Integration of First Person View drones in simulation

Peter Hafeneder
Thales Training and Simulation
Osny, France
peter.hafeneder@thalesgroup.com

ABSTRACT

Recent high intensity conflicts have emerged around the world that have witnessed an unforeseen conflagration in modern warfare: the intensive use of First Person View (FPV) drones.

These small flying machines have demonstrated a tremendous effectiveness on the battlefield and in a wide range of missions such as reconnaissance, artillery fire control support, bombing and self-destructive attack missions, such that their integration into armies has already started.

That's why FPV drones should be widely implemented in simulation. Live training solutions, already embed technologies that enable the user to get video streams from hundreds of camera deployed in a battlespace, and also, to localize small objects like hand grenades with a metric precision. When considering these characteristics, FPV drone implementation in a live training simulator has never seemed so close.

The aim of the current paper is to identify, in partnership with end-users, all missions related to FPV drone usage that should be addressed in live training simulation, at company and platoon level. Then, to submit preliminary architecture or design solutions, that would enable training on each kind of mission. Lastly, our goal is to determine what are the most relevant Key Performance Indicators (KPI's) needed to evaluate and measure the effectiveness of Drone operators as part of a tactical group, in an airspace saturated with micro and small drones.

FPV drones will be the next breakthrough in defense fields and their capabilities are skyrocketing with all projects that popup around the world. More than ever, the military needs to learn how to effectively employ them, and above all, how to counter them on the battlefield. That's why not only the offensive part shall be addressed but also the defensive side, which implies also to identify systems used against small drones such as antidrone rifles, man pads, SAM systems and how to integrate it into a live training solution.

ABOUT THE AUTHOR

Peter Hafeneder is an Integration, Verification, Validation and Qualification Manager who has worked for 5 years on the development of the biggest instrumented Live training Center in Europe. Through this experience, he developed a better understanding of Ground army training needs and assessment methods used to evaluate performance of trainees at tactical level.

During his time at University, he wrote a master's thesis about the integration of small drones in synthetic environments, which raised his awareness about small drone industry and usage. He is now working on a major upgrade of several NH90 helicopter full flight simulators.

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LIVE TRAINING SIMULATION INTRODUCTION

Because this paper deals with integration of small drones in live training simulation, it is helpful to have a general understanding of live training simulators.

In contrast to virtual simulation, live training simulation happens in the physical world, and consists of instrumenting actors and infrastructure present in the simulation. Soldiers and vehicles are embedded with localization and communication kits, which update their positions and health state, regularly and transmit it via radio signal to an antenna connected to a C2 (Command Center). The C2 enables instructors to prepare, monitor and arbitrate the combat through an instructor operator station (IOS). Instructors use map displays to follow evolution of tactical maneuvers and consolidate their evaluation using video streams captured from multiple cameras (Figure 1 and Figure 2).

All events in the simulation such as, shots, ammunition consumption, kills, wounded door-to-balloon time (the time it takes to evacuate and treat a simulated casualty), are recorded on a server. The instructor can access this data to compute Key Performance Indicators (KPI) in order to evaluate and teach the trainees.

