The US Air Force Distributed Mission Operations – A Premier Application of Distributed Modeling and Simulation in 'Training The Way We Fight'

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ABSTRACT

The U.S. Air Force Distributed Mission Operations (DMO) concept is one of the most successful applications of Modeling and Simulation (M&S) for warfighter training. The applications span virtually the full spectrum of aircrew training beyond individual pilot flight training. Applications concentrate on team, inter-team, large force, and theater-level sensor-to-shooter kill chain training. Individual flight simulators have been available for several decades, but it was not until the widespread application of distributed technologies that theater-level exercises in synthetic battlespaces, such as the Virtual Flag (VF), could take place.

Virtual Flag exercises go far beyond simply training pilots to fly aircraft. These quarterly exercises, hosted by the U.S. Air Force (USAF) DMO Center (DMOC) at Kirtland Air Force Base in Albuquerque NM (USA), link hundreds of warfighters in realistic and robust scenarios. Virtual simulators, in which warfighters can practice force employment the same way they would with real weapon systems, represent most US Air Force airborne sensor, command and control, and shooter platforms. Many ground-based systems, as well as Joint and Coalition participants, add to the training realism and depth.

DMO synthetic environments place warfighters in scenarios with simulated enemy forces reflective of those in the real-world theaters of operations. DMO also provides training for worst-case scenarios where warfighters encounter threats much more numerous, effective, and persistent than any real potential threat can currently generate.

1.0 INTRODUCTION

Modeling and Simulation (M&S) is a broad field with many applications in the defense industry, but it is also one with many limitations. Most large force simulations, particularly those that simulate large engagement areas, have been limited to entirely constructive simulations; and thus, relegated to performing analysis and experimentation, and not much training. On the other hand, most virtual simulators (e.g., flight simulators, driver simulators, etc.) have been limited to training relatively small numbers of warfighters in procedures that specify how to operate their equipment, and perform tactics specific to their particular weapon systems.

Szulinski, J.; Sorroche, J. (2005) The US Air Force Distributed Mission Operations – A Premier Application of Distributed Modeling and Simulation in 'Training The Way We Fight'. In *The Effectiveness of Modelling and Simulation – From Anecdotal to Substantive Evidence* (pp. 8-1 – 8-10). Meeting Proceedings RTO-MP-MSG-035, Paper 8. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

The DMO and the VF series of exercises changed all of that. The DMO Center (DMOC), located at the Kirtland Air Force Base in Albuquerque, New Mexico U.S.A. is the facility that hosts the VFs on a quarterly basis. The DMOC has been able to combine the large force, large-area constructive simulations with the high fidelity, weapon system-specific virtual simulators to produce a training exercise that encompasses theater-level operations while maintaining tactical-level fidelity and resolution. The challenges of such a large scope exercise in the virtual battlespace are many, which bring to life two primary objectives: 1) provide a state of the art synthetic environment where the warfighters can "train as they fight", and 2) conduct the event in such a way that warfighters are not training aides to other warfighters.

The VFs provide robust and broad environments that allow the full spectrum of operations from sensor data collection, through command and control, all the way to shooter platforms. While all of these can, and certainly have been, trained and exercised individually, it is bringing all of them together in a single venue that allows the VF participants to truly train as they fight—as part of a large force. The VF training scenarios and environments are designed in such a way as to fully engage warfighters by saturating them with tasks that they will most likely encounter in real engagements.

DMO as a program is a U.S. Air Force (USAF) initiative, but the other U.S. services have now begun similar efforts to bring their simulation assets together to provide large-scale tactical-level training. Even though the VF exercises are USAF-centric, with approximately 75 percent USAF participation, they also include participants from other services and coalition partners. Individual simulators from the other U.S. services that are starting their DMO-like programs already participate in the VFs. This is a win-win situation enabling the other services to build on the lessons learned from integrating with the USAF. The USAF benefits from having an even broader environment of its own, which allows for Joint services training events. In fact other countries, such as the United Kingdom with their Mission Training through Distributed Simulation (MTDS) Program, and NATO at large with their Exercise First Wave (EFW) have also seen the value of conducting such large-scale, large-area distributed events.

