Live Air Training in a Synthetic Environment

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ABSTRACT

There is currently a growing trend away from live air training towards apparently less expensive mission training through simulations. However, cost savings are not the only reason; specific missions simply cannot be efficiently and safely trained in a real environment. Simulations seem to be the general solution.

But fighter pilots can't achieve the required operational readiness levels in flight simulations only. Thus, the combination of both live and synthetic training could be the ideal answer.

NATO MSG activities 128 and 165 explored the operational and technical requirements for NATO Mission Training through Distributed Simulations and proposed a common Reference Architecture for Joint and Combined Air Operations. Although their main focus was on Virtual and Constructive simulations, the Live training aspect has always been considered for future expansion to LVC training networks.

This lecture highlights the benefits of blended live and synthetic training in due regard to the difficulties connecting multiple assets in multi-domain and multi-national networks. Technical solutions like LVC Gateways, Multi-Level Security (MLS) architectures, Cross Domain Solutions (CDS), special Human Machine Interfaces (HMI) are currently being developed and established to make all of this possible.

What are the remaining main constraints and what are the solution approaches?

1.0 LIVE AIR TRAINING TRENDS

Air Forces want to grow and sustain their fighter force capability by on-boarding new pilot candidates and continuous training of their qualified fighter pilots. Present training ecosystem might have to be adapted to achieve the required operational readiness levels. In the following sections we will look at a typical pilot training concept of today and consider the trends of evolving training solutions for current and future pilot training capability requirements.

1.1 Current Pilot Training Concepts

Typically young pilot candidates begin with primary and basic flight training before they specialize at the advanced flight training either for multi-engine support aircraft, or helicopters, or fighter aircraft.

Fighter pilots additionally pass a fighter lead-in training on specially equipped trainer aircraft before they enter their final fighter aircraft.

Figure 1-1 shows a typical pilot training system example.

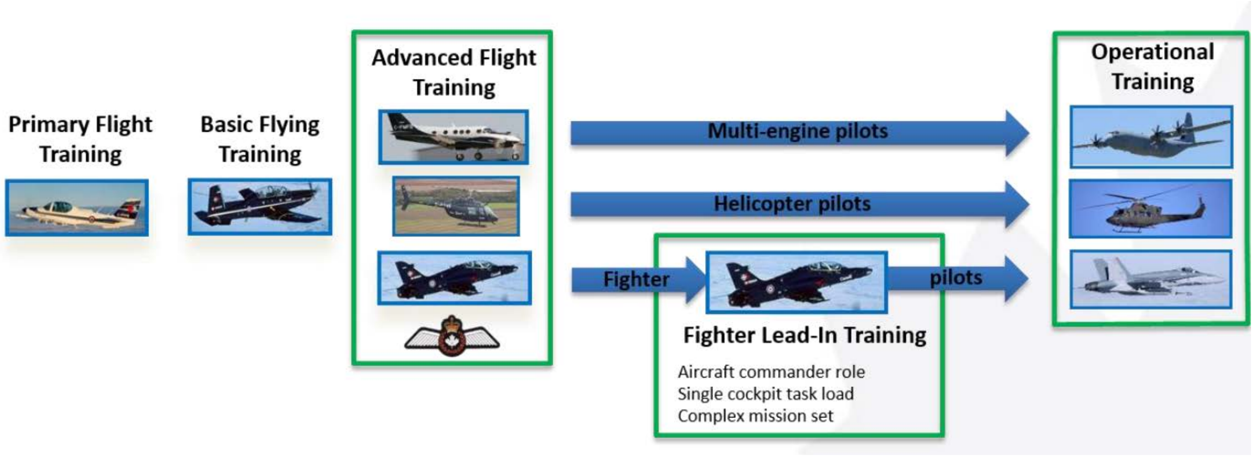

Figure 1-1: Existing Pilot Training System
Courtesy of the Public Services and Procurement Canada
Future Fighter Lead-In Training (FFLIT) RFI (W6369-210262/A)

1.1.1 Download

In order to save expensive flight hours on fighter aircraft parts of the operational training can be downloaded to the fighter lead-in training on less expensive trainer aircraft. To accomplish the download concept the fighter lead-in trainer aircraft should be equipped with similar mission systems as the fighter aircraft or those capabilities are emulated by an in-flight training system.

