Virtual C2ISR for NATO Intel Training

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ABSTRACT

Since Operation Allied Force, and spurred by lessons during Operation Unified Protector, NATO has grown its capacity to conduct Processing, Exploitation, and Dissemination (PED) of Intelligence/Surveillance/Reconnaissance (ISR) data exploitation through both organic NATO intelligence centers within component commands as well as through national contributions. This federated PED approach has meant that there has been no standardized, organic capability to train analysts, intelligence leaders, and collection managers to the levels required for optimized, cross-alliance, military effectiveness. The Virtual ISR Training Application (VISTA), developed by L3Harris, provides a scalable, scenario-based ability to generate synthetic C2ISR data, stream that data across operational networks, and provide dedicated training capability for federated PED. The VISTA was demonstrated during NATO ISR Exercise Unified Vision 2018 and enabled a Joint Task Force to task intel units to provide PED to a full-scale joint force even though very few live assets were available for the exercise. The VISTA also allowed distributed analysts to carry out their missions, exploit ISR data streaming across the network, and provide processed intel products, in the same manner as they do for live assets. This paper will present the ISR training problem faced by NATO, the capabilities of VISTA, and the results of UV18.

1.0 ISR TRAINING – PROBLEM AND PROMISE

On any given day, at any given hour, at several of the world's hotspots, national and NATO reconnaissance units are conducting missions in support of NATO operations. These may be MQ-9s belonging to the US or another NATO member. They may be the NATO Alliance Ground Surveillance RQ-4 platform. They may even be ground troops with tactical sensors tasked to perform operational Intelligence, Surveillance, and Reconnaissance (ISR). But in all these cases the operations crews carrying out those missions would be conducting some level of intelligence exploitation and analysis of the ISR data they collect—a first level of ISR exploitation.

But in most NATO ISR operations, there's a second level of exploitation. This would typically be a team of intelligence analysts, at a remote location, receiving that ISR data in real-time or near-real-time, and fusing multiple streams of data from multiple sources to provide a more detailed and actionable intelligence assessment of potential targets, threats, and other entities in the battlespace. This analysis and production of intelligence products would likely be part of a "Federated" Processing, Exploitation, and Dissemination (PED) operation whereby any of the PED cells allocated to the NATO Joint Task Force (JTF) by member nations can be tasked by alliance to exploit data from any ISR sensor—regardless of nation or domain.[1]

[1] Ralph D. Thiele, "Towards Integrated C4I—NATO Experience in Building C4I Systems," *ISPSW Strategy Series: Focus on Defense and International Security,* Issue No. 531, Jan 2018, Page 7.

The ability to provide sufficient PED resources for the ISR sensors employed, and further of that PED cell to effectively exploit the data they receive, is a function of manpower capacity—which is ultimately a function of training capacity and capability.

NATO expects this problem to be solved by the nations. In fact, it expects that contributing nations will provide intelligence personnel who are trained by the nations—in accordance with NATO standards—who are ready to commence operations on the first day they are tasked.[2]

While there have been a number of NATO Standardization Agreements on ISR PED training tasks and standards—and in stark contrast to other training problems such as that for aircrew or ground forces training—there is no standard NATO or member nation ISR PED training capability identified to achieve this state of readiness. In fact, across the alliance, ISR PED training is characterized by a lack of any dedicated training capability to technology at all.

Since 2017, L3Harris Technologies Inc. has endeavoured to address this capability by drawing on previous investments in crew training for ISR collection platforms to create a dedicated training capability for ISR PED analysts, targeteers, and other downstream users of ISR data. This paper will review the training problem faced by NATO ISR professionals, describe the development and fielding effort for the L3Harris solution, recount L3Harris' participate in the 2018 NATO Unified Vision ISR exercise, and provide some recommendations to improve future ISR training across the alliance.

1.1 Alliance Intelligence Training Capability Gap

A fundamental premise of NATO operations is that forces contributed by member nations comply with the agreed-upon NATO standards and that those forces will not require extensive support, training, or other enables to carry out their assigned missions. And to a point, the NATO allies have been quite successful at training and providing trained and expert intelligence analysts to NATO operations—either in the form of augmenting personnel for NATO headquarters and command centers, or in the form of entire intelligence units allocated to NATO operations. In the cases of NATO combat operations in the last twenty years—from Kosovo, to Libya, to Afghanistan—NATO intelligence has been sufficiently effective to achieve operational and tactical objectives. These success of the operations being the main evidence.

However there continue to be long-standing gap in intelligence manning and skill set of available personnel. For example, during Operational Allied Force in Kosovo, it typically took the joint team 3-4 hours to prosecute a target from initial detection to weapons delivery—due to both a slow target identification and approval process as well as a lack of proficiency in the coalition targeting process. As noted by a RAND study after the conflict, "One realization driven home by these and other shortcomings was the need for planners in the targeting cell to train together routinely in peacetime before a contingency requires them to react at peak efficiency from the very start."[3]

Thirteen years later, during Operation Unified Protector, challenges remained. Participants in that operation noted that to carry effective targeting inside the Combined Air and Space Operations Center (CAOC) in Italy—a C2 center intended to provide a standing capability to conduct operations—required "…major augmentation

[2] Major Andre Haider, Lieutenant Colonel Martin Menzel, and Commander William Perkins, *NATO / Multinational Joint Intelligence, Surveillance, and Reconnaissance Unit: A Feasibility Study,* The Joint Air Power Competence Centre, October 2015, Page 48.