Training objectives for individual exercises are specifically tailored based on the training audience; they are set by the warfighters themselves. The DMOC staff prepares specific synthetic theaters of operations and specific scenarios based upon these objectives. This is accomplished through careful planning of each VF event with Planning Conferences at least 12 weeks prior. The conference addresses operational and technical issues, and all participants attend and submit training objectives and requirements. Several 4-hour vignettes, small slices of time during combat operations, are developed to satisfy the participants' objectives. In the true spirit of "train as they fight," the participants are required to follow the real-life cycle of plan-brief-execute-debrief.

2.0 SYNTHETIC BATTLESPACE

There are two key features of the synthetic environment of the DMO, in general, and VFs in particular: 1) seamless integration of Live, Virtual, and Constructive (LVC) simulation assets, 2) broad and highly distributed nature. Unlike many other Department of Defense (DoD) initiatives, DMO and VFs grew, and are still growing, from grassroots efforts of a few key visionary players. Consequently, the synthetic environment has lacked the carefully controlled development cycle typically present in programs of this magnitude. The environment evolves based upon user needs and participation. There has not been a single VF exercise where the environment replicated that of a previous exercise; new remote sites and systems are being continuously integrated. The ability to rapidly change and adapt the environment is a testament to the DMOC's flexibility and ingenuity.

2.1 Live-Virtual-Constructive Integration

2.1.1 Live

The VF's focus is on the warfighters and their tactical-level training; hence, it is important to provide them with high fidelity simulators in order to achieve adequate realism. Usually, the best way to do this is to have the warfighters use the actual equipment they operate when they go to war—as in live simulations. There are several instances in the M&S arena where successful live integration with virtual and constructive assets has been achieved. Many regard live flight as the holy grail of this integration. While the DMOC has done this on limited basis, issues such as safety of flight and limited usefulness of live flight integration persist.

There are a number of live assets that have been successfully integrated in the VFs. These include the Combat Operations cell of the Combined Air Operations Center (CAOC), two Operational Modules (OM) of a Control and Reporting Center (CRC), Control Modules of the PATRIOT Air Defense Systems, the Joint Services Workstation (JSWS), Air Defense System Integrator (ADSI), and a U.S. Navy Destroyer ship connected through a Battle Force Tactical Trainer (BFFT) system. JSTARS and other live aircraft on ranges have also been integrated into the DMOC, but these efforts were outside of the VF environment.

Live asset integration is ideal for DMO training because the equipment offers the highest level of realism to the warfighters from the "touch-and-feel" point of view. However, it is also, perhaps even more, important to ensure that these systems are stimulated with realistic scenarios that adequately exercise the operators. The scenarios also need to be robust, yet flexible enough to push the crews beyond what they can encounter in other training venues, and at the same time, meet all of their training objectives. Unlike other simulation devices, live assets must be stimulated with real-world protocols and interfaces just as they would in real combat. DMOC supports a broad array of real-world protocols including Link-16, NATO-EX, Surveillance Control Data Link (SCDL), and others. Because of these factors, Command and Control assets in the DMO exercises lend themselves very well to employment of live simulations. Unlike real-life aircraft, most of the live platforms that participate in DMO and VFs can be very easily "fooled" into believing they are participating in real-life operations and not simulations. The human interfaces of these systems typically rely on some situational awareness (SA) display that can be easily stimulated with the appropriate protocols. Likewise, automated computer interfaces seamlessly integrate into exercises; since, they are also stimulated with real operational protocols.

2.1.2 Virtual

There are several benefits to using virtual simulators instead of trying to integrate live assets. Simulators tend to be cheaper to construct and use, and have greater flexibility for training, although, at the cost of sometimes reduced fidelity. Using flight simulators, it is possible for pilots to conduct operations and execute tactics that otherwise would be deemed too dangerous in real aircraft. Additionally, the synthetic environments allow for realistic 3D, terrain and sensor simulations to place warfighter trainees in situations that otherwise would be impossible to recreate. Examples of this include training for missions in hostile territories, training against a much stronger than real adversary or even mission rehearsal. Live systems typically do not have features such as pause and replay functions that make virtual simulators sometimes better suited for training.