The same download concept can be applied for the fighter lead-in training onto the advanced flight training.

Figure 1-1-1 illustrates the download concept applied to the example in Figure 1-1.

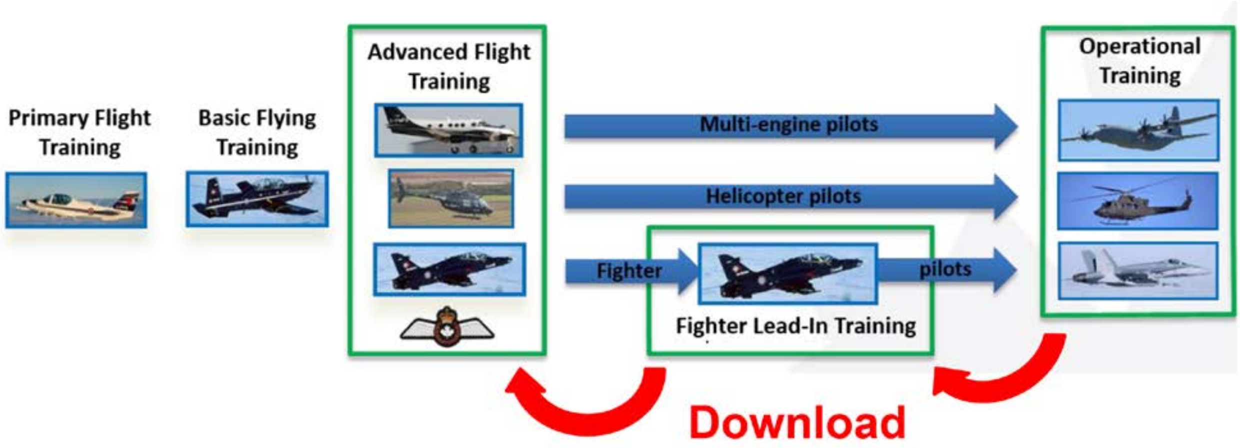

Figure 1-1-1: Download of Training Content

1.1.2 Offload

Another common method to save expensive flight hours is to offload training content from live training to simulators on ground. That requires accordingly equipped simulators connected to a distributed network.

Figure 1-1-2 illustrates the offload concept applied to the exemplary pilot training sequence in Figure 1-1.

Figure 1-1-2: Offload of Training Content

NATO MSG 128 and 165 activities already explored the training objectives and operational requirements for mission training through distributed simulations and proposed a common Reference Architecture for Joint and Combined Air Operations.

1.1.3 Blended Training

The next logical step is the combination of training download and offload to a blended training concept in a united network. This network should distribute data between all participants of a training session, on ground and in the air.

Figure 1-1-3 illustrates the blended training concept applied to the example shown in Figure 1-1.

Figure 1-1-3: Blended Training

A blended training network should connect not only the Live, Virtual and Constructive (LVC) elements of a training mission but also the different assets of the sequential training phases. Hence the blended training network will allow comprehensive training effectiveness data analytics to optimize training resources, training progress and long-term pipeline management.

The prerequisites for blended training are discussed in the following chapters.

2.0 ENABLING BLENDED TRAINING

In the previous chapter I described a couple of trends for modern pilot training which finally lead to a blended training systems architecture including advance flight trainer aircraft, fighter lead-in trainer aircraft, operational aircraft, and ground training systems. Red air service aircraft should also participate in the blended training network as well as all other supporting training elements.

All participating aircraft should be equipped with an **Airborne Training System**. These systems are also called Air Combat Manoeuvring Instrumentation (ACMI) system, Autonomous ACMI (AACMI) systems, Air Combat Training Systems (ACTS), Embedded Training Systems (ETS), or In-Flight Simulation Systems (IFSS).

All of them are equipped with an **Aircraft Interface**, mechanical, electrical and digital.

The training data flow from them Airborne Training System through the Aircraft Interface to the **Pilot Human Machine Interface (HMI)** of the aircraft avionics and missions system. At best the pilot interacts with synthetic training elements exactly like real equipment.

Aircraft Training Systems interlink all participating aircraft of a training mission by an interoperable **Datalink Network**.

An additional datalink node on ground connects the airborne to the ground training systems through an **LVC Gateway**.

The **Ground Network** interconnects the **Simulations and Simulators** with a linkage to the LVC Gateway.

