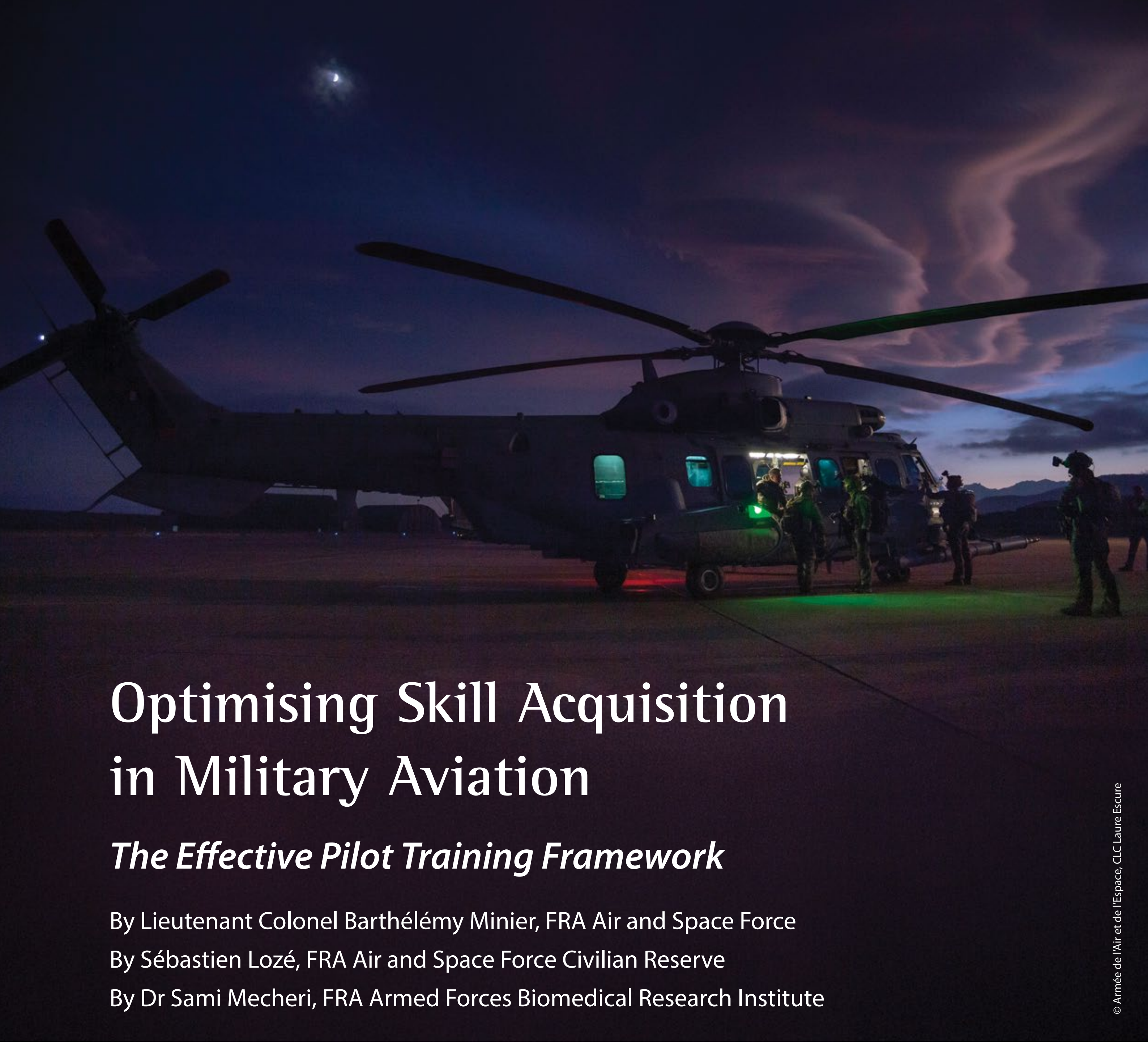

Optimising Skill Acquisition in Military Aviation

The Effective Pilot Training Framework

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CSAR mission departure. A complex operation requiring detailed planning and close coordination both in flight and on the ground.

Introduction

Training is the cornerstone of operational capability and the essential driver of skill development in aviation. However, a fundamental question remains: how should training be designed and organised to most efficiently unlock the potential of individual pilots? This question lies at the core of instructor concerns and is driving a wave of modernisation across NATO. Faced with pilot shortages and the need to expedite readiness, nations are duty-bound to explore ways to reimagine training methodologies.