[3] Lambeth, Benjamin S., *NATO's Air War for Kosovo: A Strategic and Operational Assessment,* RAND, 2001.

of US personnel—specifically targeting specialists.”[4] Another participant observed that NATO personnel working the CAOC targeting functions “…had no experience, training, or qualifications to do so.”[5]

To provide additional intelligence, analysis, and targeting skills and expertise to NATO member nations, NATO has set up various training courses at different venues. These courses, such as the N2-02 NATO Intelligence Course at the NATO School in Oberammergau, Germany, provide a combination of classroom and simulation-based training to establish core intelligence skills. However courses like this are limited in scope, duration, and capacity (the N2-02 course is one week long), and cannot provide the entirety of skills need, knowledge, and experience for an individual analyst to function effectively at a NATO-supporting intelligence center. That burden still falls on the member nations.

Within those member nations, skills development for intelligence analysis and targeting to support tactical operations is still done mostly via on-the-job training—even for those nations with the largest intelligence enterprises. For example, in the US, despite an extensive course at the Intelligence Technical school to provide the initial intelligence skill set, the United States Air Force (USAF) relies extensively on On-the-Job Training (OJT) to bring an analyst student from apprentice status to full qualification. Likewise, inexperienced analysts have very few opportunities to participate in Large Force Exercises (LFEs) to gain the experience needed.

To further examine the US Air Force as an example, there are 22 intelligence positions in a USAF Distributed Common Ground Station (DCGS), each with their own position-specific training tasks applicable across the entire spectrum of conflict. But since the Air Force or NATO as a whole lacks an intelligence-dedicated mission training simulator akin to aircrew simulators for all airborne platforms, there is no specific technology dedicated to training each of those 22 positions.

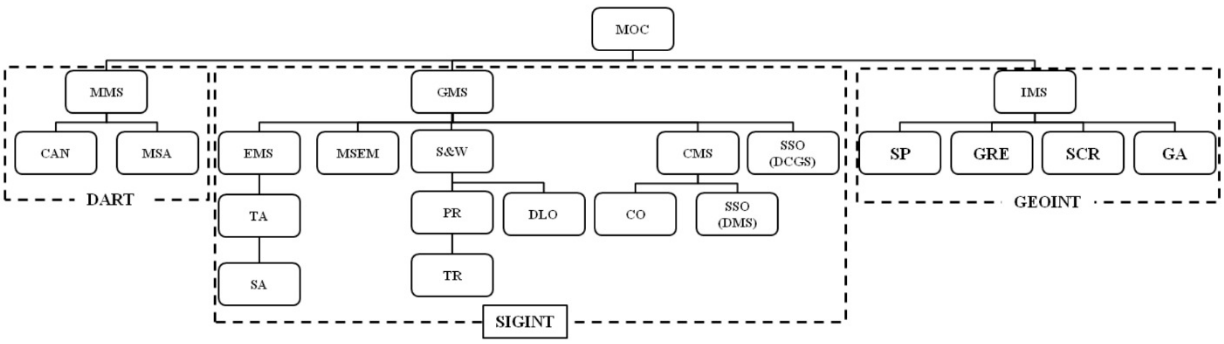


Figure 1: USAF DCGS Intelligence Crew Positions[6]

Considering the breadth and depth of the NATO Coalition ISR enterprise, and the current distributed nature of NATO ISR, creating new stand-alone training solution is not the answer. The USAF alone has 27 DCGSs and over 5,000 analysts assigned to them. The embedded and institutionalized nature of OJT would also make it difficult to change to a completely different approach to operational training.

In 2016, a development team at L3Harris Link Training & Simulation, the military training division of L3Harris, saw this as an opportunity to develop leverage off-the-shelf capability from other programs to create a new dedicated training capability for analysts, targeteers, and other downstream users of ISR data who work

[4] Joint and Coalition Operational Analysis, *Operation Odyssey Dawn: Executive Summary,* Page 18.

[5] Greenleaf, Major Jason R., “The Air War in Libya,” *Air & Space Power Journal,* March-April 2013, Page 54.

[6] Air Force ISR Agency Instruction 14-153 Volume 3, 05 Feb 2014, Page 23.

on a network. This system was initially called Virtual ISR, and now is known as the Virtual ISR Training Application (VISTA).

1.2 VISTA to Address the ISR Training Gap

The L3Harris team had significant virtual training capability available to address the problem. Over the years, both L3Harris and their military customers had made large investments in developing high-fidelity ISR sensor simulation capability as part of aircraft tactical flight and mission training. The MQ-9 Mission Training System (MTS) is a primary example.

In the MQ-9 cockpit, the Pilot and the Sensor Operator must work together to not only maneuver and position the aircraft, but to employ the sensors on board the aircraft to achieve the desired effects and collect the required ISR data. Typical MQ-9 sensor flown by NATO members include Electro-Optical, Infrared (both near- and short-wave), low light, Synthetic Aperture Radar, Ground Moving Target Indication, and even some signals intelligence. To effectively employ these sensors, the Sensor Operator of the MQ-9 must be able to train to full manual control of each sensor and be able to maximize the quality of ISR data. To do that, L3Harris has developed a series of high-fidelity sensor simulation modules to incorporate them into the MQ-9 mission simulation. Figure 2 below provides some examples.