The DMO environment relies heavily on virtual simulators. In fact, next to the CAOC, the vast majority of warfighters involved in the DMO and VFs accomplish their training in virtual simulators. These types of virtual simulators are indeed most prolific in the DMO architecture, and they represent just about every major flying platform in the USAF inventory. The aircraft represented include sensor platforms such as the E-3A Sentry Airborne Warning and Control System (AWACS), the E-8C Joint Surveillance and Target Attack

Radar System (JSTARS), the RC-135 Cobra Ball, the RC-135V/W Rivet Joint, and Navy's EP-3 ORION. These simulators are not typical "flight simulators" that are used to conduct pilot training, but rather simulate the electronic systems of the aircraft where the command and control, surveillance, and intelligence activities occur.

The flight simulators are the most common examples of virtual simulation. They are also fully represented in the DMOC's synthetic environment. These primarily include "shooter" platforms such as F-15C/E, F-16, B-52, B-1B, B-2, A-10, and a host of USAF and U.S. Army Special Operations Forces aircraft and the unmanned aerial vehicles (UAV) simulations. There are also other platforms present such as C-17 and C-130 aircraft.

Warfighters have been training in virtual simulators on a daily basis for years. Typical training scope has been cockpit familiarization, basic procedures, tactics, weapon employment, emergency procedures, and flying in adverse weather conditions. In some cases even mission rehearsal takes place where mission crews can pre-fly future missions in their simulators using the realistic terrain and threat representation of upcoming missions. In this type of stand-alone training, crews and instructors can take their time in the learning process. They can execute certain maneuvers and conditions repeatedly to build up the trainee's proficiency; they can pause and resume the scenarios at will, and they can provide immediate feedback. The aircrews can take their time in mastering operation of their particular weapon system, and how to use it to the best of its potential.

This stand-alone training is very useful and important, but it also has its limitations. The crews become experts in the use of the weapon system itself, but they also must learn how to be a part of the larger military force. They must learn how to fight as part of a team, and they need to seamlessly integrate into the larger force. Some training programs attempt this by supplying trained instructors that provide the command and control (C2) functionality. Most of this type of training, however, tends to be scripted and is not always very realistic. Crews become accustomed to these stand-alone predictable scenarios. DMO, on the other hand, provides a very dynamic environment where the large force tactical execution functions are not scripted. Additionally, it is warfighters themselves who provide the C2 functionality making it more realistic, while also being trained.

The DMO links individual warfighters and their virtual flight simulators to form teams, such as strike packages, while allowing them to fully participate in the C2 structure. Now the airborne and ground controllers exercise controlling aircraft just like they are in the real world; all aspects of mission deployment are exercised. The trainees have not only their high fidelity simulators to "fly" in, but they also have the full array of communications and sensors equipment to truly train as they fight (Figure 1).