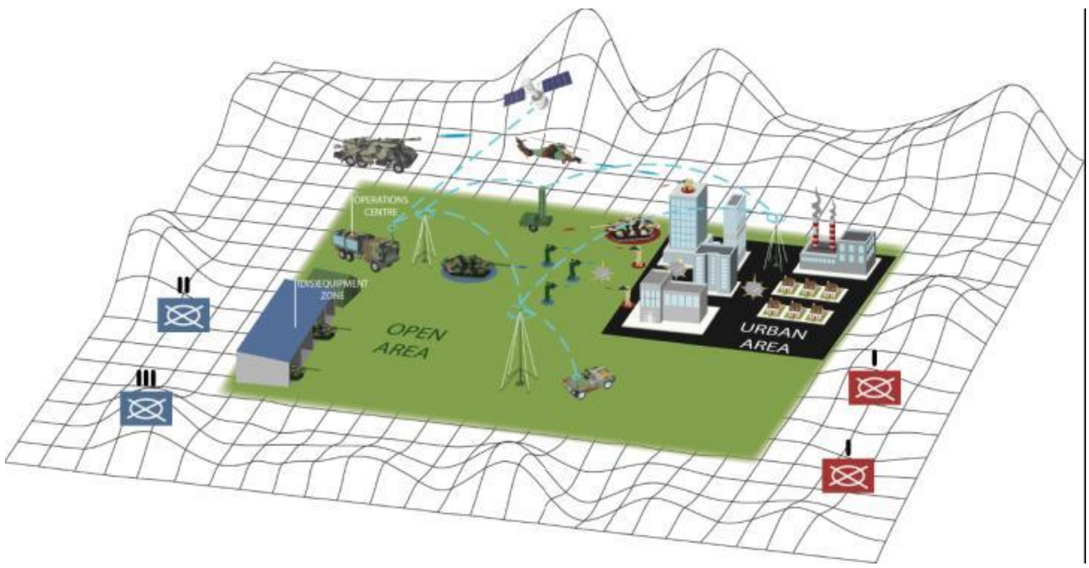

Figure 1- Live Training system overview

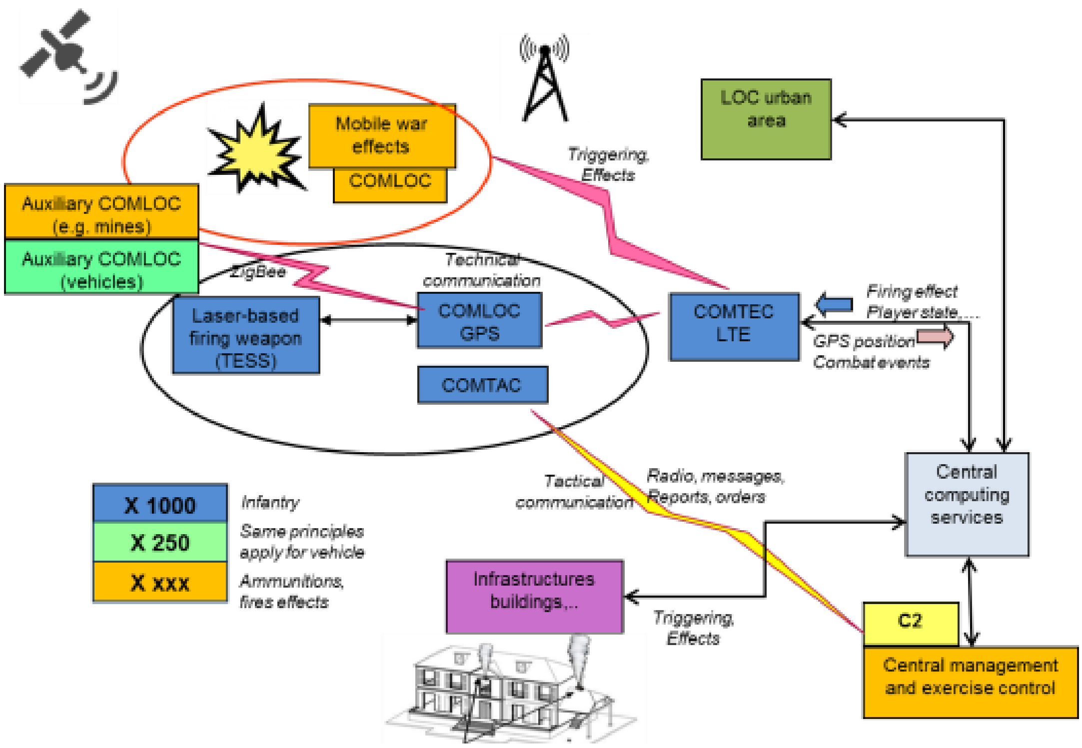

Figure 2 – Typical Live training system architecture

TRAIN AS YOU FIGHT

The choice of the platform to be used is the first step before deciding the missions and pilot performance evaluation in the simulation.

As it is not up to simulation actors to develop drone systems, it is clear that the best way would be to integrate the real drone system used by operators on the battlefield, instead of developing a training platform that will substitute for that system. Furthermore, using a drone different from the real one would significantly decrease training value and induce missed training opportunities for the user.

For these reasons, we decided to choose an existing platform available on the market, used by both French and United States militaries, and to see how we could succeed in fulfilling drone training based on its characteristics and functionalities. These characteristics are commonly found and most small drones may embed the same capabilities.

