Research Product 2018-05

Unmanned Aerial System Four-Dimensional Gunnery Training Device Development

David R. James
Northrop Grumman Corporation

James J. Gallogly
Kinex Corporation

Louis C. Miller
U.S. Army Research Institute

October 2017

Fort Benning Research Unit
Scott E. Graham, Chief

**United States Army Research Institute
for the Behavioral and Social Sciences**

**U.S. Army Research Institute
for the Behavioral and Social Sciences**

**Department of the Army
Deputy Chief of Staff, G1**

Authorized and approved:

<div align="right">

**MICHELLE SAMS, Ph.D.
Director**

</div>

NOTICES

REPORT DOCUMENTATION PAGE		*Form Approved* *OMB No. 0704-0188*
1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE** Final	**3. DATES COVERED** *(From - To)* November 2015 – May 2017

4. TITLE AND SUBTITLE Unmanned Aerial System Four-Dimensional Gunnery Training Device Development	**5a. CONTRACT NUMBER** W5J9CQ-11-D-0001 TO#0024
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER 633007

6. AUTHOR(S) David R. James James J. Gallogly Louis C. Miller	**5d. PROJECT NUMBER** A792
	5e. TASK NUMBER 409
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Northrop Grumman Corp 3565 Macon Road Columbus, GA 31907	**8. PERFORMING ORGANIZATION REPORT NUMBER**

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U. S. Army Research Institute for the Behavioral & Social Sciences 6000 6TH Street (Bldg. 1464 / Mail Stop 5610) Fort Belvoir, VA 22060-5610	**10. SPONSOR/MONITOR'S ACRONYM(S)** ARI
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) Research Product 2018-05

12. DISTRIBUTION/AVAILABILITY STATEMENT: Approved for public release; distribution is unlimited

13. SUPPLEMENTARY NOTES
ARI Research POC: Dr. Louis C. Miller, Fort Benning Research Unit

14. ABSTRACT

The objective of this effort was to develop a 4D visualization training device for Gray Eagle (GE) Unmanned Aerial Systems (UAS) gunnery in support of individual training and refresher training. The research team conducted a needs analysis to identify required gunnery task knowledge, skills, and abilities (KSAs). The research team used the results of the needs analysis to develop a training device that visually represented the airspace in which the students operated; depicted the associated models and graphics; provided instructors and/or Soldiers the ability to easily manipulate the models; and provided sufficient information to address the KSAs that GE UAS crew members must be proficient in to engage a target successfully. The training device, Gunnery UAV Application, hardware, software, user guide, and instructional guide were provided to the GE instructors for use within the GE UAS Operator program of instruction.

15. SUBJECT TERMS
Gray Eagle Unmanned Aerial System Training; 4D Visualization Training; Airspace Visualization Training

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** **Dr. Scott E. Graham**
a. REPORT Unclassified	**b. ABSTRACT** Unclassified	**c. THIS PAGE** Unclassified	Unlimited Unclassified		**19b. TELEPHONE NUMBER** 706-545-2362

v

Unmanned Aerial System Four-Dimensional Gunnery Training Device Development

David R. James
Northrop Grumman Corporation

James L. Gallogly
Kinex Corporation

Louis C. Miller
U.S. Army Research Institute

ARI – Fort Benning Research Unit
Scott E. Graham, Chief

May 2017

ACKNOWLEDGEMENT

UNMANNED AERIAL SYSTEM (UAS) FOUR-DIMENSIONAL GUNNERY TRAINING DEVICE DEVELOPMENT

EXECUTIVE SUMMARY
_____

Research Requirement:

        The objective of this effort was to develop a Four-dimensional (4D) visualization training device for Gray Eagle (GE) Unmanned Aerial Systems (UAS) gunnery in support of individual training and refresher training. Training challenges identified in the current UAS Gunnery curriculum included developing a visual representation that depicts all aspects of an autonomous or remote engagement. Dynamics of missile flight path, UAS position, exclusion zones, offset geometry, and friendly/enemy positions were some of the factors considered and represented in the training device to establish UAS operators' mental models.