Figure 2-0 illustrates the main elements of a blended training system.

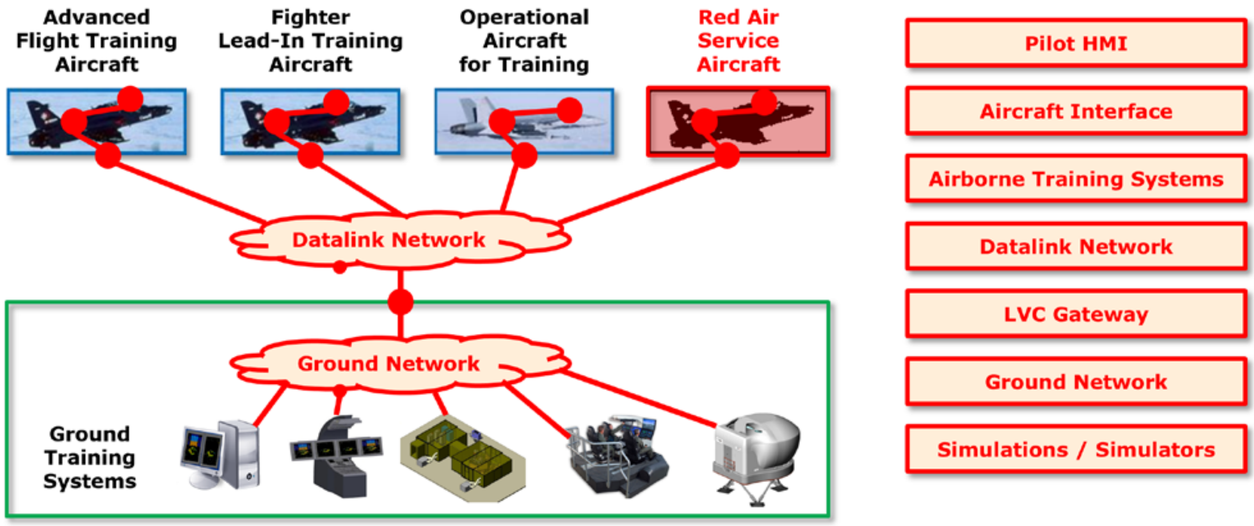

Figure 2-0: Blended Training Elements

2.1 Airborne Training Systems

There is only a small number of global Airborne Training System providers which have products fitting on various aircraft types. Below the main suppliers are listed, their related products, and their website links for further information.

- **Israel Aerospace Industries** and **Elbit Systems**
  - EHUD AACMI
  - RAIDS (UK only, will be taken out of service)
  - FPR (in cooperation with **Diehl Defence, Germany**)
    - https://www.iai.co.il/p/ehud-aacmi
    - https://elbitsystems.com/product/ehud/
    - https://www.diehl.com/defence/en/products/training/

- **Cubic** in cooperation with **Leonardo DRS**
  - KITS
  - P5 CTS/TCTS
    - https://www.cubic.com/solutions/training/air-combat
    - https://www.leonardodrs.com/air-combat-training-systems/products/acmi-pods-subsystems/

- **Collins Aerospace** in cooperation with **Leonardo DRS**
  - JSAS
  - TCTS II
  - P6 CTS
    - https://www.collinsaerospace.com/what-we-do/Military-And-Defense/Simulation-And-Training/Test-And-Training-Instrumentation

Figure 2-1 shows the typical form factors of Airborne Training Systems: external pod in the shape of a Sidewinder missile, and internal mounts for F-18, F-22, F-35 and other aircraft types.

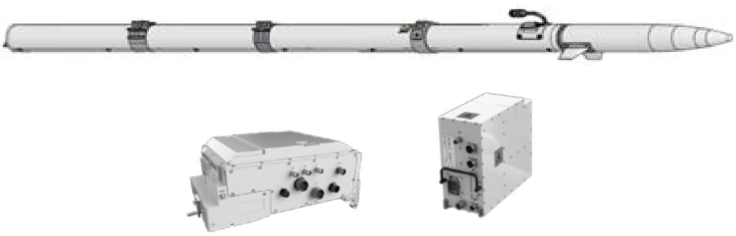

Figure 2-1: Airborne Training System Components Collins Aerospace

2.2 Datalink Network

Besides typical data link performance requirements like throughput, latency, and bandwidth there are two major requirements, which are apparently opposing:

- **Interoperability** between different aircraft types, nations and organizations
- **Data Security** of multiple different classified domains

Legacy ACMI Systems have no data encryption as international datalink interoperability was the only top requirement in the past. Nowadays, the missing data security is not anymore acceptable, neither for the latest 5th generation platforms nor for advanced 4th generation platforms.

