Using LVC Technology for the Military Planning Process

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ABSTRACT

The Department of Defense has used live, virtual and constructive (LVC) technology primarily in the training and testing communities. We feel that LVC technology has significant capabilities in the operational realm as well and built two proof of concepts to demonstrate how military organizations can use such technology operationally in the planning processes.

Joint Publication 5-0: Joint Planning lists the seven steps of the planning process as:

1. Planning initiation
2. Mission analysis
3. Course of action (COA) development
4. COA analysis and wargaming
5. COA comparison
6. COA approval
7. Plan or order development

Each service has its own publication which lists the steps its staffs should follow in planning, but they generally follow closely.

We designed two applications, one for planning ground operations and another for planning air missionsOur goal was to improve the planning process in three ways:

- To better visualize the battlefield to aid in the planning process through the COA decision phase to allow better decision making by the staffs.
- To automate the COA wargaming phase of the planning process to reduce the time required, make it more accurate, and less manpower intensive. By reducing the time for this, staffs can either shorten the planning cycle, increase the number of iterations of each COA to improve its performance, or consider more COAs.
- To account for "the fog of war," e.g., red forces locations are rarely precisely known or may be time late. Often, simulations do not reflect the imperfect battlefield knowledge that commanders and staffs have when producing a plan.

We did this by displaying the plan in a Unity-based environment and sending it to constructive simulations. These results are also displayed in a game-like environment for the staff to analyze the wargame results, compare COAs, and present them to the commander for approval.

ABOUT THE AUTHORS

Perry McDowell attended nuclear power training after commissioning as a naval officer. He served in USS VIRGINIA (CGN-38) as M-division officer, R-division officer, and DCA from 1990-1993. He later served as operations officer in USS ELROD (FFG-55) from 1996-1997 and reactors control assistant and main propulsion assistant in USS ENTERPRISE (CVN-65) from 1997-2000.

In 1995, Perry earned a Masters of Science degree in computer science at the Naval Postgraduate School (NPS), where he was awarded the Grace Murray Hopper Award as outstanding computer science student. Upon leaving the Navy in 2000, he returned to NPS and joined the faculty. Although he has served as a principle investigator for a wide variety of projects in the MOVES Institute, from 2003 – 2012 he worked primarily as the Executive Director for the Delta3D open source game engine. From 2012 to the present, he has taught courses in simulation for training and conducted research in the areas of training effectiveness and the creation of systems to improve warfighter performance.

Ryan Lee is a Faculty Associate – Research at the MOVES Institute. He earned a B.A. in mass communication & journalism, specializing in broadcast production in 2000 from CSU Fresno, and a masters of information technology in digital game development in 2010) from Southern Methodist University.

Mr. Lee has worked professionally in visual arts since 1999. After nearly five years spent making television commercials in the California Central Valley, he entered the games industry, where he worked on over 10 published titles including *Brothers in Arms: Road to Hill 30* and *Ben 10 Alien Force: The Rise of Hex*. In 2011 he came to the MOVES Institute where he works as the technical artist for the FutureTech team. Since then he has designed and created visuals for a wide variety of technologies including web, mobile, desktop and AR/VR. He has worked on dozens of projects including *Swarm Commander Tactics*, several web-based games for GlobalECCO including *Contagion* and *Cyberstrike*, and various student thesis projects. He has experience in UI/UX design, 3D Modeling, animation, visual effects, and video editing, as well as extensive programming and scripting knowledge.

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Ricard Hamming famously said, "The purpose of computing is insight, not numbers" (Groß, 1994, p. 1). Commanders who are planning an operation need insight into the battlefield, friendly forces, the enemy, and how these and many other items will interact to create the outcome of the campaign. The U.S. military has many simulations that can answer that question, but the answers are often in formats that don't help the commander preparing for battle. It also has lots of great visualization tools, but often these are also left stateside and not used by the troops in the front lines. Our goal in his research was to see if we could combine simulations in use today with current state of the art visualization methods to give commanders better insight so they can make better decisions.

BACKGROUND

This section will provide background information on three areas which the remainder of the paper touches on:

- The military planning process, which is the task we set out to improve.
- Live, virtual, and constructive (LVC) technology, which are the means we used to produce tools to assist with two types of military planning.
- Stochastic simulation, which is one of the features one of our tool provides to planners.

Military Planning

The Marine Corps very succinctly described military planning: "Planning is the art and science of envisioning a desired future and laying out effective ways of bringing it about" (Department of the Navy, 1998, p. 3).