Procedure:

        The research team conducted a needs analysis to identify required gunnery task knowledge, skills, and abilities (KSAs). Team members reviewed UAS doctrinal publications and GE gunnery course instructional material, observed the GE gunnery classroom and simulation training, and met with the GE Master Gunner to identify impediments to student learning, identify training solutions, and gather gunnery specific information. The research team used the results of the needs analysis to develop a training device that visually represented the airspace in which the students operated; depicted the associated models and graphics; provided instructors and/or Soldiers the ability to easily manipulate the models; and provided sufficient information to address the KSAs that GE UAS crew members must be proficient in to engage a target successfully. The training device was demonstrated to GE instructors at Fort Huachuca, AZ to gather feedback. Instructor feedback was incorporated into the final version of the Gunnery UAV Application (GUAVA).

Findings:

        GUAVA was a 4D training device developed using Unity software and zSpace hardware. Three scenarios were developed based on TC 3-04.45 *Combat Aviation Gunnery* minimum proficiency levels. Two scenarios depicted remote engagement conditions whereby the UAS would designated a target for an Armed Weapons Team (AWT) to engage, or the AWT would designated for the UAS to engage. The third scenario depicted an autonomous engagement where the UAS would designate and engage. Three-dimensional (3D) graphics where developed to depict the weapons footprint, Hellfire exclusion zone, and the designator fan. GUAVA scenarios were not static or "canned" scenarios that are played and repeated, rather, GUAVA provided the user with the flexibility to manipulate models to demonstrate and reinforce multiple concepts of UAS gunnery.

Utilization and Dissemination of Findings:

The training device, GUAVA, hardware, software, user guide, and instructional guide were provided to the GE instructors for use within the GE UAS Operator program of instruction. Research team members provided train-the-trainer instruction upon delivery.

UNMANNED AERIAL SYSTEM (UAS) FOUR-DIMENSIONAL GUNNERY TRAINING
DEVICE DEVELOPMENT

CONTENTS
_____

CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

Unmanned Aerial System (UAS) 4D Gunnery Training Device Development

Background

Launching an air-to-ground missile from a remotely piloted aircraft was first accomplished in 1971 when the U.S. Air Force fired a Maverick missile from a modified Firebee target drone (Whittle, 2015). However, it was not until decades later that what today is ubiquitous to the war on terrorism became a reality. On Friday, February 16, 2001, Air Force Captain Curt Hawes made aviation history by becoming the first person ever to launch a Hellfire missile from a Predator unmanned aerial system (UAS) in flight (Whittle, 2015). After September 11, 2001, MQ-1 Predators, flown by Air Force and other agency personnel, were deployed to Afghanistan and Iraq in support of Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF).

While the Air Force was supporting OEF and OIF operations with a UAS with direct fire capability, the U.S. Army began OIF operations in October 2001 with MQ-5B Hunter and RQ-7B Shadow unmanned aircraft in the reconnaissance, surveillance, and target acquisition role (RSTA) (U.S. Army Unmanned Aerial Systems Center of Excellence [UASCoE], 2010), they had no direct fire capability. Hunter and Shadow capabilities provided combatant commanders at the Brigade and Battalion levels with the ability to detect, identify, and track hostile activity over a period of up to 20 hours (UASCoE, 2010). However, the desire for continuous UAS coverage and an increase in capabilities led to the development of the MQ-1C Extended Range Multi-Purpose (ERMP) UAS.

In 2005 the U.S. Army awarded General Atomics Aeronautical Systems a contract to field the MQ-1C ERMP UAS to replace the MQ-5B Hunter as a reconnaissance and surveillance asset. The MQ-1C ERMP, based on the MQ-1 Predator airframe, was fielded as the Warrior Alpha in 2006 and as the Warrior Block 0 in 2008 (UASCoE, 2010). In 2009 and 2010, the U.S. Army successfully integrated and fired Hellfire missiles from the MQ-1C ERMP UAS and subsequently announced the deployment of four armed newly renamed MQ-1C Gray Eagle UAS systems to Afghanistan piloted by Soldiers (Leipold, 2010). Since the initial deployment Soldiers have and are currently flying the MQ-1C Gray Eagle UAS in support of operations throughout the world.