Several initiatives are already underway to maximise the effectiveness of instructional programmes. For example, the US Army's Aviator Training Next programme focuses on integrating virtual reality (VR) technologies, using headsets and physical flight controls, to deliver innovative instruction.[1] Similarly, the US Navy's Project Avenger (Naval Aviation Training Next)

Fire support is a highly complex mission that requires specific training design to ensure effective skill transfer to operational environments.

is shifting away from a rigid 'one-size-fits-all' approach toward competency-based learning, where event difficulty is individually tailored to maintain a constantly challenging environment.[2]

Collectively, these efforts pursue three important objectives:

- addressing pilot shortages by leveraging emerging technologies;
- expediting early training to gain more flight time in advanced airframes;
- increasing the throughput of aviators to minimise wait times between instructional phases.

While various initiatives address initial qualification training, the approach to training Instructor Pilots (IPs) often lags behind. IPs are not systematically provided with guidance on how to implement new methodologies and enhance pilot development. For instance, while studies provide insights into the optimal ratio of VR hours to live flight hours, they rarely offer guidance on the instructional dynamics required to maximise that time. In other high-stakes domains, such as elite sports or medical surgery, coaches and instructors are routinely guided on how to facilitate effective training through the application of skill acquisition principles.[3, 4]

Currently, this level of support is largely absent in military aviation. This gap forces IPs to rely heavily on tradition, organising training in the same way previous generations did. While tradition has its merits, relying on it uncritically can exclude innovations based on empirical evidence. Skill acquisition is complex. Without clear, evidence-based principles, deciding how to introduce new skills or reinforce existing ones can be taxing and confusing.

In this two-part series, we introduce a framework for advancing skill acquisition in military aviation by translating principles from the science of skill to the aeronautical domain. This framework, named Effective Pilot Training, aims to provide aviation practitioners with evidence-based guidelines to support the translation of theory into practical training strategies. In the first part, we discuss key concepts for designing effective training and establish the framework. The second article will address how to integrate the framework into applied instructional practice.

Providing Clarity for the Instructor Pilot: Foundational Principles of Skill Acquisition

Success in the air depends on a pilot's ability to develop a specific set of perceptual, cognitive, and motor skills.

In this context, 'skill' encompasses more than the physical handling of the aircraft; it requires effective problem-solving and functional interaction with the operational environment. To optimise this process, IPs must understand the mechanics of how pilots develop such skills, from basic aircraft handling to tactical and complex qualifications. The following concepts form the basis of the Effective Pilot Training framework.

Learning versus Performance

An important finding in skill acquisition is the learning-performance paradox: performance during a single training session does not necessarily reflect how much retention, or learning, has occurred. Performance is transient and observable. It is the immediate result of the psychological and physiological state of the trainee, the instructor's guidance and feedback, and the repetition of a specific task. IPs may fall into a 'face-value' trap, assuming that a smooth sortie today means the skill is secured for tomorrow.

Learning, by contrast, is a permanent change in capability. It can only be measured by changes in performance over time, once the temporary support of the instructor is removed and memory consolidation processes have taken effect. A trainee may perform poorly during a demanding session (showing low immediate performance) despite engaging in effective learning. Conversely, a trainee may perform perfectly in a less demanding session yet learn very little. This distinction between learning and performance is a central tenet of the Optimal Challenge Point model.[5]

Optimal Challenge Point

The 'Optimal Challenge Point' is the point at which training difficulty yields the most effective learning. The Optimal Challenge Point model highlights that the level of difficulty required for good training performance is not the same as that required for effective learning outcomes.[6] As illustrated in Figure 1, as training difficulty increases, performance naturally declines. However, the learning benefit actually increases up to a specific Optimal Challenge Point. Beyond this peak, difficulty exceeds the pilot's cognitive capacity, and both performance and learning decline sharply.

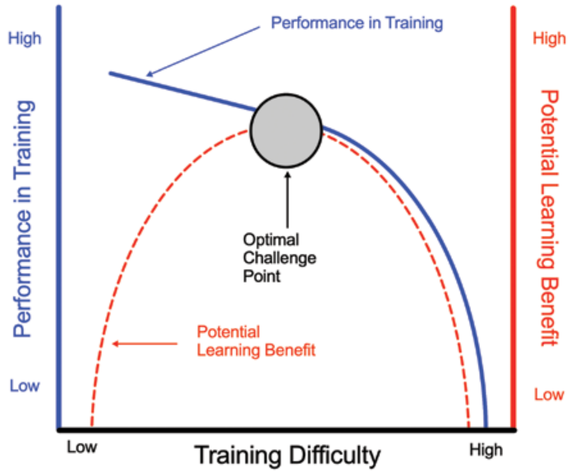

***Figure 1:** The inverse and non-linear relationship between training performance (solid line) and the learning benefit (dotted line) as a function of training difficulty (x-axis). This model illustrates how potential learning benefit during training relates to immediate performance and the Optimal Challenge Point for an individual pilot.*

This model enables us to anticipate training outcomes. Training that is too easy results in high performance but low potential learning benefit. Training that is too demanding results in poor performance and decreased potential learning benefit. The IP's goal is to adjust parameters continuously to keep the pilot near that Optimal Challenge Point, prioritising durable learning over a clean grading sheet in the present.

