucerne, 25 August 2025, and with French Air and Space Force instructor pilots, Nancy-Ochey Air Base, 3–4 February 2026.

One area in which this would be of particular concern is when teaching initial BFM sorties at the OCU on very high-energy aircraft such as the Typhoon. It is simply impossible to come anywhere near replicating, in a turboprop aircraft, the closure rates, G-onset, sustained Gforces, and acceleration and speed management challenges that come with dogfighting in a jet like a Typhoon.[35] Furthermore, the necessary proximity of other rapidly manoeuvring aircraft during BFM means a significant risk of collisions if students make split-second miscalculations or suffer G-induced loss of consciousness. Therefore, if an air force has a considerable number of twin-seat frontline jets, the PC21 is likely to be more attractive as a Phase 3 and 4 trainer option than it is for an air force with mostly or only single-seat OCUs.

For air forces looking for a modern, like-for-like replacement of their old Phase 3 and 4 jet trainers (such as Hawk and Alpha Jet), the Leonardo M-346A is perhaps the most obvious choice. The aircraft is mature, with a second-generation Block 20 variant replacing the current Block 10 in production from 2028 onwards.[36] As one would expect, the cockpit is modern and fighter-like with full HOTAS controls, a HUD, MFDs (to be replaced with an LAD in the Block 20), and simulated air-to-air radar, datalink functions, air-to-ground radar mapping, targeting pod and weapons, all with sufficient fidelity for excellent lead-in fighter training.[37] The M-346A also offers slightly greater performance and more energetic flight characteristics than the first- or second-generation Hawk, thanks to two non-afterburning F124 engines that give an impressive thrust-to-weight ratio and transonic performance in level flight.[38] With a relatively low wing loading, it can also reach 8 Gs, and then sustain far higher G-forces and speeds than a high-performance turboprop during representative combat manoeuvres. It can also reach a high angle of attack (or 'alpha') of up to 30 degrees. This enables trainee pilots who are destined for fighters with high-alpha performance (such as the F/A-18 family or the F-35) to experience that extreme part of the flight envelope earlier in their training, with an instructor on board and with full carefree handling.[39] Twin engines also provide a greater safety margin than other competitors in the event of engine failures due to debris ingestion or bird strikes, as the aircraft can take off, land and even perform aerobatics safely on one engine.

35. Author experience of basic fighter manoeuvres (BFM) sortie in a PC-21, Switzerland, 25 August 2025; and simulated BFM in an A-29 Super Tucano, Portugal, 14 August 2024, and in a Typhoon at RAF Coningsby, UK, 21 March 2024, and at Nörvenich Air Base, Germany, 3 November 2023.
36. Author interviews with Leonardo SMEs and M-346A programme test pilot, International Flight Training School, Decimomannu Air Base, 13-14 November 2025.
37. Author familiarisation flight in an M-346A, Decimomannu Air Base, 14 November 2025.
38. Author familiarisation flights in an M-346A, Decimomannu Air Base, 14 November 2025; a Hawk 126, RAAF Williamtown, 26 March 2025; and a Hawk 66, Jyväskylä–Tikkakoski Air Base, 2 October 2024.
39. Author familiarisation flight in M-346A, Decimomannu Air Base, 14 November 2025. Carefree handling means that the pilot can make any control inputs they wish, and the flight control system will ensure that airframe stress limits are not exceeded, and that the aircraft will not stall, spin or otherwise depart from controlled flight.

Among the jet-powered options for fast-jet trainer modernisation, the M-346A is also arguably the best suited for Phase 3 training. This is because its digital flight control system can be 'tuned down' with selective modes that reduce the pitch and roll sensitivity, and limit the maximum G-forces that can be induced.[40] This allows student pilots coming out of Phase 2 from turboprop aircraft with relatively limited performance (such as the T-6 Texan II or PC-7), or even potentially from pistonengine basic trainers, to become familiar with flying a fast-jet trainer gradually, as the full performance envelope can be enabled as they gain confidence and proficiency. In terms of its effectiveness in Phase 4, the LVC capabilities and performance have enabled users (such as the Italian Air Force) to bring significant parts of the training syllabus that used to be done on more costly frontline aircraft at the OCU stage, forward into Phase 4.