U.S. Army UAS Operator Training

Current Army UAS training for operators of the Shadow and Gray Eagle[1] (referred to as GE from this point forward) systems occurs at Fort Huachuca, Arizona in the 2-13th Aviation Regiment. Soldiers attend an eight-week common core curriculum followed by platform-specific training – 18 weeks for Shadow and 25 weeks for GE. The curriculum consists of classroom instruction, simulation training, and live-flight exercises that stress the employment of the UAS and the associated payloads. Simulation and live-flight training are conducted using simulated and live ground control stations (GCS) which provide key information on flat panel

---

[1] The Shadow UAS is considered a weaponized platform as the payload consists of a laser designator and range finder only, whereas the Gray Eagle UAS is considered an armed platform as it carries munitions as part of the primary operational configuration (Department of the Army [DA], 2014a)

screens that is text based or two-dimensional (2D) graphics. Where the curriculum differs between the Shadow and GE airframes is that GE has the capability of carrying and launching four Hellfire missiles and, as such, operator training must include how to fire these missiles.

Problem Definition

The acquisition of armed UASs for Army Aviation with the resulting transition from RSTA to RSTA and *direct fire engagement* missions has necessitated modifications to GE UAS Operator individual training to include gunnery within the program of instruction (POI) (Capri, 2014). Updated U.S. Army doctrine outlines GE UAS operator proficiency requirements for Combat Aviation Gunnery (DA, 2014a) to include knowledge through Gunnery Table V. Specifically, the GE operator must proficiently exercise the ability to "engage and achieve required target effect standards on stationary and moving targets" (Department of the Army [DA], 2014a, p. 7-6).

At present, U.S. Army GE individual level training introduces tenets of gunnery in Common Core training, followed by payload-specific gunnery instruction in UAS platform-specific training. Laser designation and missile engagements are introduced in classroom curricula and subsequently exercised in a simulation environment. Upon demonstrating proficient use of laser and/or weapons deployment in simulation, the UAS operator's gunnery knowledge and skills are reinforced in a live culminating training exercise.

Training challenges in the current UAS Gunnery curriculum include developing a visual representation that depicts all aspects of an autonomous or remote engagement as well as building the Soldier's mental model of the three-dimensional space in which they operate. Dynamics of missile flight path, UAS position, exclusion zones, offset geometry, and friendly/enemy positions are some of the factors to consider in establishing the UAS operator's mental model. Successful individual gunnery training should enable the UAS operator to understand the impacts of three-dimensional parameters plus time (fourth dimension [4D]) to employ maximum weapons effectiveness and/or accept tolerable levels of diminished capabilities.

Research Objective

The objective of this effort was to develop a 4D visualization training device for GE UAS gunnery in support of individual training and refresher training. To this end the report describes the development of the training device which became known as the Gunnery Unmanned Aerial Vehicle Application (GUAVA).

Structure of the Report

The results of this effort are presented in three sections. The first section discusses the needs analysis, the second section presents the training device development process, and the third section describes the piloting and subsequent refinement of the training device.

Needs Analysis

The research team conducted a three-phase needs analysis. First, research team members reviewed UAS doctrinal publications and the GE gunnery course instructional material to identify required gunnery task knowledge, skills, and abilities (KSAs). Next, team members observed the GE gunnery classroom and simulation training. Lastly, team members met with the GE Master Gunner[2] to identify impediments to student learning, identify training solutions, and gather gunnery specific information.

UAS Doctrine and GE Gunnery POI Review

The picture of the GE Operator training course graduate is a Soldier, as a member of an aircrew, who has the knowledge, skills, and abilities required to successfully complete Gunnery Table One (GT I) for UAS platforms (personal correspondence). GT I consists of seven minimum proficiency levels (MPLs) of which five are related to either designating a target for a firing platform (remote engagement) or self-designating and launching a missile (autonomous engagement) (DA, 2014a, p. 7-2). UAS aircrew training doctrine lists 33 base aircrew tasks: 27 related to flying the aircraft and six related to gunnery (DA, 2014b, p. A-2). Of these six base gunnery tasks, "Engage Target with Point Target Weapon System", task number 011-630-1458, describes the task, conditions, standards, crew actions, and procedures to conduct a remote and an autonomous engagement (DA, 2014b, p. A-58).