Joint planning between the U.S. services is governed by Joint Publication 5-0 (Department of Defense, 2017), commonly referred to as "JP-5-0." It defines the joint planning process (JPP) as "an orderly, analytical set of logical steps to frame a problem; examine a mission; develop, analyze, and compare alternative courses of action (COAs); select the best COA; and produce a plan or order" (Department of Defense, 2017, p. xxiv). Other than combining some steps or slight variations in wording, the individual services planning processes are similar (Department of the Army, 2012) (Department of the Navy, 2010) (Department of the Navy, 2013) (705th Training Squadron, 2017). We built applications to improve the processes for Marine Corps planning and aviation planning, so we will cover these two in more depth.

USMC Planning

The Marine Corps follows one of two processes when planning operations. The first is the Marine Corps planning process (MCPP), the six steps of which are similar but slightly different than those of the JPP. There are six steps which comprise MCPP:

1. Problem framing.
2. Course of action (COA) development
3. COA wargaming
4. COA comparison and decision
5. Orders development
6. Transition" (Department of the Navy, 2010, pp. 1-1)..

The other process is the rapid response planning process (R2P2), which is a time constrained version of MCPP designed to be used when time does not allow following the full MCPP. As such, it will not be covered further here.

MCWP 5-1 stresses that the commander is the central figure throughout the planner process and he/she must direct the formulation of the plan at the conceptual level. Thus, the tools and their outputs as the process is ongoing must be focused on maximize commanders' ability to craft the best possible plans (Department of the Navy, 2010).

Aviation Planning

Aviation planning at the joint force air combatant commander's level is essentially the same as the steps of the joint planning process:

1. Planning initiation
2. Mission analysis
3. COA development
4. COA analysis and wargaming
5. COA comparison
6. COA approval
7. Plan or order development (705th Training Squadron, 2017)

Again, like the Marine Corps, planning "is commander-centric. The commander is the central figure due to his or her education and experience, and because the commander's judgment and decisions are required to guide the staff through the process. It also requires the commander to create an environment that encourages open discourse and leverages dialogue to solve complex problems" (705th Training Squadron, 2017, p. 7).

Live, Virtual and Constructive

LVC technology is viewed as a recent concept, but actually dates back to 1989 (Henninger, et al., 2008). It was originally defined as meaning any subset of the three capabilities (Henninger, et al., 2008, p. vi). However, recent usage calls for an LVC system to be a combination of at least two of the three, as given by the DoD's M&S Glossary defining LVC as, "A broadly used taxonomy describing a mixture of live simulation, virtual simulation, and constructive simulation" (Modeling and Simulation Coordination Office , 2011). The component parts of LVC simulations are defined as follows:

> Live simulation involves real people operating real systems. Military training events using real equipment are live simulations. They are considered simulations because they are not conducted against a live enemy.

> Virtual simulation. A simulation involving real people operating simulated systems. Virtual simulations inject human-in-the-loop in a central role by exercising motor control skills (i.e., flying an airplane), decision skills (i.e., committing fire control resources to action), or communication skills (i.e., as members of a C4I team).

> Constructive simulation. A constructive simulation includes simulated people operating simulated systems. Real people stimulate (make inputs) to such simulations, but are not involved in determining the outcomes (Modeling and Simulation Coordination Office , 2011).

It should be noted that a game falls under the definition of a virtual simulation.

All the various services, singly and together, are pursuing LVC as a major part of future training. The Potomac Institute reports that "all the US Services, and several of our close allies, are exploring innovative ways to employ LVC to improve the effectiveness of training while controlling costs. As the US seeks to 'offset' the emerging technological parity of adversaries, LVC training capabilities could be a key pillar of that strategy" (Potomac Institute for Policy Studies, 2016).

There are many advantages to LVC simulations for training. Some of the most commonly cited ones include:

- Cost – the cost of bringing large number of organizations and personnel together to train, or to bring organizations to locations where they can train (e.g., National Training Center (NTC) at Ft. Irwin, Twentynine Palms) can be prohibitive (Potomac Institute for Policy Studies, 2016).
- Benefit/cost – although there may be minimal cost savings, training with LVC can yield better results (North Atlantic Treay Organization Research and Technology Organisation, 2010)
- Safety – it is possible to train maneuvers or operations which would be too dangerous to perform live, such as certain aviation maneuvers.
- Environmental concerns – these can limit types of training (the Navy has been limited in performing active SONAR training due to perceived damage to marine mammals (Morrell, 2015)) or when training can occur (at the NTC and Twentynine Palms, training events must be halted whenever a desert tortoise is noticed and relocated (Department of the Army, 2012).
- Reliability of opposing forces (OPFOR) – in simulations, OPFOR can be relied upon to perform correctly for each training event. In the real world, it takes significant training to have realistic and effective OPFOR, and they can make errors which affect training.
- Recording of events – it is trivial to record events trainees perform in simulations, while this can be problematic in live training. It is also much easier to replay events from a simulated environment for after action reviews.
- Weather independent – many events can be limited by weather, either due to bad weather forcing cancelation or a specific type of weather required for the task (e.g., high seas carrier landings). In simulations, the weather can be set to whatever is required for the training.
- Current ranges are too small for new weapons systems – Lt. Gen. Douglas Fraser, USAF, when he was deputy commander at PACOM, said, "Look as supersonic delivered JDAMS. There is no range in globe that will allow us to do that" (Department of the Air Force, 2013).