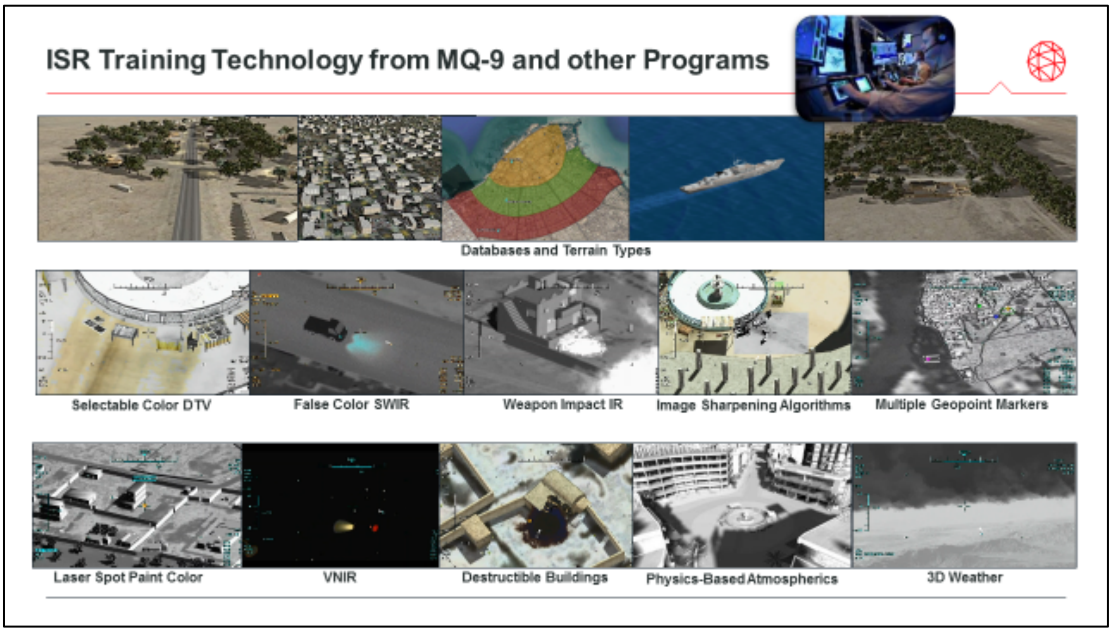


Figure 2: ISR Sensor Model Examples Available for ISR Training

In addition to the sensor models, the L3Harris team also drew upon both internally-developed and commercially available tools to create both the physics based virtual environment for tactical training events, but the joint and coalition forces as well as the targets that could be represented in simulations. The idea was to enable ISR instructors to create the same dynamic scenarios—to be scripted ahead of time or adjusted dynamically in real time—that aircrew have taken for granted for many years. Rather than be dependent on live mission data flowing into their network from live ISR collection platforms—and therefore being limited to the missions those assets happen to be flying—ISR students and instructors should be able to create their own complex scenarios to meet their own training objectives.

To do this, the L3Harris team incorporated existing imagery/scene generation tools as wells as a Semi-Automated Forces system capability of creating whatever ISR collection platforms, red and blue forces, targets, weather conditions, and terrain needed for any training scenario. This technology also provides a high level of terrain and atmospheric fidelity so that Infrared, Synthetic-Aperture Radar (SAR), and highly level imagery would appear correct and realistic so that students can train to target recognition and analysis as they would with live imagery.

1.3 Scalability and Modularity

The solution also needed to scale to operational networks and avoid the cost and limitations of stand-alone training systems. The L3Harris team therefore incorporated cybersecurity and network standards compliance into the VISTA system. This enables the system to connect to operational networks (at any level of classification) and also to interface with other modelling and simulation systems for integrated network training. Sensor simulation modules produce the embedded sensor data along with raw imagery or Ground Moving Target Indictor (GMTI) dots. This means that when the VISTA is connected to an operational network, the data it produces can be processed and manipulated by existing operational tools as if it were live data. ISR students can therefore train on their operational systems with no need to switch to a more limited training system.

The result is a scalable, highly cost-effective solution that enables the entire Task/Collect/Process/Exploit/Disseminate (TCPED) and Command, Control, Communications, Computers (C4) ISR training audiences to create their own scenarios, train to their specific individual or team training objectives, connect with other virtual training systems (air, space, ground, maritime, or cyber), and dramatically increase the flexibility, fidelity, and capacity or their OJT and exercise training. Figure 3 below shows an overview of this training approach.

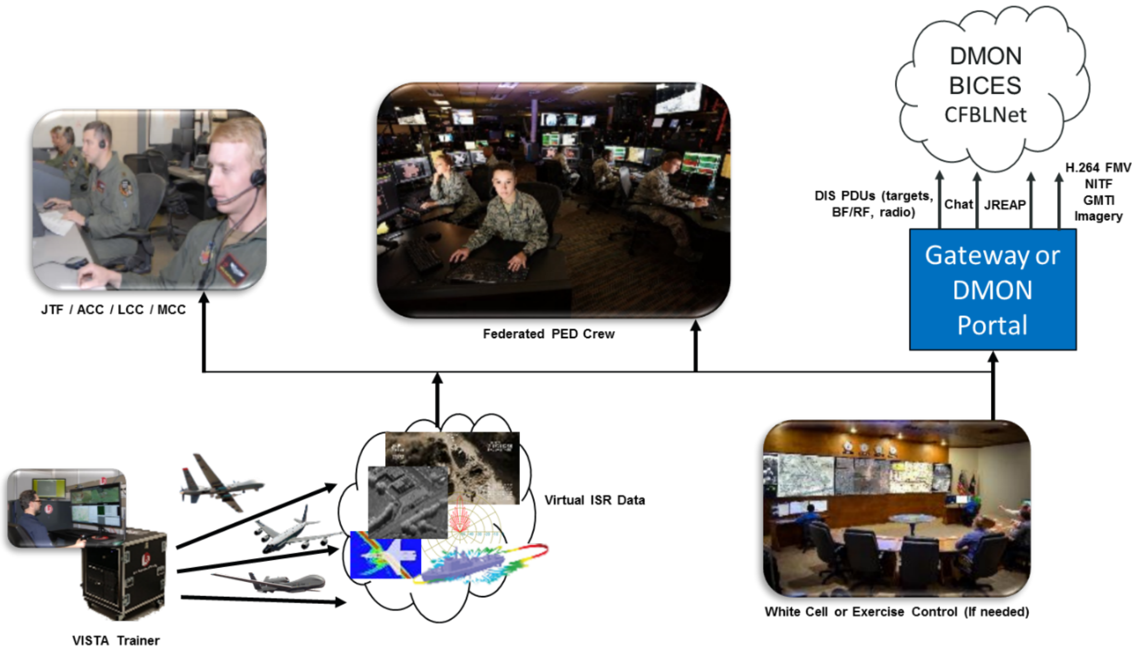


Figure 3: Operational View of the Virtual ISR Training Concept

As this was an initial development effort, using internal investment funding, the aim of the VISTA team was to build a system using off-the-shelf components, and then seek out opportunities for operational testing and employment to both prove the value of the concept and to continue to refine the training requirement. The team was also mindful to keep the capabilities unclassified for the initial prototypes. The result was the ability to create a wide array of virtual ISR collection platforms and their associated data. The table lists the capabilities of the prototype system.