Figure 2: Alenia Aermacchi T-346A Master MM55155

Source: Gian Marco Anzellotti / Wikimedia Commons

The Boeing/Saab T-7A and KAI T-50 are both slightly further up the performance spectrum towards being fully-fledged fighter aircraft, as they have higher wing loadings than the M-346A and are powered by a single afterburning F404 engine (a variant of the one used by the F/A-18C/D Hornet). This means that they fly even more like a frontline fighter than the M-346A, in terms of their performance and how the

40. Author familiarisation flight in M-346A, Decimomannu Air Base, 14 November 2025.

controls feel. Both have a similar fighter-like cockpit-design philosophy to the M-346 and PC21, with ejection seats, HOTAS controls, a HUD, MFDs (in the case of the T-50), and a single LAD (in the case of the T-7A). Both are also designed around an LVC-centric approach to training, with the capability to simulate a range of radar modes, targeting-pod functions, weapons and datalink functions to train pilots in tactical skills, without having to pay the acquisition and maintenance premium of carrying real sensors, datalinks and weapons.

Figure 3: Boeing test pilots conduct taxi tests of the T-7A Red Hawk at the Boeing aircraft delivery center in St. Louis, Missouri, 22 June 2023

Source: Chase Kohler / Wikimedia Commons

The T-7A is designed primarily to replace the ageing T-38C Talon for US Air Force Phase 3 and 4 training.[41] The cockpit is optimised to train pilots destined to fly the latest fifth- and next-generation fighters, with a customisable LAD interface that mimics the cockpit layout of the F35, as well as some advanced fourth-generation fighters such as the F-15EX.[42] Once the aircraft is in large-scale use for training, it is likely that the USAF will start to explore the reallocation of Phase 3 sorties. For example, those that are currently dedicated to safely managing the T-38's tricky flight characteristics, but that are not relevant for modern frontline types equipped with digital flight-control systems, could be reallocated to focus on developing better tactical skills at an early stage. The T-7A has faced considerable delays due to a range of contractual issues,

41. Thomas Kaminski, 'Celebration of the T-38 Talon', *Key Aero*, 21 October 2025, <https://www.key.aero>, accessed 1 February 2026.
42. Author interviews with Boeing T-7A SMEs and test pilots, Washington DC, 20 January 2026.

manufacturing challenges and disruption from the Covid-19 pandemic, but initial deliveries to the USAF Education and Training Command began in December 2025.[43] It represents the newest of the advanced fast-jet trainer options currently in production, and will undoubtedly be produced at a considerable scale. The USAF requirement is for around 350 aircraft,[44] and BAE Systems recently announced a partnership with Boeing and Saab to market the aircraft as a replacement for the RAF's Hawk T1 and Hawk T2, with a sub-assembly line in the UK.[45]

In the ROKAF, the T-50 is only used for Phase 3 training, with the more advanced TA-50 variant being used for Phase 4 lead-in fighter training. The TA-50 forgoes LVC capabilities, but carries a real radar, and has real air-to-air and air-to-ground weapons carriage and delivery capabilities, and a proprietary datalink.[46] This makes it more complex to maintain as a Phase 4 trainer than its competitors, but means that it can also perform as a light fighter for air defence, Quick Reaction Alert (QRA) or adversary air missions if required. It has also enabled the ROKAF to reduce the number of sorties in its KF-16 OCU course considerably, because so much of the tactical conversion syllabus can be done more cheaply in the TA-50 and handling is similar.[47] Compared to the T-7A, both the T-50 and TA-50 have around 10% more internal fuel capacity, are routinely flown with a single external fuel tank on the centreline, and can also carry two wing-mounted fuel tanks. The T-7A cannot carry external fuel tanks in its current form, although they could be developed as an option for underwing carriage in future. The fuel capacity and lack of external tanks may be a limiting factor for air forces that have to fly with relatively high 'bingo' fuel safety margins due to regular bad weather, and/or limited diversion-airfield options near their main training base(s).[48]