However, LVC simulations are not without their disadvantages when it comes to training. Strangely enough, cost can also be a disadvantage of LVC. It can be very expensive to create effective LVC training and it does not always provide cheaper training. This is often task dependent, but it often occurs for tasks where there are a limited number of performers, so they do not benefit from economies of scale. Likewise, depending upon how much live training is involved, the training may not replicate the task nearly as well as actually performing the task. Aviators have been using simulators longer than any others in the military, but every aviator will always stress the differences between the actual and simulated cockpits. Finally, LVC is still an emerging technology, and the infrastructure has not been built at all locations and used enough to reach a point to be confident that all the bugs have been worked out.

To date, the most common usage for LVC has been in the training arena, but recently it has been broadening in scope. It has been used for capabilities-based testing and evaluation of the P-8 (Iriarte, 2018), cyber security analysis (Leeuwen, Urias, , Eldridge, & Villamarín, 2010) (Petrie, 2015), and tests of net-centric systems (DiGennaro, Walker, Doshi, Bressler, & Bagrodia, 2010). However, as LVC technology matures and many of the issues with LVC are worked out, we expect it to transition into many other areas.

Stochastic simulation

Stochastic simulations are those run using a stochastic model. This is one in which the results are determined by using one or more random variables to represent uncertainty about a process or in which a given input will produce an output according to some statistical distribution (Modeling and Simulation Coordination Office , 2011). The result of only running once a scenario which relies on stochastic data is very unreliable. This is similar to getting seven when rolling a pair of dice and assuming that every future roll will yield seven. For example, a simulated mission may succeed because an enemy weapons system with a very high probability of kill (P_k) (say, 0.9) may, due to the random number generated at that run time, fail to destroy a friendly A/C. Had the friendly A/C been destroyed, the resulting mission would have failed miserably, but due to the unpredictability of randomness, the simulation reports that the plan will succeed. Had the user run the simulation many times, the effect of randomness should be mitigated, and it should fail the vast majority of the time.

Many of the systems behavior in military planning cannot be predicted with absolute certainty. Weapons effects, radar detection of aircraft or missiles, effectiveness of electromagnetic jamming, and many other items do not always

respond perfectly and therefore must be represented as probabilities. Likewise, intelligence may provide the location of enemy forces, but that location may only be a probability due to being time late (if mobile, the enemy may have moved) or due to the collection method. Some electronic warfare (EW) methods to locate electronic transmissions may be stated as a specific location, but it is actually an ellipse of uncertainty (Paradowsk, 1997).

OUR EFFORTS

Technology used in the military planning process varies depending upon the location, organizations involved, and the scale of the event being planned. Large-scale planning at the joint chiefs or combatant commander level involves scores of people and high tech computer simulations. However, at the lower levels, it is generally more *ad hoc*, even though there are many existing simulations that could be used to assist in the process. The problem is that most of these simulation systems are very complex and not easy to use. Therefore, they require specialized personnel, generally contractors, to set-up systems and execute the simulations. Additionally, the outputs of these systems are often difficult to interpret and are not produced in a format that is designed for decision makers to utilize in the planning process. Our goal was to utilize LVC technologies to create tools which would aid planning at the lower levels. Specifically, we wanted to give operators tools to perform the following:

- To better visualize the battlefield to aid in the planning process through the COA decision phase to allow better decision making by the staffs.
- To automate the COA wargaming phase of the planning process to reduce the time required, make it more accurate, and less manpower intensive. By reducing the time for this, staffs can either shorten the planning cycle, increase the number of iterations of each COA to improve its performance, or consider more COAs.
- To account for "the fog of war," e.g., red forces locations are rarely precisely known or may be time late. Often, simulations do not reflect the imperfect knowledge of the battlefield that commanders and staffs have when producing a plan.

Gaming Technology

We feel that adapting gaming technology to the military planning process shows great promise for improving it. As Nolan Bushnell, the founder of Atari, famously said, "Games should be easy to learn, difficult to master" (Bogost, 2009). For military planners, the "difficult to master" part should be how to create a plan to defeat the enemy; the "easy to learn" part should be the tools they use to craft the plan. There are two features of games that we felt would avail themselves especially to military planning tools: their ease of use, and their effectiveness in displaying information.