	Virtual Assets Available								
Data Type	MQ-1	MQ-9	RQ-4	U-28	MC-12	RC-135	E-3	Small UAS	Other Manned ISR
EO	✓	✓	✓	✓	✓			Under Development	Under Development
IR	✓	✓	✓	✓	✓			Under Development	Under Development
SWIR	✓	✓		✓	✓				
Low Light	✓	✓							
SAR	✓	✓	✓						
GMTI	✓	✓	✓						
ELINT						Under Development	Under Development		
Voice Communications				✓	✓	✓	✓		✓

Figure 4: Virtual ISR Assets Available in the VISTA Prototype

1.4 Interoperability, Exportability, and Cyber Compliance

The VISTA was designed with exportability and interoperability in mind. For the later, the team ensured that all virtual ISR data produced by the system was not only standardization agreement (STANAG) compliant in the same manner as live ISR data, but that the data and meta-data format of those feeds matches live data in every possible way. For example, the full motion video produced by virtual assets like the MQ-9 or MC-12 are produced and streamed in the same H.264 format as live video. Likewise the SAR images are produced in National Imagery Transmission Format (NITF) used by the NATO AGS RQ-4 and other STANAG-compliant formats. GMTI data is provided in the STANAG 4607 standard format. VISTA then creates Joint Range Extension Applications Protocol (JREAP) messages for all Blue Force and student-identified Red Force/Target entities in the scenario. This enables the training audience to create and manipulate a tactical datalink picture on their operational network to increase training realism.

To ensure exportability, the VISTA team sought out sponsorship from the US Government to oversee the export review process. They found a willing partner in Colonel Chris "Otto" Recker of the US Secretary of the Air Force for International Assistance office. Col Recker spearheaded a full review of the system with an eye towards approval for full releasability to NATO members as well as traditional NATO allies such as Sweden and Australia. Thanks to Col Recker's help, approval by the US State Department to export the system for demonstration and testing purposes was approved in short order.

To obviate any releasability issues of the virtual ISR sensor data to NATO nations, the VISTA team opted to create their databases using commercially available source data rather than DoD imagery. They then applied the same processed used on flight simulator programs to combine that commercial imagery with commercially-available Digital Terrain Elevation Data (DTED) and create high-fidelity 3D databases of various geographic locations for use in training scenarios. This ensured that not only was any data easily released to NATO nations, but that nearly any place on earth could be built up as a training area to meet the intel training objectives of NATO and its member nations.

Finally, the VISTA team applied the same cyber compliance approach to VISTA that we use for all of our networkable training systems. This included exhaustive document of system architecture, hardware and software components, network connection protocols, the use of firewalls where needed, and a process to ensure all the most recent software patches were in place. They also conducted initial and ongoing virus and cyber-vulnerability scans to ensure there were no critical or serious cyber vulnerabilities. This documentation was provided to the cyber compliance office of the Headquarters US Air Force staff for training systems, who reviewed the documentation and then granted an Authority to Test certification. This gave the VISTA team the authority to connect the VISTA system to government and coalition operational networks for testing and development purposes.

2.0 NATO ISR EXERCISE UNIFIED VISION 2018 (UV18)

The opportunity to test VISTA in an operational environment came when the US delegation to NATO, at the behest of Col Recker, sponsored the VISTA team to participate in NATO ISR Exercise Unified Vision 2018 (UV18). Due to a lack live ISR assets, the UV18 exercise management team was facing significant challenges in providing enough ISR data in diverse scenarios to properly stimulate the NATO ISR networks and develop tactics and procedures to carry out federated PED. The use of VISTA would both provide a forum for the VISTA team to further develop the capabilities of the system and also provide a significant increase in ISR capacity to the UV18 exercise team.

The UV series is a bi-annual NATO exercise/trial forum to test and develop the latest in coalition, federated, joint ISR exploitation and targeting Tactics, Techniques, and Procedures (TTPs). UV18 had the specific intent of employing joint collection management—via a Joint Task Force Command and Control (C2) structure—to carry out Federated PED as part of a large-scale operation. Figure 5 below provides a snapshot of UV18.