Transfer of Training

'Transfer' describes how well performance gains from training situations carry over to untrained tasks, or to trained tasks under novel tactical scenarios. It is the ultimate return on investment (ROI) of training. Transfer can be categorised along a continuum, or broadly as either 'near' or 'far', depending on how closely the new scenario resembles the original training:

- Near Transfer: Trained skills apply to novel situations that remain highly similar to the training setting, for example, switchology or checklists.
- Far Transfer: Trained skills apply to complex, dynamic environments unlike the original training setting,

NVG operations are among the most demanding missions. Effective training is essential for aircrew, enablers, and C2 elements to perform successfully in such environments.

for example, composite air operation (COMAO) or dynamic retasking.

The ultimate purpose of military operational training is to produce far-transfer effects, ensuring pilots acquire the ability to perform adaptively in contexts and scenarios they have never explicitly practised.

Training Specificity

Specificity is the degree to which training reflects mission demands. While a training environment may appear realistic at first glance, training specificity refers to replicating the underlying cognitive processes – the perception-action links, uncertainty, and time constraints of combat. If a pilot performs a skill in a sterile, predictable environment like a simulator, the specificity remains low, even if the simulator's dynamic flight model is accurate. To ensure knowledge retrieval and adaptive behaviour under fire, training must recreate demands found in operational sorties, as doing so favours the transfer of trained skills.

Introducing the Effective Pilot Training Framework

The Effective Pilot Training framework structures aviation practice around two critical dimensions – see Figure 2. The first is difficulty: the degree of challenge imposed on the pilot relative to current skill level. The second is specificity: the extent to which the training environment faithfully replicates the demands of a combat mission.

The intersection of these two dimensions defines three distinct instructional approaches, each producing a different effect on pilot development:

- **Training-to-Learn:** Prioritising long-term acquisition over short-term performance.
- **Training-to-Maintain:** Reinforcing confidence and automaticity in existing skills.
- **Training-to-Transfer:** Replicating the friction of combat to ensure skills hold up under operational pressure.

As established in high-performance fields such as elite sports and surgical medicine, effective training requires more than just repetition; it requires targeted design.[7,8] Differentiating training allows the IP to act not just as an evaluator, but as an architect of skill development. By deliberately manipulating the parameters of difficulty (challenge) and specificity (mission realism), IPs can purposefully design flying tasks and contexts to pursue three distinct instructional goals.

These goals are discussed according to the lifecycle of a military skill: acquiring it, maintaining it, and ultimately transferring it to the fight.

1. **Training-to-Learn (Acquisition):** Training-to-Learn is the foundation. It aims to foster the acquisition of new skills by prioritising long-term retention over