Ease of Use

New Zoo, a gaming analytics company, estimates that the computer gaming industry sales in 2018 at $139 billion, more than the film industry. This is split roughly evenly between mobile devices and PC/consoles, as shown in **Error! Reference source not found.**. In such a large market, the completion to succeed is huge and the games must be easy to use or they would be huge flops. Try to imagine gamers, who want to be able to insert a disc into a console or download a game to a PC or mobile device, being asked to go through the steps required to get most military simulations running. No matter how great the game, none would be willing to go through those steps to play it.
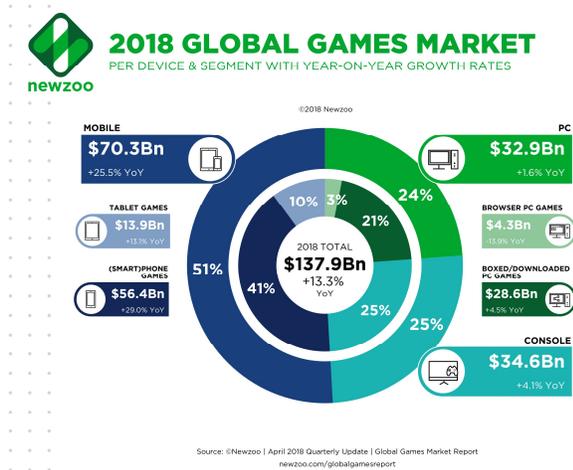
Figure 1. Global Games Sales, 2018 (Wijman, 2018)

Thus, game systems are built to allow designers to create simple and easy to use interfaces that most users can learn with little to no instruction. In fact, for most games, users are taken through a 10-15 minute orientation level and they are ready to play the game. Game designer Richard Rouse III writes, "Your game's input and output systems are two of the primary factors that determine how steep the learning curve for your game is and whether players will find it intuitive to play. Using the input/output systems you design, players must be able to control and understand the game effortlessly" (Rouse III, 2004).

People have predicted that the easy to use designs of video games will make their way to other computer systems. Theodor Nelson, the information technology pioneer who coined the term "hypertext", wrote, "To see tomorrow's computer systems, go to the video game parlors! ... Look there to see true responsiveness, true interaction. Compare these with the dreary, pedestrian office software we see everywhere, the heavy manuals and Help Screens and Telephone Support" (Nelson, 1990).

Effectiveness of Displaying Information

While the ease of use can be thought of as how the user inputs data to the game, how the games output information to the player is equally important in their playability. Another feature of computer games that makes them good candidates for use in the military planning process is their effectiveness of displaying large amounts of data. In the more complex games, such as *EVE-Online* or *Gary Grigsby's War in the East: The German-Soviet War 1941-1945*, the player is performing a very similar task that staff officers do in planning operations. The latter is a "World War II strategy game down to the division and brigade level, stretching across the entire Eastern Front at a 10 mile per hex scale. Gamers can engage in massive, dramatic campaigns, including intense battles involving thousands of units with realistic and historical terrain, weather, orders of battle, logistics and combat results" (Matrix Games, 2019). Figure 2 shows the complexity of the display for this game.

Figure 2. Gary Grigsby's War in the East (Matrix Games, 2019)

The amount of information a player needs to access in many games rivals that of a staff officer planning a mission. Players demand the ability to quickly reference this information and game designers must deliver, since a bad display leads to a lack of sales. Therefore, they push the state of the art in the field of human computer interaction to create information displays that use as many modalities as possible to show the maximum amount of information in a manner the player can comprehend.

Additionally, gaming companies recognize that players have several different approaches to their games, and therefore allow the players to customize their displays. This is key in building interfaces that large numbers of diverse individuals must use, which is the case in military planning.

Two Efforts

For these reasons, we felt that using computer gaming technology to create tools for the military planning process was an excellent way to proceed. Using entertainment technology for military purposes is not a new concept. Over twenty

years ago, the National Research Council convened "a multidisciplinary committee to evaluate the extent to which the entertainment industry and DOD might be able to better leverage each other's capabilities in modeling and simulation technology and to identify potential areas for greater collaboration" (National Research Council, 1997, p. vii).

Our approach was to use gaming interfaces to create an interface that personnel planning missions could use that would provide them with much of the capability of available constructive simulations. We felt that making these systems accessible to staffs would make several of the parts of planning more effective. Although we feel eventually that technology could be applied to all aspects of the planning processes, we decided to focus on steps from problem framing/through approving the COA.

To evaluate whether such a system could be created, we built two proof-of-concept systems. The first was a ground planning tool for the Marine Corps, and the second was an planning tool for Naval aviation.