API and Interface

Once a platform has been selected, we have to discover its Application Programming Interface (API) structure. In fact, due to the decision to using an existing Commercial off-the-shelf (COTS) drone, the functionalities, and data the simulator expert can access are limited to those made available by the drone supplier. As will be seen below, the author will check that all the variables used in the realization and evaluation of the different missions are available through API (see content in references).

Key Limitation: Large variety and short lifecycle of drones

In order to get a wider view and a better knowledge of the drone market, the author attended the JIDAC ‘Small and tactical UAV manufacturers Day’ that gathers many drone manufacturers, Ministry of Defense and army representatives. The first astonishing fact about drones is their wide variety. During this event that only focused on national manufacturers, about 25 different platforms were presented.

The integration of drones into live simulation therefore faces initial difficulty: the huge amount of different platform available on the market in the <150kg category. This large number of different systems poses issues for simulator companies to integrate and to interface with their own live systems. In addition the short life cycle of small drones is an issue. Even if drones may be compared to small aircraft, they have much more in common in terms of life cycle with a smartphone than an aircraft. Thanks to their simplicity, the short development phase combined with the high frequency update rate of their software, will make it more difficult for simulation companies to maintain compatibility between simulator and integrated platforms. Most defense programs have a lifetime of ~30 years whereas a small drone system may be obsolete after just a few years.

The combination of the factors listed here above, high variety, short lifecycle, and high rate of product updates may be a strong limitation for simulation companies to integrate these platforms.

One technical solution that may solve this problem could be an initiative of simulator companies to convince drone manufacturers to agree on a common Drone Joint Framework Interface. This standard would enable us to limit the number of interfaces to implement and to maintain in our live simulator systems, and so keep up with fast moving drone market.
Such initiatives have already been deployed but the number of adopters remain insufficient.

DRONE OFFENSIVE MISSION PROFILES

The offensive missions addressed by small drones comprise the following:

- Reconnaissance/ Observation
- Bombing
- Self-Destructive Attack (loitering munition)

These missions will be individually described in the following sections:

RECONNAISSANCE/OBSERVATION

Reconnaissance is the first mission addressed by small drones (Figure 3), after interviews with small drone operators and experts in reconnaissance, it appears that the KPIs necessary to evaluate the capability of a drone operator may be listed as follow:

- Elapsed time to arrival at target
- Battery management
- Stealth
- Global Navigation Satellite System (GNSS) position recovery

Elapsed time to arrival at target

A reconnaissance drone expert should be able to navigate efficiently in order to reach the target as fast as possible, and should not lose time seeking the target.

In the live training simulation, the instructor shall be able to designate the target to look for in the Man Machine Interface (MMI), such as a location or an entity. After the drone take off, the timer starts and continues increasing until the target is contained in the camera field. The camera field may be associated to a cone depending on camera resolution, range, zoom level and orientation. By knowing the drone’s GNSS position, its camera characteristics and target location (designated in MMI) or position thanks to localization equipment (GNSS, Inertial system, Ultrawideband or BluetoothLowEnergy tags…) attached to the soldier or vehicle, it is then possible to compute when the operator succeeds in finding its target. Because GNSS position may be inaccurate in urban warfare and because an obstacle may be present between the target and the drone’s camera, it should be possible for the instructor to consolidate the success of the mission in the MMI or to integrate in the Simulator, image recognition algorithms to validate that the operator detected the target.

As most small drones already embed human and vehicle recognition software, a coupling between target recognition, and geometrical computation of the target position inside the drone camera’s cone, would be an effective and robust solution.