43. Ryan Finnerty, 'T-38C Phase Out Begins as USAF Flight School Receives First T-7A Trainer', *Flight Global*, 12 December 2025, <https://www.flightglobal.com>, accessed 1 February 2025.
44. Michael Marrow, 'Exclusive: Air Force to Approve T-7 Trainer Production Within Days', *Breaking Defense*, 22 February 2026, <https://breakingdefense.com/2026/02/exclusive-air-force-to-approve-t-7-trainer-production-within-days/>, accessed 30 April 2026.
45. Thomas Newdick, 'T-7 Red Hawk Jet Trainer Offer to United Kingdom Includes Local Assembly', *The War Zone*, 18 November 2025, <https://www.twz.com>, accessed 1 February 2026.
46. Author interviews with Korean Aerospace Industries SMEs on the T-50, TA-50 and FA-50, Seoul, 3 July 2025; author familiarisation flight in TA-50, Gwangju Air Base, Republic of Korea, 18 December 2025.
47. Author interviews with Korean Air Force instructor pilots on the T-50, TA-50 and FA-50, Gwangju Air Base, Republic of Korea, 18 December 2025.
48. 'Bingo' is a codeword for a pre-planned fuel total at which the pilot must stop what they are doing and head back to base. It consists of the expected amount of fuel required to reach home base from the training or operational area, plus a safety margin sufficient for several missed approaches and circuits, followed by a diversion to a nearby airfield if the home-base runway is unusable due to an incident or bad weather. If the nearest diversion option is far away, and/or there is a higher likelihood of bad weather making one or more primary or backup airbase options unusable, a higher bingo will be needed than if there is an alternative runway nearby and the weather is good.

Figure 4: KAI FA-50 Fighting Eagle of ROK AirForce

Source: Republic of Korea Armed Forces / Korean Airspace Industries / Wikimedia

Each of the forerunner options for fast-jet trainer modernisation have features that will make them comparatively more or less attractive to different potential air force users. The optimal choice for a given air force will depend on how it wants to modernise its Phase 3, 4 and OCU training structure. If there is considerable twin-seater frontline jet and instructor capacity to do a longer OCU conversion course, then making operating cost savings, and flying more and cheaper live hours in a PC-21 throughout Phase 4, and possibly Phase 3, may be more efficient and deemed to have manageable airmanship risks. If air forces have already modernised Phase 2 and 3 training with a low-medium performance turboprop trainer, but do not want the risk of sending pilots straight from a Phase 4 turboprop phase to a single-seat frontline jet at OCU, then the M-346A or T-7A are likely to be highly competitive options. This will be especially true if it enables part of the existing OCU syllabus to be moved into Phase 4, allowing a smaller OCU with fewer instructor pilots and aircraft, which can be used in frontline squadrons instead. This can offset at least some of the cost of buying a new fast-jet trainer rather than an advanced turboprop. Finally, an additional factor in favour of something like the TA-50 (at the high end) is if an air force has additional requirements, such as lightfighters, companion frontline trainers or adversary red-air provision.

Secondary Duties: Light-Fighter Missions, Red Air Provision and Companion Frontline Trainers

Historically, many air forces have also operated their advanced fast-jet trainer aircraft in secondary roles alongside their primary training mission. For example, the RAF operated the BAE Systems Hawk T1 as a red air adversary for frontline fast-jet squadrons, and to simulate air and anti-ship missile attacks for the Royal Navy within 100 Squadron until 2022.[49] Many also use their advanced fast-jet trainer as the mount for a national aerobatic display team, such as Hawk for the British Red Arrows and Finnish Midnight Hawks, Alpha Jet for the Patrouille de France, MB-339 for the Italian Frecce Tricolori and T-50 for the South Korean Black Eagles. Given the current global geopolitical security situation, and how chronically overstretched defence budgets and industrial capacity are relative to the need for additional frontline aircraft, ground-based air defences, air-launched munitions and a host of other needs, it would be frankly self-indulgent to skew a choice of fast-jet training solutions around one choice or other for a display team. However, there are two obvious secondary missions, described below, that ought to be considered within requirement-scoping activities and weighed up for inclusion for each air force.