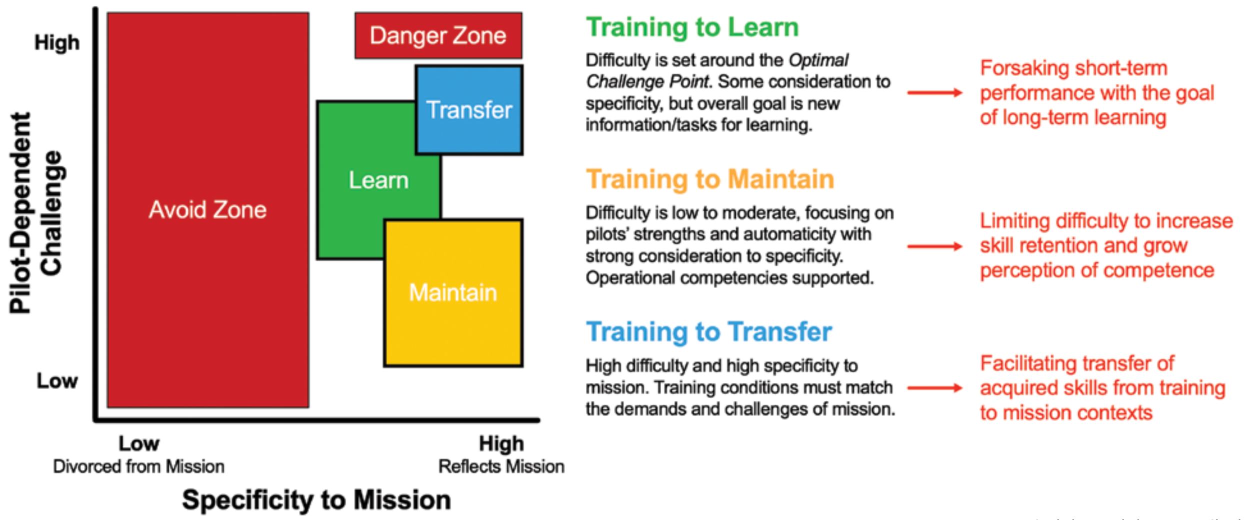

***Figure 2:** A training session can be positioned along two dimensions: the degree of training specificity (x-axis) and the level of training difficulty (y-axis). When the degree of specificity is low, training yields little transfer to mission contexts. It is therefore advisable to stay out of the 'avoid zone', regardless of whether the training difficulty is high (resulting in learning with minimal transfer) or low (resulting in no learning). At high levels of specificity, training is likely to produce good transfer of acquired skills to operational situations, allowing IPs to adjust the training difficulty according to instructional objectives. To foster learning, difficulty levels should be set to push pilots beyond their current capacity (Optimal Challenge Point), introducing new tasks and information into their flight environment to stimulate progress. To foster skill maintenance, difficulty should be moderate or low relative to the pilot's ability, but combined with a high degree of specificity. Finally, it is critical to avoid pairing very high difficulty with very high specificity ('danger zone') to prevent severe cognitive overload and flight training accidents.*

short-term performance. To support this, IPs should place pilots at their Optimal Challenge Point. Because this zone compels the pilot to engage with new concepts, immediate performance may appear uneven or sub-optimal. The IP must accept this trade-off. This approach should underpin initial training, or any phase in which a pilot transitions to a new airframe or weapon system. Since the optimal level of difficulty is a moving target, the IP must continually adjust difficulty and specificity parameters to keep the pilot within this learning-focused zone, rather than allowing them to coast on easy successes.

2. **Training-to-Maintain (Retention):** Training-to-Maintain aims to sustain existing capabilities. Here, the goal is to develop automaticity and strengthen pilot confidence. The IP achieves this by maintaining high specificity (realistic cognitive demands and mission scenarios), while keeping difficulty moderate. This allows the pilot to execute known procedures fluently in realistic contexts without being overwhelmed by failure. This type of training is crucial for reinforcing cognitive schemas in experienced pilots, or for rebuilding confidence in highly qualified aircrew returning from non-flying staff tours. It solidifies foundational skills before progressing to complex operations.

3. **Training-to-Transfer (Mission Rehearsal):** Training-to-Transfer represents the pinnacle of the framework. It fosters the application of acquired skills to the complexity of operational settings. Here, the IP utilises high levels of specificity and difficulty to reproduce the friction of combat faithfully. This training goal is critical in the work-up to deployment, such as Red Flag or Tactical Leadership Programme (TLP), where the objective is no longer teaching a skill, but facilitating its transfer to operational environments and ensuring it holds under pressure. Training design must create situations that compel

Air-to-Air Refuelling of two Caracals by an A400M Atlas assigned to special operational forces. This capability required pilots to develop advanced skills through a dedicated and targeted training programme.

the pilot to make split-second decisions based on all task-relevant information available in 'real missions' leading wingmen and unmanned systems, coordinating with special operations forces in evolving tactical situations, conducting risk assessment and management, and maintaining sound situational awareness. This is not merely practice; it is wartime rehearsal, conditioning the pilot's brain to recognise and react to the lethal cues of combat.

Conclusion

As NATO flight schools face increasing strategic pressure to raise throughput without compromising competency, the 'business-as-usual' approach to instruction is no longer sufficient. Modernising hardware, such as introducing VR, is only half the battle; training design must also modernise.

By integrating key principles of skill acquisition science into daily operations, the Effective Pilot Training framework provides IPs with reference points and the conceptual tools necessary to move beyond tradition. It empowers them to align every sortie with a specific developmental goal, whether acquiring new skills (Training-to-Learn), cementing proficiency (Training-to-Maintain), or rehearsing for combat (Training-to-Transfer).

This framework is not limited to undergraduate pilot training; it can guide development across the full spectrum, from initial training students to Mission Commanders. In a forthcoming follow-up article, we will move from theory to practice, outlining how to operationalise this framework using advanced simulation, data analytics, and behavioural analysis to help deliver the next generation of combat aviators. ●

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Barthélémy Minier is a pilot in the French Air and Space Force. He qualified as a fighter pilot in 2010 and as a helicopter pilot in 2012. Since 2017, he has served as a mission commander and flight instructor and has logged more than 2,000 flight hours across multiple mission profiles. He previously commanded the French Air Force Helicopter Crew Training Center (CIEH), where he was responsible for the design, standardisation, and certification of helicopter training programmes. He also served as Head of Innovation for the French Air Force helicopter branch. Lieutenant Colonel Minier delivers tactical courses and lectures to international helicopter crews and NATO partners, with a focus on integrating new technologies into training. In collaboration with IRBA, he contributes to applied research aimed at detecting cognitive overload during flight training, mitigating its instructional impact, and optimising training effectiveness.

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