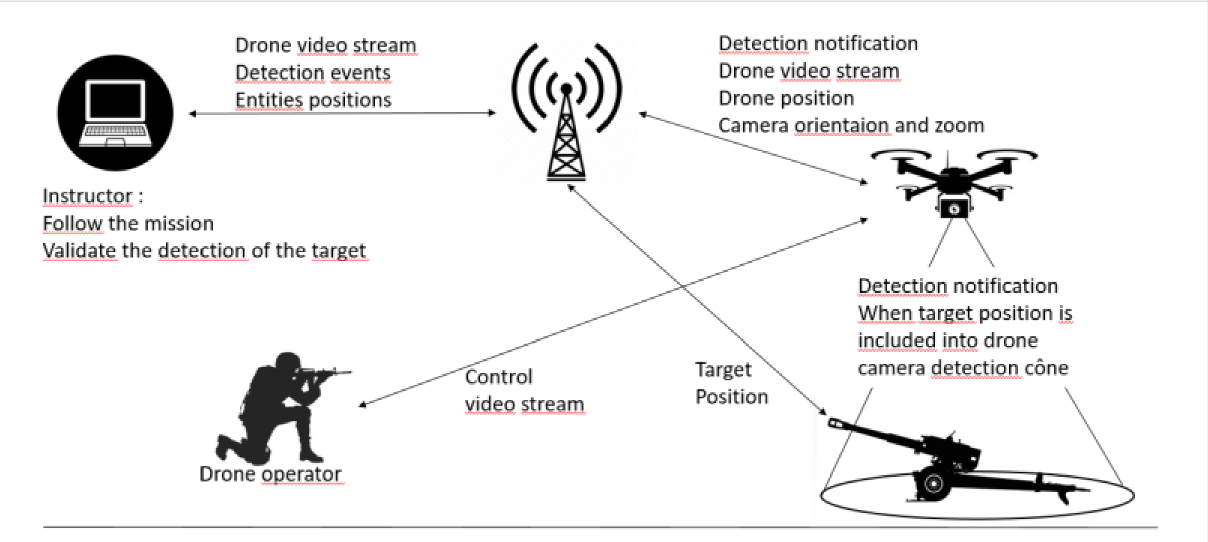

Figure 3 - Reconnaissance mission procedures

Battery Management

Just as it is necessary for a fighter pilot to manage fuel consumption, it is of prime importance for a drone operator to manage the battery level of their drone. A drone should never come back from its mission with just 1% of it battery level. A low battery level at landing, might result from a difficulty to find the target or a mistake in estimating flight time duration required to achieve its mission. Therefore, the system should enable to record the battery level left at landing time.

Stealth

A drone must remain unseen and operate in total discretion for the duration of the mission. In fact, revealing its position to the enemy force is something to avoid in combat. That is why it should be possible to measure the capacity of a pilot to remain unseen during the achievement of their mission.

One suggestion to evaluate stealthiness would be to identify if a shot has been made in a radius around the drone operator from the takeoff until the team leaves the deployment zone.

If any soldier, within a radius around the drone, gets a health status modification, during the drone reconnaissance mission, it may be because the drone revealed the position of the squad. The most probable threat would be from an indirect shot such as artillery, bombing or rockets. An indirect strike landing in the radius should be interpreted as a fail in the stealth aspect of the mission, even if this shot does not result in a wound or a kill among the team. In addition, a loss of the drone because of interception shall also be considered as a lack of stealth and be recorded as a mission failure.

GNSS position recovery

During flight, it's possible for the drone to loose GNSS. It may happen when drone flies at very low altitude, in a hilly terrain. A pilot should be able to quickly recover GNSS coverage of their drone, by increasing its altitude. The time spent in a non-jamming environment, with no GNSS position along the entirety of the drone's flight, should be recorded.

BOMBING MISSION

Before the use of drones as loitering munitions, bombing has been the primary method for using small drones as an offensive system. Most of the time, this consists in dropping an explosive device on top of a target.
Solutions to address this mission have already been developed by simulator companies, and therefore won't be detailed any further in this paper.

One solution proposed is to simply drop an emulated grenade system on the target. After a delay, the system emits a short range radio bubble that contains a detonation message. All entities within range of the signal will receive it through sensors positioned on jackets. To enhance immersion, an explosion sound effect might be played on the small speakers usually place on soldiers' jackets as well as larger speakers installed in the combat zone. The entities are damaged, and the status modification is propagated through radio wave to the C2 in order to update the simulation.

Naturally, the grenade device has to be upgraded with shockproof material such as foam to prevent the device from injuring trainees should it land on them.

To ensure drone bomber pilots are properly evaluated, status modifications from emulated grenades carried by drones should not be confused with those generated by hand grenades even if the training device used is the same. It shall be possible to distinguish damage done by hand grenades from drone grenades during debriefing sessions.

SELF-DESTRUCTIVE ATTACK MISSION

Self-Destructive attack mission is a key mission operated by small drones nowadays. The challenge is to emulate the strike without endangering the safety of trainees.

A first approach would be to use the GNSS position of the drone, and to trigger a virtual detonation that would simulate wounding or damaging surrounding actors also equipped with localization device. However, if using GNSS position might be a suitable solution in an open field, it would not be appropriate in an urban area.