The first is a light-fighter mission to provide a secondary source of QRA capacity and defensive counter-air (DCA) capability against high-volume, relatively simple threat systems such as one-way attack (OWA) unmanned aerial vehicles like the Russian Geran 2/3 and Gerbera series. There are many day-to-day QRA tasks that represent an inefficient use of high-end fighter aircraft, such as intercepting unresponsive airliners

49. Josef Campion, '100 Squadron: RAF's Hawk T1 Aggressor Unit Disbands', *Key Aero*, 27 March 2022, <https://www.key.aero>, accessed 27 January 2025.

and general aviation pilots. DCA against OWA drones is also an expensive and inefficient way to burn through airframe hours and munitions for frontline fastjet types.[50] This is especially likely to be a concern for air forces that have already entirely transitioned – or soon will – to the F-35 for their frontline fighter force, and for those looking to develop and procure next-generation fighters such as the Tempest within the Global Combat Aircraft Programme. Fifth-generation fighters are purpose-designed to penetrate and operate effectively against the latest Russian and Chinese ground-based air defences and combat aircraft, and demand a considerable price and complexity premium to be able to do so. Next-generation fighters are likely to be larger, more expensive to operate, and purchased in even smaller numbers. It is therefore logical to purchase an advanced fast-jet trainer that can also be configured as a credible light fighter. These could conduct QRA scrambles against non-responsive civilian aircraft in peacetime; for example, to cover the air-policing mission and conserve high-end fighter capacity for air defence and other offensive mission sets. Light-fighter units could also train specifically for DCA missions against OWA drone threats, using targeting pods, small-form active electronically scanned array radars, and laser/infrared-guided rockets such as the BAE Systems Advanced Precision Kill Weapon System II.[51] This would enable the inherently small primary fifth/next-generation fighter fleets to concentrate their limited flying hours, munitions stocks and combat mass on primary missions where their advanced capabilities are needed.

The next secondary potential mission set to consider is as a companion frontline training aircraft alongside next-generation fighters. Ambitious range, internal weapon load and broadband stealth are common features of next-generation fighters such as the American F-47, British-Japanese-Italian Tempest/GCAP and Franco-German-Spanish SCAF/FCAS. These aircraft are therefore all likely to be significantly larger and more expensive to operate than the current-generation combat aircraft they are being developed to replace. However, if they have pilots, those pilots will need to remain current in all kinds of critical airmanship skills, such as nighttime and bad-weather tactical flying; working under high-G manoeuvres; and managing, diagnosing and reacting appropriately to complex system failures while in flight. The latter is one of the things that even advocates of AI-augmented next-generation fighters still often concede might be necessary – a pilot who can take over if the system has a problem. Pilots will also need to remain current and have excellent airmanship to be able to do

50. For example, the AIM-120C/D AMRAAM missiles fired by Royal Netherlands Air and Space Force F-35As to down two Russian Gerbera decoy drones violating Romanian airspace in late 2025 cost well over $1.2 million each, whereas the Gerberas cost around $20,000. Furthermore, each F-35A can carry up to four AIM-120C/D missiles, while Russia routinely launches 250–350 Geran 2/3 and Gerbera drones into Ukraine in a single night. Author observation of live Ukrainian air defence operations, Ukraine, 7–15 January 2026. For AIM-120C/D unit costs for the US military, see US Department of Defense, 'Program Acquisition Costs by Weapon System: Fiscal Year 2026 Budget Request', July 2025, pp. 5–7, <https://comptroller.war.gov/Portals/45/Documents/defbudget/FY2026/FY2026_Weapons.pdf>, accessed 30 April 2026.
51. BAE Systems, 'APKWS® Laser-Guidance Kit', <https://www.baesystems.com/en/product/apkws>, accessed 27 January 2025.

this. Even for pilots who fly multiple times a week, taking over and safely navigating an aircraft with failing systems to a safe landing in bad weather and/or at night, through complex airspace in unfamiliar areas, and with potentially very limited or erroneous information and sensor readings, is a serious challenge.[52] The consequences of failure are, at least, the loss of one of a small number of next-generation combat aircraft available and, at worst, the potential death of the pilot.