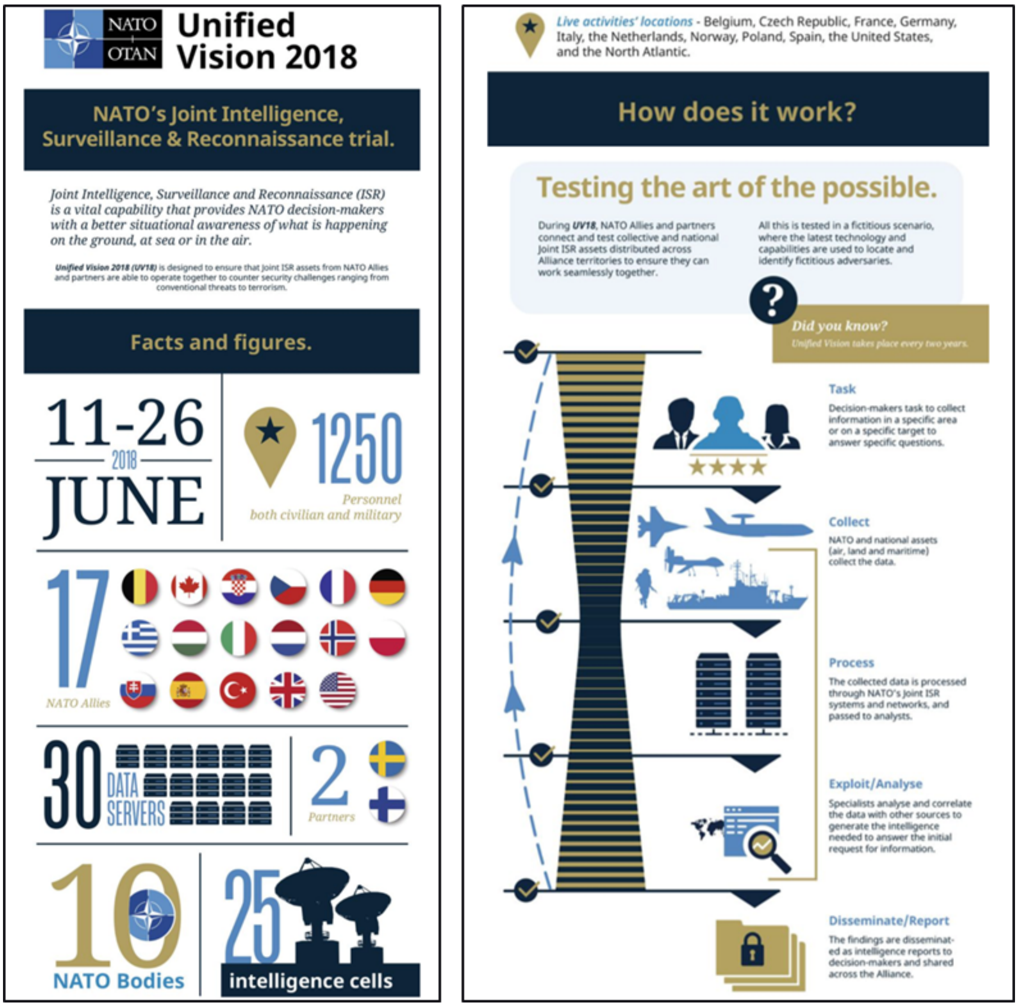


Figure 5: Unified Vision 2018 at a Glance

2.1 VISTA Integration in UV18

The scope of UV18 was to set up a Joint Task Force C2 structure—with the intelligence elements of the component commands (collection managers, J2 (intelligence), and targeteers of the air, land, maritime, and special operations components as well as the Joint Task Force) to execute the joint collection management and

TCPED process. This JTF was then connected to 20 different PED sites across Europe and North America to carry out Federated PED. Coalition Shared Databases (CSDs) were also set up at critical PED and C2 nodes to ensure proliferation of ISR data across the Blue Force team.

The VISTA system was set up in the Exercise Control cell near the Blue Force JTC area. This allowed the exercise management team to adjust the scenario, create new targets, and make real-time changes to steer the Blue Force team towards the exercise objectives or to bring out learning points. Figure 6 below shows the VISTA Instructor Station as it was set up during UV18.

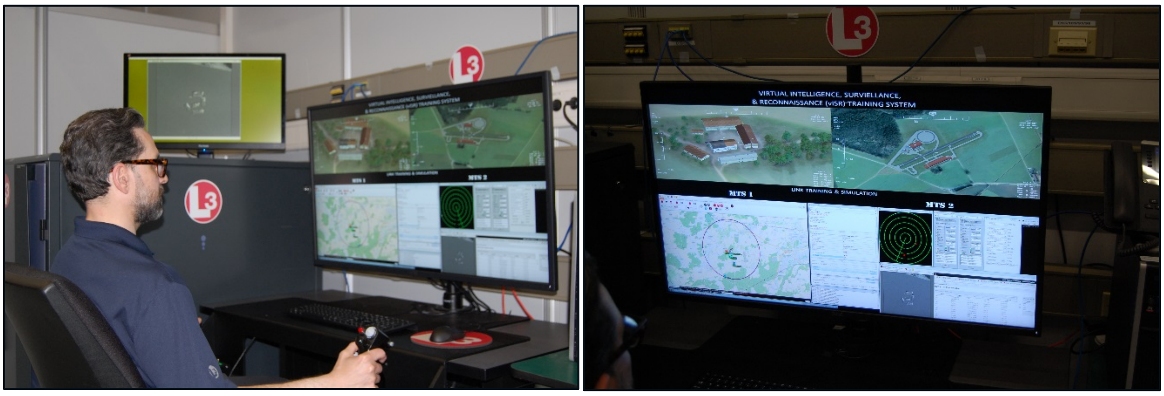
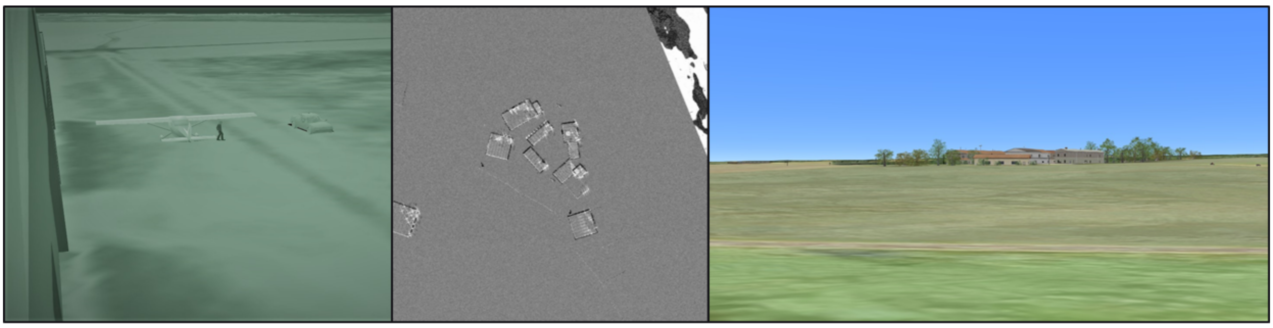


Figure 6: VISTA Setup During UV18

Through this proximity, the VISTA team was able to fully integrate into the UV18 mission network with bridges to the Coalition Federated Battlelab Network (CFBLNet) and Battlefield, Information, Collection and Exploitation Systems (BICES), thereby streaming ISR data to all 20 PED sites and the entire blue force JTF.