Ground Planning
We designed the first planner we built, the Marine Corps Ground Planner (MCGP), to assist in planning a ground operation for the USMC. It meets the first two goals we articulate above of better visualizing the battlespace and improving the wargaming part of MCPP. While we designed our system for use in the MCPP, with some streamlining MCGP could likely be used in R2P2, especially if pre-planned scenarios were built ahead of time.

We began by examining the task of MCPP. We had hoped to find a complete task analysis (TA) for the process, but no TA existed for MCPP. Therefore, the researchers investigated the applicable publications and attended a training event for the staff of a special purpose Marine Air-Ground Task Force (MAGTF) at Expeditionary Warfare Training Group, Pacific, in Coronado, California. From this, we created a "light" TA, focusing on the areas where LVC technology could add maximum improvement. We decided that this was primarily in the first four stages of MCPP:

> Stage 1: Problem framing
> Stage 2: Course of action (COA) development
> Stage 3: COA wargaming
> Stage 4: COA comparison and decision

We examined several constructive simulations for use in the system:

- MAGTF Tactical Warfare Simulation (MTWS)
- OneSAF
- Combat XXI (CXXI)

We decided to use CXXI, despite the fact that it was primarily geared towards analysis. The primary factor driving that decision was that it provided the greatest probability of success to create a working prototype because it had the easiest interface to work with and we could create a mechanism to pass information from a game engine to CXXI and back faster than any of the other options.

We used the Unity Game Engine as the underlying virtual platform. This is because Unity has become almost a standard in the industry for low-cost development. It is among the simplest engines to use while delivering significant power to the developer at a very low price.

We built a VE where the user could examine the terrain in a 3D environment, which can be used for problem framing. The user can view a traditional top-down view of terrain, or slew the view to show the terrain as the red or blues units would view it from a given position, as shown in Figure 3. MCGP can also display line of sight calculations from any location via a drag and drop mechanism as shown in Figure 4. The colored areas show the areas visible from the location of the compass rose.
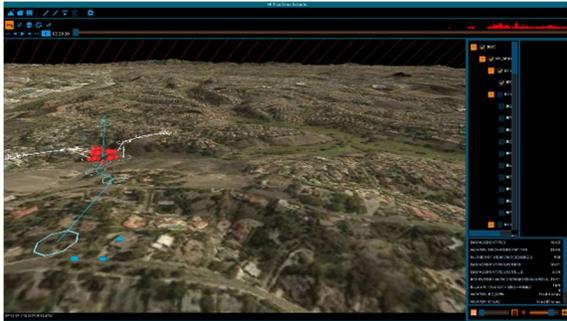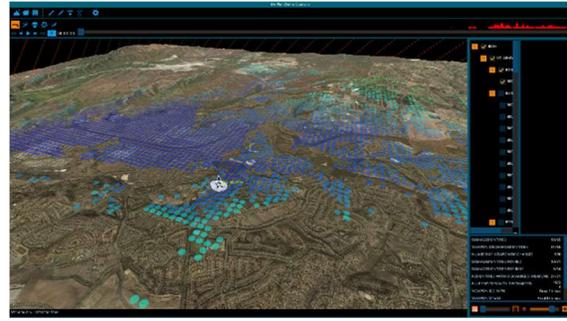
Figure 3. View from blue position

Figure 4. Line of sight calculations

The interface can also be used to position both friendly and enemy entities (e.g., vehicles, personnel, IEDs). This is to perform COA Development. This can be used to perform the first step of MCPP: problem framing. We anticipate that the staff intelligence officer (S2) would place the red forces in the best estimate of their positions, and the staff operations officer (S3) would position friendly forces in their locations. This is done in an easy to use gaming interface, shown in Figure 5.. The users can drag and drop the blue and red units to their initial locations as well as using drag and drop to move waypoints and objectives. They can select which entities are active in the run using the hierarchies on the right side.