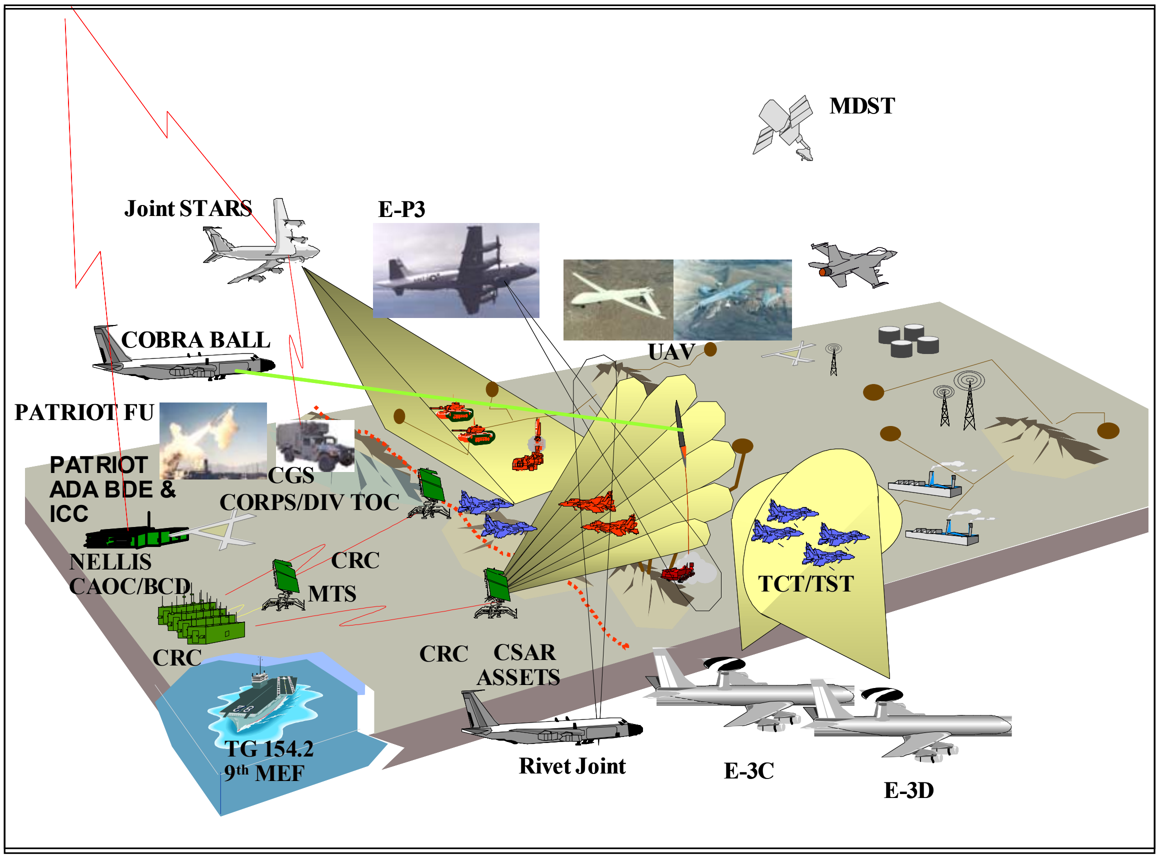

Figure 1. VIRTUAL FLAG Synthetic Battlespace

2.1.3 Constructive

A robust theater-level synthetic environment must be created to fulfill each exercise's specific objectives as set during the pre-exercise planning conferences. The simulated environments, as battlefields in real life, must consist of thousands of friendly, opposing and neutral entities: aircraft, ground offensive and defensive forces, and fixed targets as well as realistic airborne and ground threats and countermeasures. Enemy forces are almost exclusively modeled using constructive simulations. At the DMOC they are referred to as environment generators (EG), but are also known as semi-automated forces (SAF), or computer generated forces (CGF). Additionally, friendly constructive entities also have to be created because there are simply not enough virtual and live simulations to create an entire theater-level force structure.

There are many EGs in use in the M&S field. Some are very specific in nature with narrow focus, while others are meant to support a wide range of applications. Despite such a broad field, it is impossible to find a single EG that satisfies all of the requirements of DMO training exercises. In fact, there are about a dozen different EGs used in DMO alone. DMOC uses five different primary EGs to support the VF exercises. Each has its strengths and weaknesses, thus the right mix is required to achieve an adequate level of fidelity and realism.

As described earlier, realistic employment of aircraft calls for a high level of teamwork and cooperation between various platforms. The amount of interaction depends on the missions being executed (e.g., defensive counter air (DCA) versus suppression of enemy air defenses (SEAD)). Whenever possible live or virtual simulators are used to allow warfighters to exercise their team and inter-team play. When there are no such devices available, constructive entities are created to maintain the realism of the environment. Members of the twenty-person "white force" team then operate these constructive entities in such a manner as to make it totally transparent to their live and virtual counterparts. Constructive entities and their white force operators have a full suite of C2 equipment available to them including voice communications and Link-16. This approach has three benefits. First, it contributes to the theater environment robustness allowing the C2 nodes, such as the CAOC, to have a complete picture of the training scenario. Secondly, it supplements the platforms already populated by the warfighters in live and virtual simulations, thus providing them with a more realistic and complete training environment. Thirdly, scenarios can be modified during event execution such that crews cannot anticipate what will occur next, thus providing dynamic training environments.