A better solution would be to use the obstacle avoidance system embedded in most common small drones.
A stereo camera pair uses the parallax principle to estimate distance between a target and the sensor. Infrared and Ultrasonic sensor systems can estimate the distance of the target by computing the time to target, reflection, and return to the sensor.

Such system are widely deployed on small drone system and might be used to trigger an obstacle-warning system. After reaching a certain distance, configured in the drone, the system sends an obstacle warning notification to stop the drone movement.

Once the drone has sent the obstacle warning notification, it may emit a radio bubble, such as described in the previous section. The surrounding entities would then be damaged depending on their distance from the drone.
To enhance the simulation, it would be relevant to equip vehicles with inertial systems in order to sense their orientation. By doing so, it would be possible to compute damage done to the vehicle depending on the part that was hit. A strike from the rear should results in an immediate destruction whereas a strike on the better protected front side may only result in the damage to the vehicle.

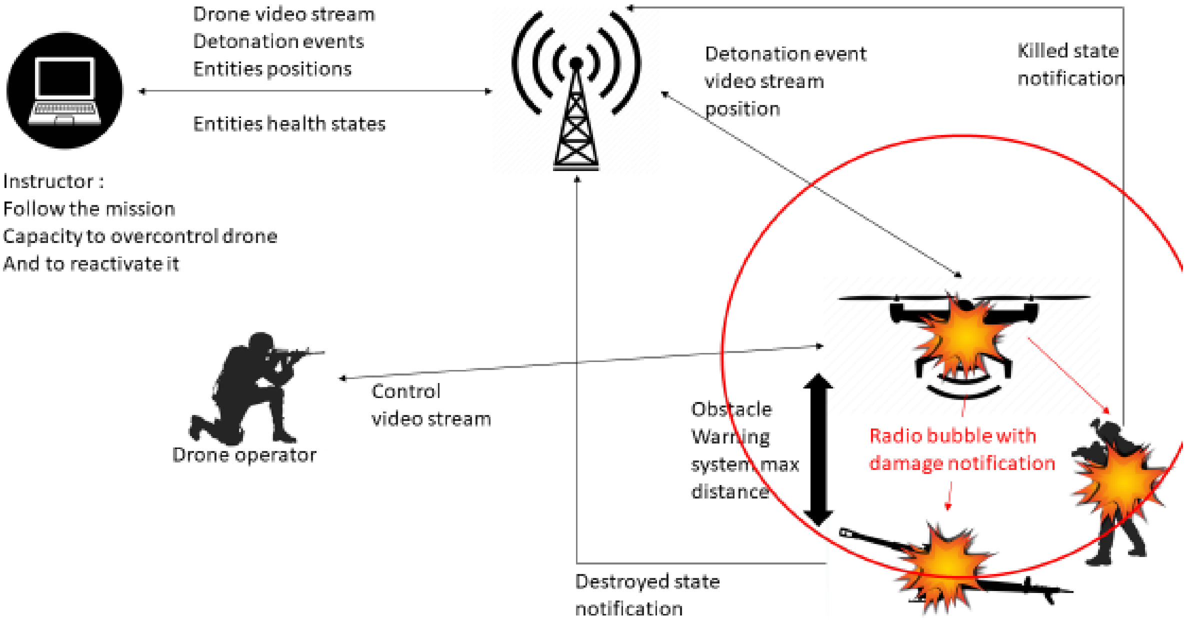

Figure 4 - Self-destructive attack mission procedure

DEFENSIVE MISSIONS

After reviewing all the missions that a small drone pilot may carry out on the battlefield the defensive aspect of small drone simulation is now considered. The integration of small drones in armies not only affects the soldiers that will have to learn how to use them but also these that will have to learn how to fight against drone attack. In order to enable infantry, armored and engineering corps to perform their missions, it is of prime importance to also integrate drone defense in live simulation defensive systems (i.e. Counter UAS).

Defensive solutions can be divided into two categories:
- Jamming
- Physical Interception

These missions will be individually described in the following sections:

Restrictions on potential solutions

For safety and economy reasons, the following rules have been set. In contrast to the real world, drones won't be considered as expendable in the simulation and so no matter the proposed solution , it shouldn't include damage or the destruction of the drone system during the training drill.