Once users have created a COA, they use the system to conduct COA wargaming. The use a single button to begin a constructive simulation, CXXI, using actual behaviors, doctrine, and adjudication of combat events to determine the outcome. If the result is needed within a certain time, users can constrain the CXXI runtime. The constructive sim evaluates the plan and returns the results in terms of casualties, resource expenditures, etc. The can playback the wargame results using the controls in Figure 5. There are controls in the upper left-hand corner similar to most video players for starting/pausing playback, for increasing/decreasing the speed (up to 64x), and a timebar that allows users to choose any time of the simulation. Above these are buttons (in the red oval) which allow the user to display in the area above the timebar a histogram of those events as they happened; these can be seen in the white oval on the upper right-hand side. (In this particular scenario, the bars are limited to the last part of the run, since events only happened after the sides made contact more than three quarters of the way through the run.) The different events which can be distributed there include weapons firings, weapons damage, casualties, weapons detonation, and entity movements.
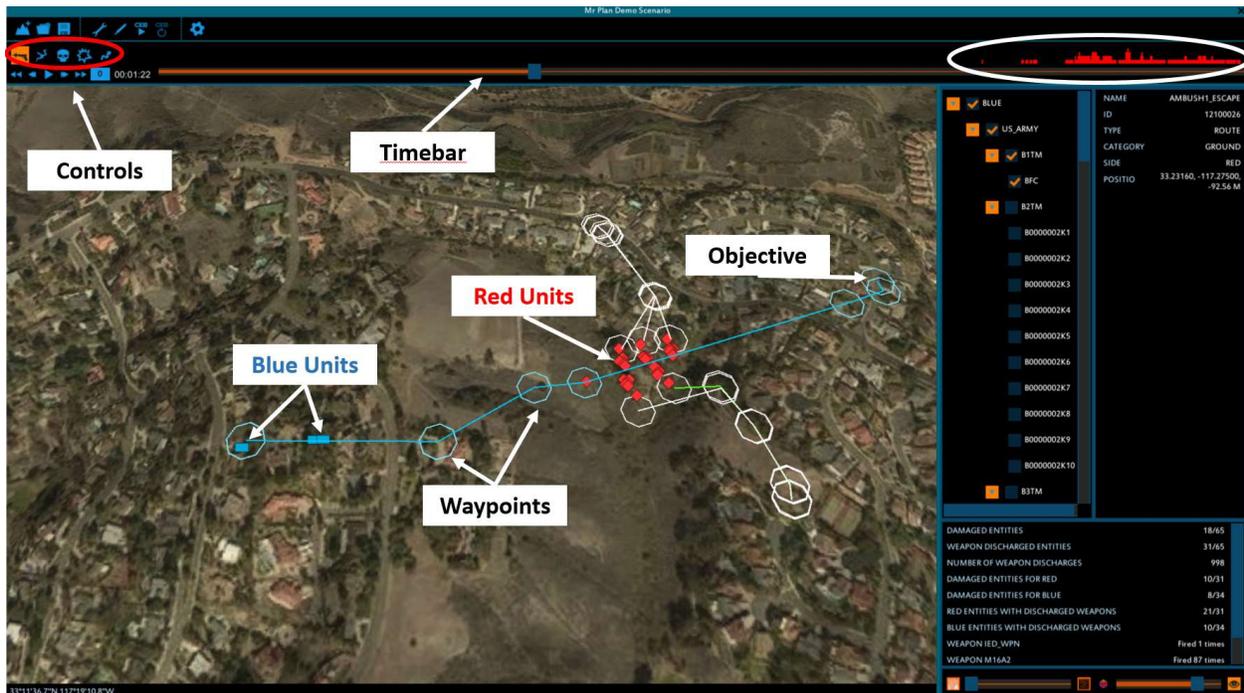

Figure 5. MCGP interface

The user can examine the results of each run, and make adjustments to the location of all elements in the environment, and rerun if necessary. Once the users are satisfied with the result of the how the COA performed in the wargame, the can repeat this for the other COAs under consideration. Once this has been repeated for all COAs, they can use this same functionality to present the results to the commander for the COA Evaluation and Decision.

Aviation Mission Planning
The second system we created assists in performing aviation planning – the Collaborative Aviation Planning Tool (CAPT). This meets all three of our earlier stated goals – better visualization, improved wargaming, and running scenarios multiple times.

Mission planning is defined as:

> "Mission planning is the development of a detailed flight plan based on threats, targets, terrain, weather, aircraft performance capability, and configuration. It is an essential task that must be performed prior to any fixed-wing or rotary-wing aircraft sortie. The planner must have the ability to plan weapon, cargo, passenger, and/or fuel delivery; calculate aircraft fuel requirements; and assess the route based on known enemy threat location and type. Mission planners must be able to optimize and de-conflict flight routes with other aircraft; review, print, and brief the mission plan; and download pertinent flight information to on-board aircraft avionics" (Department of Defense, 2016, p. 5)