DMOC uses the Scenario Toolkit and Generation Environment (STAGE) to supplement the friendly airborne forces commonly referred to as "blue air." The blue air scenario follows a published air tasking order (ATO), which can be pre-scripted to a high degree. The white force team is comprised of personnel with strong military background, typically active duty and recently retired personnel. The team possesses thorough knowledge of the USAF tactics, techniques, and procedures (TTP) and specific missions of the aircraft, which they control.

DMOC also uses the Extended Air Defense TestBed (EADTB), which provides a constructive AWACS with Link 16 reporting capability, and cruise missiles to enhance blue air assets.

The enemy airborne forces are simulated using the Next Generation Threat System (NGTS). Similarly to the way STAGE does for blue air, NGTS creates a robust airborne threat environment, known as "red air." The requirements for red air differ from those for blue air, and thus an EG which is a better fit for this tasking is employed. For instance, blue air must provide realistic voice, Link-16, and Identification, Friend or Foe (IFF) capability. Red air models do not need any of this capability; however, they must provide realistic electromagnetic and infrared emissions, and adversary tactics. White force requirements are also considerably smaller for the red air components of the battlespace, because, there is no need to realistically interact with the opposing C2 structure. Most of the opposing air forces' movements are pre-scripted to fulfill training objectives. The dynamic portion still occurs through the on-the-fly changes to the scenarios that can be executed by the white force at run time. Ideally, most of the red air interaction should be scripted. Once they come into contact with human-in-the-loop simulations, such as virtual flight simulators, they have to act realistically and dynamically. Highly scripted behavior quickly becomes predictable and thus reduces the training value. NGTS offers a good balance of scripting and realistic autonomous behavior. DMOC has also implemented a "Red Cell", in which personnel can take control of red NGTS and ground forces, thus providing even higher degree of realism for the crews engaging them.

Over the last few years the DMOC and the Virtual Flags have been increasingly concentrating on the air-to-ground missions in addition to the traditional air-to-air campaign. This is possible largely, thanks, to the increased fidelity brought by the Joint Conflict and Tactical Simulation (JCATS) system. This, primarily U.S. Army system, is used to create the majority of the thousands of ground entities, friendly, opposing, and neutral, needed to effectively train in air-to-ground operations including close air support (CAS). The JCATS allows for a high degree of scripting with little need for interactive play.

Two other, highly specialized EGs, round out the six primary constructive systems in use at the DMOC for Virtual Flags. The Distributed Information Warfare Constructive Environment (DICE), part of the DMOC Red Cell, provides the high fidelity integrated air defense systems (IADS) modeling necessary to realistically conduct the suppression of enemy air defenses (SEAD) missions. Thanks to its high fidelity modeling of IADS, this constructive simulation is mostly automated once the exercise begins, and it provides adequate air defense representation for the virtual shooter and sensor platforms.

Like DICE, Extended Air Defense Simulation (EADSIM) offers very specialized services where high fidelity is a must – the tactical ballistic missile (TBM) simulation. Simulating these enemy missiles and their launchers stimulates the CAOC and the time critical target (TCT) functions within it. The warfighter trainees employ simulated reconnaissance and surveillance sensor platforms to give the necessary information required to properly follow target designation. Given the breadth of the Virtual Flag environment, the true sensor-to-shooter kill chain can be seamlessly exercised.

3.0 DISTRIBUTED ENVIRONMENT

The distributed nature of the DMOC's synthetic environment is one of its major advantages. Only a handful of simulations are actually located at the DMOC itself. Most are scattered throughout the contiguous United States and Alaska. Soon the DMOC will incorporate simulators spanning Asia, North America, and Europe.

The key to the environment is that even though the simulators are scattered throughout the country, their synthetic battlespace representation remains coherent and consistent. For instance, strike packages are frequently composed of aircraft that are to execute missions together. Hundreds or thousands of miles, however, may geographically separate the individual flight simulators representing those aircraft. Constructive entities flown in STAGE can accompany aircraft represented by virtual simulators in the same virtual airspace. Even in these situations, the aircrews have realistic radio voice communication with each other as well as realistically simulated tactical data link networks.