2.2 Virtual ISR Support Provided

Through the UV18 planning process, the VISTA team was prepared to present three ISR assets in the exercise: two virtual MQ-9s and a virtual NATO Alliance Ground Surveillance (AGS) RQ-4. But in the course of the exercise, the UV18 management team discovered that they needed additional sensors. For example, they need to represent Unattended Ground Sensors as well as Closed Circuit TV cameras to replicate civil support for counter-terrorism. The VISTA team was able to create these virtual sensors on the fly and place them in the same simulated environment as the other blue forces and targets. Figure 7 below shows some imagery examples from these efforts.



CCTV Images | **SAR Images with GMTI** | **Unattended Ground Sensor (MASINT) Images**

Figure 7: VISTA Sensor Examples from UV18

By the end of the exercise, the VISTA team had provided the following support for UV18:

- 84 hours of full motion video from 2x virtual MQ-9s
- 59 video clips uploaded to CSDs
- 210 Measurement and Signature Intelligence (MASINT) images produced for UGS exploitation
- 32 Human Intelligence (HUMINT) and Signals Intelligence (SIGINT) injected produced and provided to the exercise management team
- Four Closed-Circuit Television (CCTV) clips produced to support the counter-terrorism vignette
- SAR images with GMTI data for all four primary target areas
- Scenarios adjusted in real-time at the request of the UV18 exercise management team

The L3Harris VISTA team also assisted the NATO Communications and Information Agency (NCIA) team to troubleshoot the extensive UV18 mission net by providing constant streams of ISR data during the network setup and testing phases of the exercise.

2.3 UV18 VISTA-Enabled Immediate Benefits

The most immediate and obvious result of VISTA integration into UV18 was the ability to stimulate the entire JTF ISR Collection Managed, targeting, and TCPED network in absence of sufficient live fly operations—to include the actual ISR data needed for intel analysts to perform their roles in a complex joint environment. The fact that the data could be streamed to all players with no limitations on capacity further enabled the exercise team to run multiple vignettes and Techniques, Tactics and Procedures (TTP) tests, and ensure that all PED players were sufficiently engaged to gain value from the exercise.

Other benefits observed by the VISTA team included:

- The ability to change, in real time, the scenario inputs, virtual sensors, Red Force actions, target characteristics, and scenario pacing in a way that would be much more difficult using live assets
- The ability to represent a much larger and more variety Red Force order or battle than would be possible using live Red Force players
- The ability to show the both the positive of negative outcomes of Blue Force targeting actions
- The ability to provide focused scenario inputs to each component, unit, and even individual to meet their specific training and testing objectives
- Greater situational awareness for the exercise management team to know the difference between “sim truth” and Blue Force perception of the tactical situation
- Integration with all three operational networks used in the exercise (UV Mission Net, BICES, and CFBLNet) which enabled proliferation of the data for all live players and also into the CSDs
- The potential to conducted distributed LFEs and reducing the need for and cost of travel

2.3.1 NATO Feedback and UV18 Out-brief Results

In addition to the observations of the L3Harris VISTA team, the NATO UV18 exercise management team also presented several relevant observations and lessons during the out-brief. They included[7]:

- Federated PED requires the bridging of multiple operational networks which aren’t normally connected during day-to-day operations. At the onset of Federated PED ops, the networks need to be

[7] As noted by the author during the UV18 out-brief to all participants

exercised and tested to ensure stability and robustness—a task greatly facilitated by the presence of cross-domain streaming ISR data

- UV18 execution showed many of the doctrinal and TTP gaps that have been seen in previous operations. This implies that day-to-day NATO and national operations are not reinforcing the lessons learned from combat. Day-to-day large force training—enabled by simulation capabilities such as VISTA—would give NATO and member nations much more opportunity to experience, incorporate, and ingrain those lessons.
- Maturing Federated PED as an operational norm for NATO will required a dedicated effort to provide networked services and applications such as ISR asset simulation, as well as dedicated OJT training resources and capabilities.

2.3.2 Individual Training Results

While not the focus or primary objective of UV18, the exercise did demonstrate the potential for individualized intel analyst training during LFEs where sufficient data capacity is provided. Figure 8 below shows an example of an intelligence product built by one of the analysts participating in the exercise to meet an individual training objective. Other examples include Intelligence Summaries built from multiple VISTA data streams, specific assessments made from VISTA full motion video and SAR images, as well as activity rollups from exploitation for multi-hour activity monitoring using the VISTA-generated virtual MQ-9s. This type of individual analyst training was only made possible because of the multi-sensor, dynamic scenario capability of the VISTA system.