If pilots are to remain in the frontline at all, they will have to fly regularly enough to remain current as operators, especially when sensors, systems and/or software fail – inevitably in challenging circumstances. As the affordability case for next-generation fighters relies at least partially on them flying far fewer live hours than current-generation jets, it seems worth exploring whether there is a resulting requirement to have mixed squadrons. Companion trainer aircraft could be flown for Gfitness, instrument flying and general airmanship at a far lower cost than the primary frontline nextgeneration type. And if that is a foreseen requirement, it would make a great deal of sense to purchase an advanced fast-jet trainer type for a primary training requirement that could also provide a common fleet for a companion fighter force. The USAF has long used the T-38A variant of the Talon for precisely this role, and for units that operate particularly scarce and expensive frontline types. It still does in the case of U-2S Dragon Lady and B-2 Spirit squadrons.[53]

These secondary tasks are worth considering, because if they do form part of a country's future requirements, they may be sufficient to tip the balance of cost/benefit judgement between the different trainer aircraft and training-pipeline configuration options available. For example, an air force with a light-fighter, frontline companion-trainer or aggressor requirement is likely to see considerably more value in a Phase 4 training solution that can also perform well in those missions (most notably the TA-50, the upcoming M-346FA, or possibly a T-7 light fighter derivative). The TA-50 is already a credible light fighter. In fact, it is better optimised for that role than for Phase 3 training, as it has genuine fighter-class performance, a radar, and air-to-air and air-to-ground weapons capabilities, and does not have the capacity for LVC training with simulated weapons or targeting pods.[54] The M-346FA is a light-fighter derivative of the M-346A that has been purchased by the Austrian Air Force.[55] The T-7 was also designed with sufficient performance margin and load-carrying potential to enable a straightforward light-fighter conversion if required.[56] However, this would entail more

52. Author interviews with RAAF fighter weapons instructor pilots, RAAF Amberley, 15–16 September 2025; and US Air Force fighter weapons instructor pilots, Columbus Air Force Base, 7 February 2025.
53. Thomas Kaminski, 'Celebration of the T-38 Talon', *Key Aero*, 21 October 2025, <https://www.key.aero>, accessed 1 February 2026.
54. Author type-familiarisation flight in TA-50, Gwangju Air Base, Republic of Korea, 18 December 2025.
55. Stefano D'Urso, 'Austria Finalizes M-346FA Acquisition', *The Aviationist*, 1 December 2025, <https://theaviationist.com>, accessed 1 February 2025; author interviews with Leonardo SMEs, International Flight Training School, Sardinia, 13–14 November 2025.
56. Author interviews with Boeing T-7A SMEs and test pilots, Washington DC, 20 January 2026.

development time, funding and developmental risk than either the TA-50 or M-346FA, as these aircraft already exist in light-fighter form. A high-end Phase 4 trainer (such as the TA-50) may end up being cheaper for an air force overall if it is also used as a light fighter for lower-end QRA/alert missions, and/or companion flying in frontline squadrons, to save significant flying hours for F-35 or next-generation frontline aircraft. This would be in addition to the savings made possible in a smaller, shorter OCU phase by expanding the Phase 4 syllabus using a suitably advanced lead-in fighter trainer.

Conclusion

High-quality training for fast-jet pilots is a critical requirement for modern air forces. It will remain so for the foreseeable future, despite increasing levels of in-cockpit automation, modern flight control systems, and the probable introduction of collaborative combat aircraft and uncrewed combat aerial vehicles by many countries. There are a wide range of technologies that have made, and will continue to make, flying training more efficient. Among the most notable are the modern, networked, highfidelity, fullcockpit simulators that enable pilots in training to develop tactical skills and practise emergency procedures far more cheaply and frequently than they could during live flights. Most modern flight-trainer options on the market come with a range of simulators, as well as software and hardware systems to enable each student's progress to be tracked and the syllabus optimised for their individual learning. The ability to practise the elements of a sortie in the simulator first also greatly increases the tactical training value of each hour of expensive live flying. However, from both an operational effectiveness and flight-safety management point of view, airmanship development must be a primary consideration when assessing options for how to configure a modernised flighttraining system, and when weighing cost savings against risk.