This principle extends beyond just air platform communication. Ground-based Common Reporting Centers (CRC), JSWS, CAOC and other nodes can also communicate within the C2 structure using voice radio, and native or simulated digital links. The challenge is to manage two disparate geographic spaces: 1) the real geographic separation of the simulations and simulators, and 2) geographic co-location of simulated entities in the virtual battlespace.

The real separation provides a basic challenge of physically connecting the distributed sites and their simulations together through a modern information technology (IT) infrastructure. The overall DMO network itself, like the rest of DMO, has not gone through a typical procurement cycle. Instead, it has gradually grown over the years, and it is very much heterogeneous in nature. Approximately fifty remote sites are connected through a plethora of means including six asynchronous transfer mode (ATM) clouds owned by various government organizations, and 25 additional point-to-point T-1 links owned directly by DMOC (Figure 2). Management, maintenance and information assurance of these networks are an enormous undertaking.

Another challenge due to the geographic separation of simulators and personnel is executing the plan-brief-execute-debrief cycle of Virtual Flags. DMOC employs a Brief/Debrief system capable of linking warfighters through the same simulation IT infrastructure with live chat, video teleconferencing, file sharing, and virtual white boards capable of instantly sharing information between warfighters scattered throughout the country.

The synthetic battlefield, on the other hand, must present a common and consistent environment in which virtual war can take place. Because Virtual Flags link and integrate such a high number of simulation devices, the issues of synthetic database correlation and scenario integrity are paramount to realism, and thus training effectiveness. Unfortunately, it is impossible to expect 100 percent correlation. Various simulation owners, fidelities, capabilities, and missions preclude this from occurring. It is important then, to ensure that the simulation environments correlate where it makes the most sense— essentially taking the approach of the "best bang for the buck." Similar simulations, those having to operate in close proximity, and those having to interact with each other are the best candidates for the greatest correlation efforts.

The main simulation interoperability protocol used by individual simulations to talk to each other is the Distributed Interactive Simulation (DIS) protocol as defined by the Institute of Electrical and Electronics Engineers (IEEE) 1278.X series of international standards. Link-16, also known as TADIL-J, is also supported in the simulation environment. This allows for simulating a complete and accurate C2 structure of the force.