Aviation mission planning already has a commonly used tool: the Joint Mission Planning System (JMPS), which has multiple variants to support the various services specific needs. Pilots enter flight information such as waypoints, required time on target, and aircraft configuration into JMPS, which then produces fuel calculations, flight headings, and other important flight data, which it can output directly into aircraft aviation software as well as create the knee boards pilots refer to during their flight for basic information about their mission. Rather than compete with JMPS, we designed CAPT to work with JMPS by displaying much of its information in a more game-like display as well as perform tasks not implemented in JMPS.
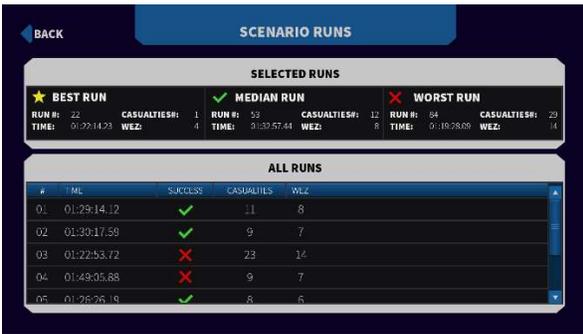
In many ways, CAPT is very similar to MCGP. It is based upon the Unity game engine. In this case, however, instead of being directly built atop Unity, its base software is the Collaborative Route Adjustment and Gaming Rehearsal – Virtual Reality (CRAGR-VR), created by the NAVAIR Naval Air Warfare Center Weapons Division (NAWCWD) at Point Mugu. CRAGR-VR is a collaborative and immersive mission rehearsal system in VR designed to increase operator understanding of the battlespace, rehearse contingency plans and fire control, which could be used in LVC events as well. It utilizes the Next Generation Threat System (NGTS), created by NAVAIR Naval Air Warfare Center Aircraft Division (NAWCAD), as the underlying constructive simulation which drives the behaviors of aircraft and other systems, such as radars, missiles, etc. (Frampton, 2018). It also can input files from the JMPS, so that it can be used with the current mission planning workflow and provide a VR experience for aviators to get a better understanding of the geography and threat profile than a 2D representation can provide.

We are modifying CRAGR-VR to create a tool which better reflects and it utilizes a constructive simulation to evaluate the plan. Once the users chose a scenario, they can modify it using the graphical interface as desired. CAPT's modified version of CRAGR-VR has an additional interface, which allow users to choose how many times they want it executed and the degree of speed-up desired. The scenario file is then sent to a "manyifier."

NGTS does not currently have the ability to take a given scenario file and automatically introduce randomness. For example, the location of an enemy radar located through EW actually reflects an ellipse of uncertainty, it must be positioned in NGTS at a given position. As the name implies, the manyifier takes his one scenario and creates many versions of it. Currently, it does this by randomly modifying the location of entities, but there are many other ways to introduce the desired randomness which are discussed in the future work section.

After the manifyifer creates as many variations of the scenario files as the user desires, each is run on the NGTS core simulation engine. The engine is run without any visuals output and can run up to 100 times faster than real time, allowing long simulations to be completed fairly quickly. It outputs events as distributed interactive simulation (DIS) packets, which are recorded and written to a separate log file for each of the scenarios the manyifer created. These results are then aggregated and reported to the user via the screen shown in Figure 6. The screen displays the best,

median and worst results at the top of the page, and the results of all runs at the bottom of the page. The user can select any run and watch the results in the scenario being replayed on screen shown in Figure 7.

Figure 6. Multiple run summation screen

Figure 7. Scenario playback screen

We display the results using cursor-on-target (CoT) symbology (Butler, 2005). CoT is commonly used in the aviation community so the users will be familiar it and not require additional training in its meanings or usage. The user can manipulate the view to watch from many different locations. Additionally, there are playback controllers, timebar and buttons to determine which events to show on the histogram, similar to those used in MCGP.

Because users can display any of the runs, they can gain insight into why their plan may have succeeded or failed. Like all military operations, the actual events are unlikely to occur exactly as planned, but the commanders and operators learn about the upcoming event via the process of planning. Planning can point out flaws in assumptions or highlight information that must be learned to successfully carry out the attack. For example, in the case of an air mission, a mobile surface to air missile (SAM) site may have moved into a new location where it was perfectly situated to devastate the strike group as it approached its target. If there are runs which indicate this, the commander might make a critical information request that intel assets verify that the SAM is not located at that site shortly before launching or add contingency plans to account for the SAM's threat.

Communication Between Applications
The interaction between CRAGR-VR, NGTS and the manyifier are shown in Figure 8. Most commands from both CRAGR-VR and this program to NGTS go through an intermediate program called the RCICompanion. This small CRAGR-VR support application is written in C++ in order to interface with the established NGTS "Remote Control Interface". Since CRAGR-VR is effectively a Unity module, the bulk of its code is written in the standard Unity scripting language, C-Sharp. RCICompanion translates the messages from C# to the NGTS standard.

The manyifier, mainly interfaces with CRAGR-VR and RCICompanion, but also with NGTS directly. Commands to process a scenario come from CRAGR-VR, and go from manyifier to NGTS through RCICompanion. Commands to stop and start the simulation go directly from manyifier to NGTS in the form of the standard DIS protocol messages, StartResume and StopFreeze.