When avionics, sensors and software inevitably have in-flight failures, glitches, or are spoofed or otherwise disrupted by adversary or friendly electronic warfare capabilities, pilots must fall back on core airmanship skills to navigate to a suitable runway for a safe landing. This must often be done in bad weather and at night, while navigating complex airspace, maintaining communication with air traffic controllers and battlespace managers, following failure-checklist procedures and monitoring for cascading system failures. Developing and then maintaining these core airmanship skills requires regular live flying at representative speeds and performance levels, including in IMC and at night, both during flight training and once in a frontline squadron. Reducing live flying hours in jet aircraft during fast-jet training involves accepting risk that is difficult to measure, as accidents later in training or in frontline service are often hard to attribute entirely to one factor. However, there is a clear trend among multiple air forces that the author visited for this project: crashes and near-misses at the OCU or on the frontline are substantially more likely among pilots who come out of Phase 4 with only turboprop experience, and/or with low live-flying hour totals in real or simulated IMC at jetrepresentative speeds.[57]

Air forces looking to modernise their fast-jet flying training will all already have unique fleets and syllabus configurations in place for Phases 1–4, and a different OCU and frontline fleet context that student pilots are being trained to join. There is therefore no best option for modern trainer aircraft, as much will depend on the way that a given country specifies its fast-jet trainer requirement set.

However, there are a few rules of thumb that policymakers who are not deeply familiar with fast-jet training and operational flying should consider.

1. For air forces with single-seat-only OCU squadrons, such as any air force operating the F-35, a turboprop-only Phase 4 trainer aircraft solution will probably involve accepting a considerable increase in flight safety risk due to the inherent jump in moving straight from a modern turboprop trainer aircraft to a first solo flight in a frontline fighter. Equally, air forces that have many twin-seat frontline jets in the OCU and frontline squadrons will be much better placed to manage the jump from a turboprop Phase 4 trainer, although this will involve more (expensive) live-flying hours on those frontline jets to convert students safely to jet operations.
2. Air forces looking for a jet trainer for Phase 4 have multiple good options, most obviously the M346A and T-7A. Choosing between them will hinge on geopolitical and industrial factors at least as much as technical differences.
3. If air forces want a full jet trainer for Phases 3 and 4, then the M-346A is likely to be particularly attractive among the jet trainer options, as it is well optimised to cover the full range of both syllabus areas. It is also easier for student pilots to start flying at Phase 3, after a low-performance turboprop or piston basic trainer, than the T-7A or T50/TA50.
4. With any of the leading modern fast-jet trainer options on offer, air forces can offset some of the cost compared to a turboprop Phase 4 option by incorporating some of the OCU syllabus into Phase 4 instead. The M-346A, T-7A and particularly the TA-50 are all sufficiently fighterlike, and can either carry or simulate weapons, targeting pods and sensors to a sufficient level of fidelity to cover parts of the traditional OCU tactics course, on a cheaper airframe than a frontline jet.
5. If air forces only have a jet trainer requirement for Phase 4, there is a strong case for specifying that requirement to include the capacity to perform secondary roles such as light-fighter, redair provision or companion-trainer functions for future next-generation combat aircraft squadrons. If such secondary requirements are included, then the higher-performance, (potentially) somewhat highercost TA-50 stands out as an option, with the M-346FA as another route that is already available.

57. Author discussions with instructor pilots in OCU and Phase 4 squadrons at Columbus Air Force Base, 7 February 2025; RAAF Williamtown, 26 March 2025; Kingsley Field Air Force Base, 5–6 June 2025; and Nancy-Ochey Airbase, 3–4 February 2026.

About the Author

Justin Bronk is the Senior Research Fellow for Airpower and Technology in RUSI's Military Sciences research group, and the Editor of the RUSI Defence Systems online journal.

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Justin is a private pilot with more than 300 flying hours in light aircraft and gliders. In addition, he has over 35 hours' backseat flying experience with 12 different air forces on fast-jet types including Eurofighter Typhoon, Rafale, Gripen, Tornado, Mirage 2000, F-15, F-16, F/A-18, MiG-29, M-346, T-38, TA-50 and Hawk.

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