Radio interference systems

Military technology has always been a competition between the sword and the shield. If drones may be considered as the sword, then jamming then best epitomizes the shield. Due to their low radar signature and low price, drones are barely detected by typical surveillance systems and are not worth being destroyed by a missile that may cost several times the price. Hence, jamming is currently the most adapted response to drone threat.

However, some drones don't use any kind of connectivity and can move freely without the need of GNSS, 4G or radio communication to an operator. Therefore, it needs to be possible, during the equipment phase of the simulation, to distinguish between jammable and unjammable drone systems. All the effects described in this chapter wouldn't affect a drone configured as unjammable.

As this paper only deals within small FPV drone category, we will focus on the jammable category. Several kind of jamming types exist:
- GNSS jamming and spoofing
- Video jamming
- Radio jamming

Jamming device simulation

The jamming system might be emulated by a physical device, on the battlefield that would notify the C2 about the activation of a jamming system. The device would be equipped with physical selectors that would enable the user to select the jamming category, the power of the signal, and the ON/OFF status.
Depending on the parameter selected on the device, the following effect would be applied on the drone interface whenever the drone or its pilot is inside the radius effect of the jammer.

GNSS jamming

If a drone enters in a virtual jamming area, the GNSS position returned by the drone shall be overwritten and position noise generated artificially in the drone interface. The GNSS lost connection warning shall be also triggered.

Video jamming

If a drone enters in a video jamming area, the video stream shall be disrupted with noise. The noise effect rendering shall increase progressively as the drone comes closer to the jammer position.

Radio jamming

If a drone enters in a virtual radio jamming area, its 4G connection with the drone shall be interrupted. The pilot then loses control of the drone.

Safety measures

To ensure trainees' safety, the instructor positioned in the C2 should always have feedback on the drone state, including its GNSS position and its video stream, and have the possibility to cancel, at any time, any virtual jamming effect added in the simulation whenever the need arises, using the Instructor operating station.

Counter jamming

Because of the increasing number of jamming technologies, drone manufacturers have started to develop counter jamming systems. For example, (CRPA) Controlled Reception Pattern Antenna ensures a high level of protection from intentional electromagnetic interference. Basically, the concept consists in optimizing signals that come from the GNSS source and detect and filter out signals coming from the jamming source.
Due to the introduction of these technologies, it should be possible for the instructor, through the IOS, to set the rejection efficiency percentage of jamming on the selected drone. For example, if the instructor sets the efficiency percentage to 10% and the jamming device has been set to 1W power (~ 50km jamming radius) then the drone will only be affected at less than a 5km distance from the jammer.

Direct Hit

The other solution in the real world to get rid of drones is to hunt them down with projectiles. Defense missile system, AA guns and Manpads are common equipment types used to hit small drones.
Simulating the systems listed above with physical devices may be either too complex or require too much modification of the small drones . Most of the time, shots are emulated in live training system thanks to laser emitters placed on weapons and sensors positioned on entities. Small drones are too small to be equipped with sensors, and the sensor weight coupled with the necessity to power it, would increase the battery consumption in a way that would stop the simulation from being representative.

That's why it would be better to select a totally virtual solution. After receiving a shoot call from the battlefield, an instructor may select a weapon system from a list and then select the drone to hit. This means that the ammunition travel time would be simulated, and after being "virtually" hit, the drone would be destroyed in the MMI and a destruction indicated on the battlefield. The indication could be implemented through the small drones' embedded LEDs (controllable through the drone API). One option would be to have red LED blink and for the C2 system to send a Return-to-home command to remove it from the battlefield.

As for the other missions described earlier, all drone kills shall be recorded in each weapon category.

SUMMARY & CONCLUSION

As drone manufacturers are booming everywhere the number of platforms deployed on the battlefield will significantly increase. Despite that, drone manufacturers only focus on basic training of their system and not on its integration in a bigger ecosystem. Without the implementation of drone integration in live training simulation, it will not be possible for users to be trained to use drones efficiently in a team situation.

This paper has showed that small drones available on the market can permit live simulation providers to cover all drone missions, and to allow the evaluation of operators , thanks to the availability of open source APIs that speeds development. However, it may be necessary to convince drone manufacturers to open more of their systems and to permit simulator experts the capacity to access more low level drone control functionality.

Simulation companies, belonging to countries with common interests, should now agree on a Drone Joint Framework Interface to improve interoperability and training of drone operators in their respective armies.

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