Multiple Levels of Security (MLS) or Multiple Independent Levels of Security (MILS) architectures can dissolve this conflict. Typically an MLS/MILS system comprises two main components:

- **Cross Domain Solution (CDS)** managing the secure data flow between different domains
- **Multi-Channel End Cryptographic Unit** encrypting and decrypting different classification levels

The industry already provides Air Combat Training Systems (ACTS) with a certified MLS/MILS architecture. However the Governments as the data owners still must define their data security policies which will automatically applied by the ACTS in form of data security rules.

2.3 Aircraft Interface

The ACTS receives sensor and control data from the aircraft and sends synthetic data and status information back to the aircraft. This requires a Level 3 aircraft integration including a digital 2-way communication. See Figure 2-3 Aircraft Integration Levels.

As far as possible, the training data should be processed separately from the operational data in the aircraft to avoid aviation safety conflicts and to allow changing the training parameters without need to recertify the system every time.

Level	Integration	Aircraft Modification
0	Power only	No
1	Analog / discrete	No
2	Digital 1-way	No
3	**Digital 2-way**	**Yes**

Figure 2-3: Aircraft Integration Levels

2.4 Pilot Human Machine Interface (HMI)

Pilot should train their behaviour patterns as they would be in a real mission. Therefore the manual control and aural and visual information of the ACTS should be as equal as possible to the operational HMI.

Virtual and augmented reality (VR/AR) visualisation systems in Helmet Mounted Displays (HMD) can project synthetic elements into the pilot's field of view.

Human body sensors can capture and assess the pilot's cognitive workload for real time monitoring and for comparison between real operations, live training, and training in simulators.

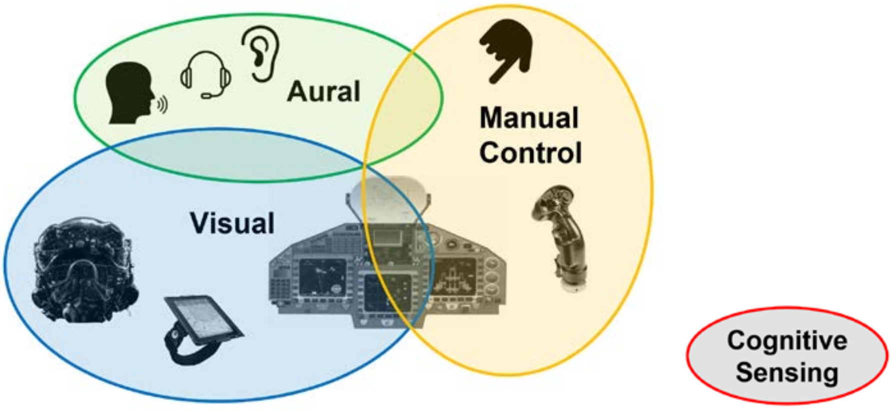

Figure 2-4: Pilot HMI

2.5 Simulations / Simulators

Computer generated simulations and training simulators at different locations are connected to the ACTS through the ground and datalink networks. The task group MSG-165 delineated all required elements of NATO Mission Training through Distributed Simulation (MTDS) for Joint and Combined Air Operations.

Although the main focus of this activity was on Virtual and Constructive simulations, the Live training aspect has already been considered for future expansion to LVC training networks. Up-to-date ACTS can host differently classified weapon simulations in corresponding secure Host Computing Resources (HCR) in an embedded Multiple Independent Levels of Security (MILS) architecture.

Figure 2-5 illustrates some simulation systems and simulators able to connect to ACTS.