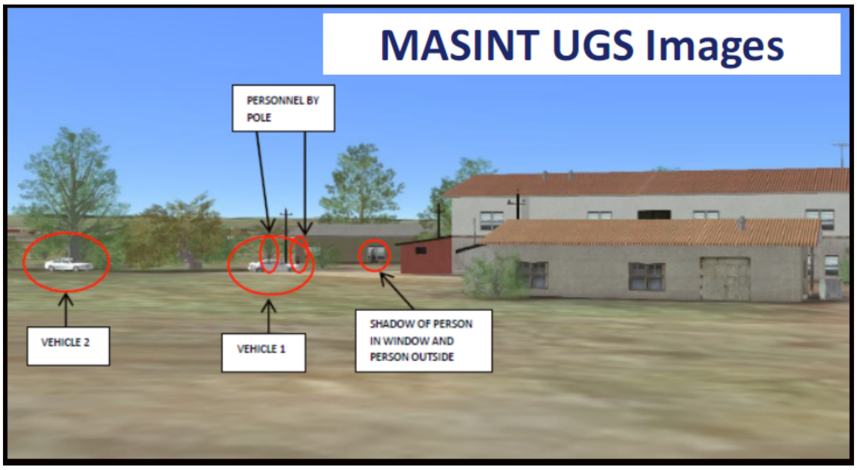


Figure 8: Example Intelligence Product Built for Individual Training Using VISTA data

3.0 FUTURE CAPABILITIES

In the short term, L3Harris will continue to develop the VISTA system to provide more value and flexibility from the current software suite. Short term upgrades—to be incorporated over the next year—will include:

- Improvements in ease-of-use and a simplified user interface
- Multiple configurations of the SAR/GMTI sensor module to replicate other SAR systems such as the Joint Surveillance Target Attack Radar System (JSTARS), radar pods, and ground-based radars
- Additional Full Motion Video (FMV) sensor models such as the WESCAM and FLIR series
- Automated Joint Common Operating Picture (JCOP) export for JREAP messages

- An easy-to-use tool for creating non-traditional sensor employments such as MASINT and CCTV
- The VISTA team has already made several improvements such as a tailorable, web-based interface for analyst students in a formal training environment (Figure 9 below). This gives the instructor the ability to present individualized ISR data feeds to any number of students and interact through chat and sketches made directly in the data feed—regardless of location or distance.

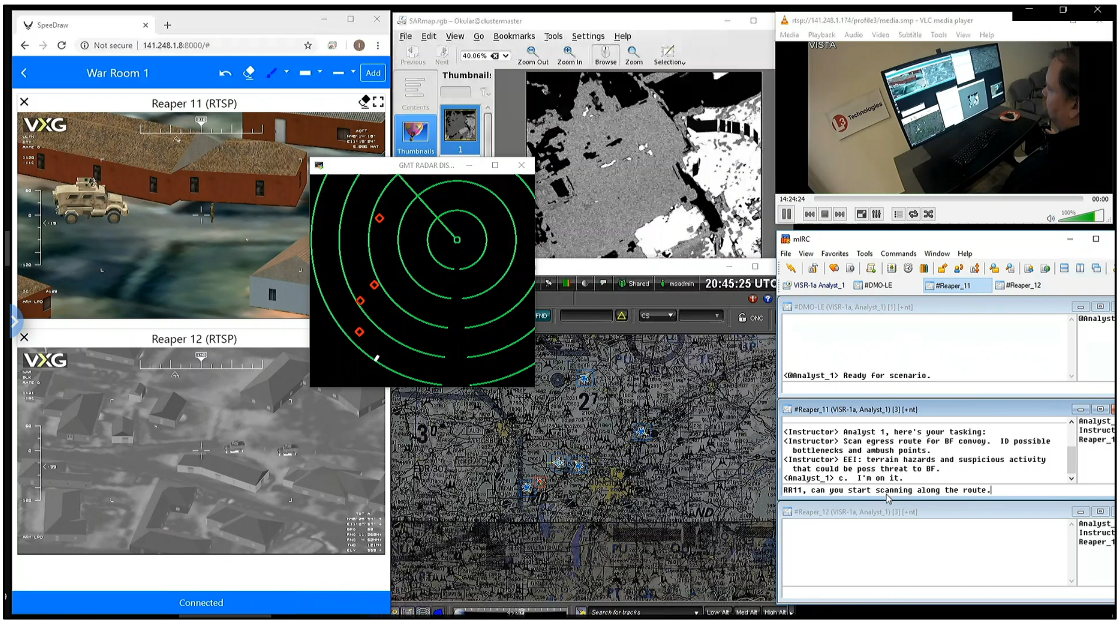


Figure 9: Individualized Web-based VISTA Presentation for Intel Analyst Students

3.1 Automated Data Processing Tools

As L3Harris and our industry and NATO partners investigate the potential of the VISTA approach to scalable training on operational networks, we envision the development and integration of new data-centric capabilities to increase the value of VISTA as a set of applications.

Based on this thinking and our experience in UV18, the VISTA roadmap now includes the incorporation of the following emerging technologies:

- Automated imagery recognition to provide recommendations on target ID, sensor positioning, and existing gaps in intelligence for specific information requirements
- Automated cross-domain solutions incorporated into the VISTA architecture
- Reduced footprint and transition to an all-software solution
- Embedded mission rehearsal and collection plan fly-out tools to enable collection management and C2 teams to rehears their plans prior to execution—including automated assessment of the effectiveness of those plans and recommended improvements

The above improvements would not only provide an embedded, scalable, and individually tailorable training solution on current and legacy operational networks for NATO and member nations, but it could also be the basis for future C4ISR architectures such as the Alliance Future Surveillance and Control (AFSC) solution and national Joint All-Domain C2 (JADC2) systems. Future NATO approaches to JADC2, sensor-to-shooter targeting, and Federated PED, will require an embedded modelling and simulation capability to achieve maximum operational effectiveness and overcome the challenges noted in previous NATO operations.