The manyifier also communicates with CRAGR-VR through a dedicated TCP port. A small set of JSON message are defined which allow the Unity application to specify program parameters, retrieve manyifier status, and stop and start processing. As part of this project repository, there are two C# files with serve as the Unity connection to manyifier through that TCP link.
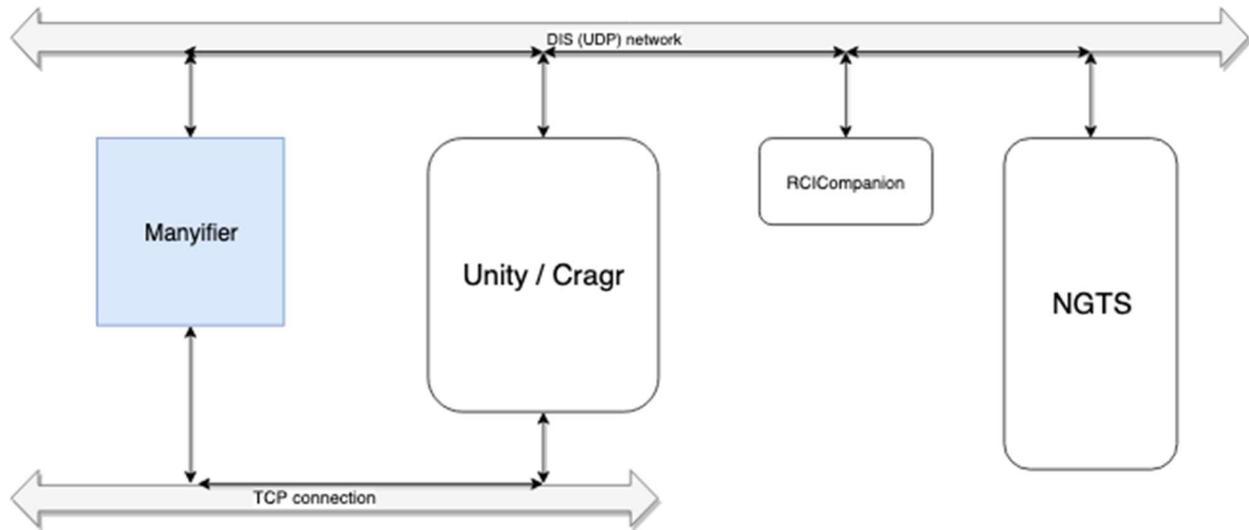
Figure 8. CAPT communications diagram

CONCLUSION

We have followed Hamming's dictum to use computing to provide insight in the field of military planning. We have designed two tools as proofs of concept to show that it is possible to improve the planning processes of two diverse military fields using existing simulations and game-based technology. Doing so has allowed us to improve the planning process by:

- Using 3D visualization tools to provide better awareness of the battlespace for all phases of the planning process from initial examination of the problem through deciding upon a COA. This promotes a better understanding of the problem, which should produce better COAs.
- Using constructive simulations for the wargaming step, which has significantly reduced the time required for it. This increase in speed can either reduce the entire planning time, allow more iterations to create a better and more detailed plan, or allow evaluate a larger number of COAs to be considered.
- Applying stochastic simulation to the planning process. By doing this, it gives commanders more insight into what the results mean as well as more confidence that the results are correct and not just the result of some unlikely combination of random numbers.

Future Work

There is a great deal of future work which can be done in these areas. As MCWP 5-1 says, "Planning should never be viewed as an isolated activity or process; rather, as a part of the planning execution-assessment continuum" (Department of the Navy, 2010, pp. 1-2). At the end of the planning process using these tools, the tool contains the entire plan. It should be possible to use the tool for the remaining parts of the planning process and automatically output the required orders to carry out the plan.

The way the manyifier creates multiple scenarios is currently far too simple: randomly moving units in the scenario. Instead, applying AI to the problem to give the units more realistic behaviors. For example, if the enemy doctrine is to often move SAM sites and a proclivity to station them on ridges, the manyifier can decide to move SAM sites to locations based upon that tendency. Likewise, it would only move them to locations they could reach given the constraints of the vehicles and the terrain. Something similar was done in (Doris, Larkin, SIlvia, & McDowell, 2005).

Another way to improve the manyifier would be its architecture. In order to manipulate the scenario files that NGTS processes, the manyifier must be cohosted with NGTS. Ideally, each main component of this project (CRAGR-VR, manyifier and NGTS) should be able to run on separate machines, since each is a relatively hungry user of CPU resources, and each is network-savvy. Further work is required to make this happen.

Finally, although we feel strongly that these systems would improve the planning process, they should be tested by having real staffs complete plans using them. The staffs could provide feedback, as well as evaluation of the plans against those made with traditional tools to see whether they provide improved performance.

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