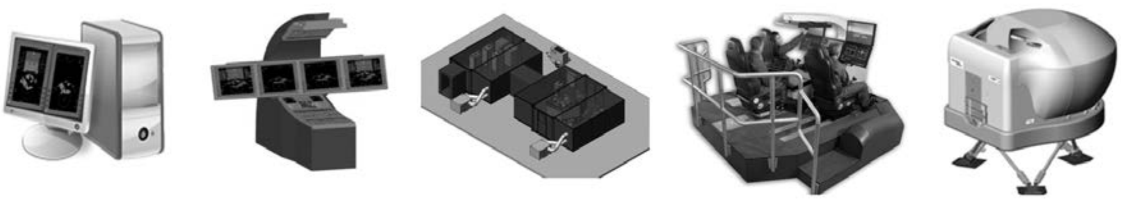

Figure 2-5: Simulations / Simulators

2.6 Ground Network

The ground training network shall connect all participating simulators, Computer Generated Forces (CGF) created by simulations, and provide a node to the ACTS datalink. The task group MSG-165 NATO MTDS for Joint and Combined Air Operations outlined the requirements for a ground training network and described the ideal MTDS architecture in a general reference book.

Another main focus of the MSG-165 activity was on multi-level security requirements and possible solutions. Deployed Cross Domain Solutions (CDS) gateways, guards, security labelling services, and filtering concepts shall be interoperable not only within the ground network but also through the LVC Gateway and the datalink network to the ACTS of the aircraft, see Figure 2-6.

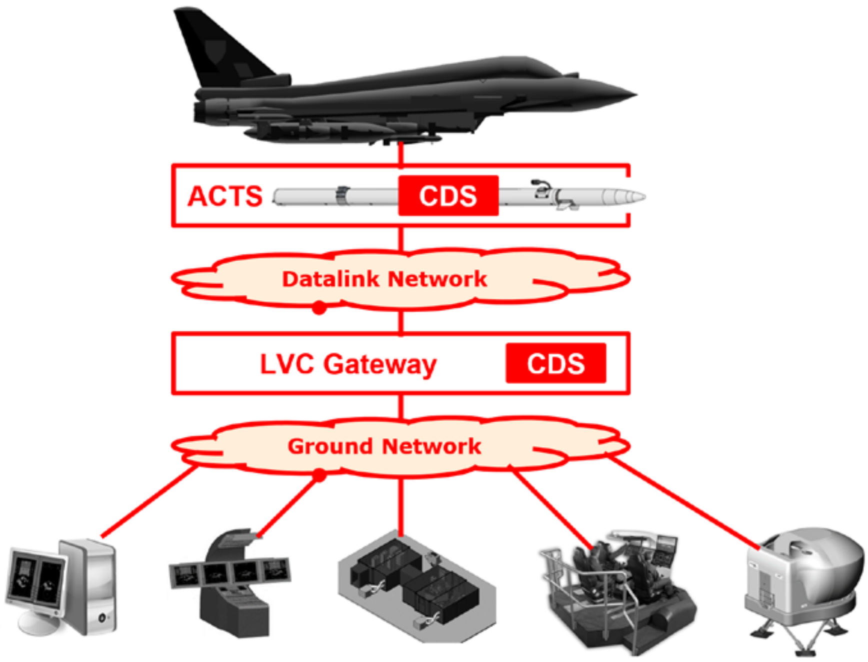

Figure 2-6: CDS on Ground and in the ACTS

2.7 LVC Gateway

The LVC Gateway connects the airborne participants with the ground network and translates the data formats and protocols of the different systems so that they can interact.

Typically the LVC Gateways are placed next to the datalink ground station to convert and compress the DIS or HLA messages so they aren't overloading the limited datalink capacity.

LVC Gateways translate different protocols like DIS, HLA, MIL-STD-1553, TENA, ICD 1598.01, EAG, ARINC 429, JREAP, and many others.

Furthermore a Cross Domain Solution (CDS) in the LVC Gateway can support the secure multi-level classified information exchange.

3.0 REMAINING CHALLENGES

Table 3-0 summarizes the remaining challenges related to each main element required for live air training in a synthetic environment.

Table 3-0: Way Forward Towards Blended LVC Training

Pilot HMI	Use the existing cockpit layout adding synthetic elements.
Aircraft Interface	Enable an isolated data flow through the avionics system for training purpose only.
Airborne Training System	Take the most recent available ACTS technology towards future training concepts.
Datalink Network	Achieve both, interoperability and cyber security by MLS/MILS.
LVC Gateway	Connect various training systems through most common interfaces.
Ground Network	Build connections up on available infrastructure.
Simulations / Simulators	Link existing simulation systems to networks.