3.2 Adaptive Learning

Targeted applications such as VISTA alone cannot guarantee proficiency and operational readiness across the entirety of knowledge, skills, and abilities (KSA) that an individual analyst requires to operate effectively at a NATO-supporting intelligence center. In fact, gathering real-time and accurate performance data on trainees' performance in fast-paced, dynamic training environments such as ISR is critical to ensure positive training outcomes while sustaining high throughput demands. Additionally, performance factors to improve readiness in complex, high-stakes environments are growing beyond traditional Measures of Performance (MOPs) and highlight the need to objectively assess trainees' psychophysiological states and cognitive processes that are key enablers to the Orient, Observe, Decide, and Act (OODA) loop. L3Harris's Adaptive Learning Environment (ALE) answers these pressing needs by incorporating innovative technologies that are being rigorously validated via scientific experiments and executed across multiple use cases. Its application to ISR training is a logical next step.

Specifically, ALE is an intelligent training system that can connect to multiple networked training devices simultaneously to automatically provide real-time, objective, and comprehensive assessments of students' performance against a formal syllabus. ALE captures training tasks proficiency requirements across KSAs from existing syllabi, and scores performance alongside tasks' behaviors, conditions, and standards. Moreover, ALE goes beyond traditional proficiency criteria by measuring, in real time, trainees' mental states (such as stress) and higher-order cognitive constructs (such as cognitive workload) via scientifically validated biometric-based Machine Learning (ML) classifiers that are diagnostic of performance8. As a result, this comprehensive assessment enables ALE to accelerate students' skill acquisition along a specific curriculum very efficiently, while supporting instructors' needs, and reducing their workload and bias.

Overall, ALE's impacts on ISR training could help transform the current lockstep, rigid, one-size-fits-all training paradigm into an adaptive, learner- and instructor-centered paradigm that accelerates skill acquisition while improving instructional efficacy. ALE's goal is to align to current and future training needs to support individuals, teams, and team of teams performance in multi-domain and joint warfare, where insights into higher-order cognitive constructs will become indispensable to achieve mission readiness. Initial results from the use of ALE in fast jet and unmanned vehicle training use cases highlighted the potential to drastically improve both training efficiency and effectiveness, while providing critical and actionable psychophysiological metrics9.

A final note, ALE has shown the potential for significant cost reductions, mainly by increasing instructor to student ratios. For example, in the aviation training domain, current simulation-based training events require a 1 to 1 instructor/student ratio. Across fast-jet use cases, ALE has doubled that ratio (1 instructor and 2 students, as demonstrated at I/ITSEC 2018)10, and shown the potential for further increases. Additionally, when ALE is paired to high-fidelity training devices, training tasks that were previously OJT can now be standardized and assessed automatically. As a result, integrating ALE with VISTA, or any other advanced training platform, would allow the ISR community to (a) standardize training assessment for NATO or member nation ISR PED training curricula to achieve operational readiness, (b) reduce instructor workload and overall cadre requirements by passing the student scoring burden and skill progression tracking onto ALE,

[8] Wilson, J., Nair, S., Scielzo, S., & Larson, E. C., *Automatic Gaze Classification for Aviators: Using Multi-task Convolutional Networks as a Proxy for Flight Instructor Observation*, International Journal of Aviation, Aeronautics, and Aerospace, 7(3), 2020.

[9] Scielzo, S., Wilson, J., & Larson, E. C., *Towards the Development of an Automated, Real-Time, Objective Measure of Situation Awareness for Pilots*, The Interservice/Industry Training, Simulation and Education Conference (I/ITSEC), Orlando, FL, 2020.

[10] Hanson, T., *L3 Introduces First-Ever High-Fidelity, Mixed Reality Deployable Training Simulator*. Retrieved August 9, 2020, from https://www.l3t.com/link/press/l3-introduces-first-ever-high-fidelity-mixed-reality-deployable-training-simulator, 2018.

and (c) reduce overall training costs as a result of gaining training efficiencies and improving the overall student to instructor ratio.

4.0 RECOMMENDATIONS AND CONCLUSION

The VISTA was created via L3Harris internal investment to solve the specific problem of providing a dedicated, dynamic, scalable, modular, and interoperable training capability for national and allied intelligence analysts, targeteers, and other downstream users of ISR data. It was built to be added to operational networks, to be compliant with NATO and national data standards, and to obviate the need for stand-alone large-investment training systems. The experience of the VISTA team in Unified Vision 2018 validated that approached and demonstrated a host of benefits as well as the potential to great training and mission rehearsal value to NATO and member nations.

More specifically, the VISTA trial in UV18 showed that individualized as well as team training can be done in a joint, large force exercise environment. It also showed that large deployments of tactical forces to play both blue and red forces in large force exercise are simply not needed to achieve the operational exercise objectives. Federated PED, joint targeting, and joint command and control can all be exercised on multiple operational networks using all simulated assets—with the potential to produce tremendous savings for NATO and member nations.

The above benefits and potential were demonstrated entirely as industry expense with no request for NATO or member nation funding. But industry cannot carry the entire load. We therefore recommend the following actions for both NATO and member nations:

- Invite industry to demonstrate multiple approaches to network-based, scalable, virtualized training capability for C2ISR operators during future NATO LFEs
- Based on industry demos, provide funding and other resources (such as management of cybersecurity compliance) for high-potential prototypes
- Establish a set of standards for modelling and simulation on operational networks. The USAF is currently engaged in this process through the Simulator Common Architecture and Requirement Standards (SCARS) program, which would be a good model for the rest of NATO.
- Make NATO-specific software tools (such as JCOP, JChat, and other data processing tools) available to industry for incorporation into training systems under development.
- Ensure the embedded modelling and simulation capabilities for training, mission rehearsal, TTP development and operational plan assessment, be included as foundational requirements in NATO AFSC and member nation JADC2 programs of the future.

Finally, the L3Harris VISTA team has also been invited by US Department of Defense Joint Staff to participate in Bold Quest 20.2 this year. We recommend all interested audiences to monitor the progress of this exercise and examine the results for further evidence of the potential for embedded and dedicated training capability on operational networks for the C4ISR professionals of NATO.