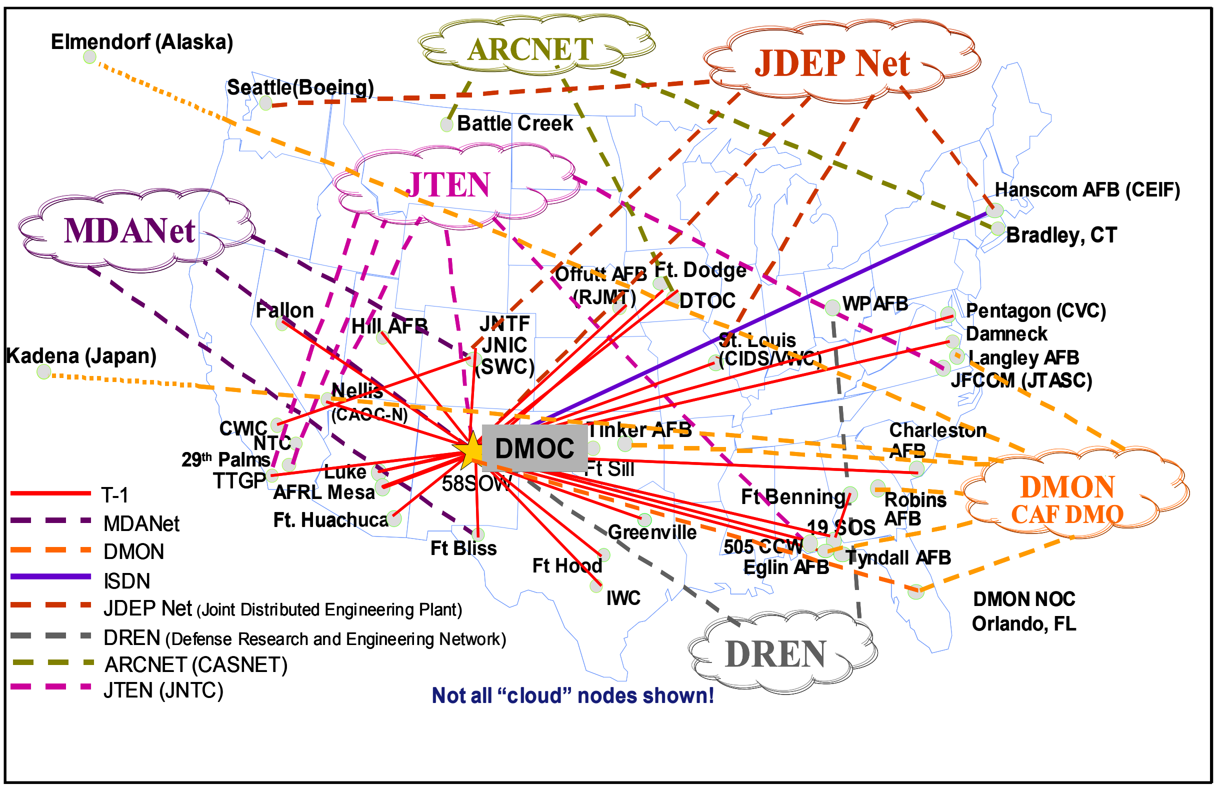

Figure 2. DMOC networks

3.1 M&S Tools

The current Virtual Flag simulation environment is far too complex to allow most systems to be fully exposed to it; the sheer volume of data overwhelms most systems from the computer-processing standpoint. The DMOC has developed a number of simulation utilities to aid in real-time simulation data management. Two of the most widely used applications throughout the DMO are DMOC-developed DIS Filter and the TACCSF Software Router, TACCSF (Theater Aerospace Command and Control Simulation Facility) being DMOC's former name. The DIS Filter is a simulation gateway that shields individual simulations and entire networks of simulations from being overwhelmed by data. There are about 50 instances of this highly configurable, low latency application currently in use throughout the DMO community. The DIS Filter ensures that the specific data required by a given application, and only that data, gets to it in a timely manner. It limits the amount of superfluous network traffic by filtering data at the source, thus keeping latencies down to a minimum.

The TSR, on the other hand, is a transport utility that allows DMOC to conform to the unique bandwidth and protocol restrictions of each of the seven major networks DMOC is connected to. When necessary, the application acts as a simulation gateway for a particular site. It collects all of its real-time simulation data, and ships it to all remote sites while complying with the particular Wide Area Network (WAN) restrictions. At the remote sites, the TSR re-distributes the data locally in their respective native formats, ready for consumption by individual simulators. The added benefit of using this software is in low bandwidth situations. The network loads in distributed exercises vary highly during the exercise execution, but the available bandwidth on many links, such as the T-1s, are constant. Data loss occurs when the simulation data loads exceed the network's capacity. The TSR utility detects maximum network conditions approaching, and it begins buffering non-time critical data. Additionally, there is a priority scheme built into the software, which ensures the data packets with highest time-criticality always have priority.

4.0 CONCLUSION

The warfighters have been training in virtual simulators for a long time. Improvements in computer processing power and 3D graphics in particular are continuously pushing the envelope by providing more realism at a lower cost. Recent advancements in networking technology are now allowing simulators to be more readily linked and networked together to provide the team, inter-team, and large force training not previously possible. As evidenced by numerous USAF and DoD awards, including DoD's Best Modeling and Simulation Training Program, 2001 and 2004, the DMOC and its Virtual Flag exercises provide unmatched synthetic combat environments.

By linking approximately 25 major live and virtual joint weapons systems in disparate locations, the warfighters have an opportunity to train as they fight without having to leave their home-bases in many cases. Nearly all of the combat air platforms and C2ISR assets in the USAF inventory are linked in an immersive environment allowing the trainees to realistically engage in execution of the sensor-to-shooter kill chain. Additionally, many of the joint, mainly U.S. Army and U.S. Navy, weapon systems also participate in the realistic plan-brief-execute-debrief cycle. Coalition partners have already participated using the U.S. simulation devices, and in the near future they will also be able to connect with their own simulation devices. With U.S. services as well as other NATO countries expanding their modeling and simulation programs to provide similar capability to the DMO, it is easy to envision some day exercising entire military campaigns in virtual battlespaces.