Within the description of the crew actions and procedures hide the KSAs that each crew member must be proficient in to engage a target successfully. Examples of the KSAs are:
- Maneuver the aircraft within the engagements limits of the missile,
- Keep the aircraft in laser constraints until missile impact,
- Determine minimum/maximum engagement ranges, maximum offset angles, safety zones, laser-on times,
- Interpret launch acceptability region and weapons footprint symbology, and
- Verify that all engagement conditions are met before the missile is launched.

Armed with these KSAs we set about reviewing the lesson plans that support the task Engage Target with Point target Weapon System.

Our initial review of the GE gunnery lesson plans revealed that the gunnery specific instruction the Soldiers would receive was primarily related to procedural tasks for laser designation and firing the missile, that is, a review of weapons menus and firing checklists. The lesson plans provided additional information related to gunnery, for example, tactical airspace considerations, DIDEA (detect, identify, decide, engage, and assess) process, reconnaissance and security operations, missile capabilities, and laser operations. However, we could not determine how the information in the lesson plans would relate to the crew actions and procedures required for a remote and autonomous engagement. To supplement our review of doctrinal publications and the GE gunnery lesson plans we requested an opportunity to observe the training as it was conducted with a class of students.

---

[2] The Gray Eagle Master Gunner acts as the subject matter expert for all weapon system platforms in the aviation battalion/task force (DA, 2014a, p. 2-11)

GE Gunnery Training Observations

       The research team, through coordination with the GE Operator training supervisor, was afforded the opportunity to observe the GE gunnery classroom and simulation training. Training was conducted over a three-day period with 1.5 days in the classroom and 1.5 days in the simulator. The classroom training we observed was conducted by the GE Master Gunner. The lesson plans used were similar to the lesson plans we had reviewed previously with minor changes.

       Over the course of the classroom training the instructor made a point of relating as much of the information presented to remote and autonomous gunnery scenarios. For example, during the "Introduction to Gunnery" class he briefly discussed the weapons footprint and Hellfire exclusion zone. Similarly, during the "Laser Operations" class the instructor discussed how the positioning of the UAS directly impacts the laser return from the target, which impacts the probability of hitting or missing the target. We noted that there was extensive use of a whiteboard on which he drew geometric shapes related to positioning of the UAS in relation to the firing platform and the target for both the remote and autonomous engagements. Similarly, he used UAS payload footage of actual engagements to discuss additional aspects of gunnery, i.e., ranges to target, payload offsets, laser effects, and munition parameters.

       In addition to the classroom observations, the research team observed the simulator training. The students were spilt into 2-man crews, one as the aircraft operator (AO) and one as the payload operator (PO), to conduct training in a ground control station (GCS) simulator.[3] The UAS crew was led through a series of exercises by the assigned instructor operator that familiarized the crew with the sequence of procedural steps – i.e., checklists – to designate a target and launch a missile in the autonomous mode. The exercises focused mainly on the buttonology and crew coordination required to successfully engage a target. Exercise pre-conditions – UAS altitude, location, etc. – eliminated the need for the crew to correctly determine UAS engagement parameters prior to launching a missile. The exercise was repeated with the students switching AO and PO roles. For the most part, simulation training ended after each Soldier had completed two exercises as an AO and two exercise as a PO. We ended our training observations by meeting with the GE Master Gunner to discuss training solutions.

GE Master Gunner Input

       We were provided an opportunity to meet with and discuss GE gunnery with the GE Master Gunner at the completion of training. The focus of the discussion was to ascertain what areas of GE gunnery students have difficulty understanding, identify possible training solutions, and to gather gunnery specific information.

       As to the first, student difficulty understanding GE gunnery, the GE Master Gunner identified that the number one issue he had to overcome was getting the students to understand the geometry involved when aligning the UAS and firing platform in space and time as seen in Figure 1.

---

[3] The GCS simulator is modeled after the actual GCS for live-flights, that is, the controls and displays within the simulator match the controls and displays within the actual GCS.
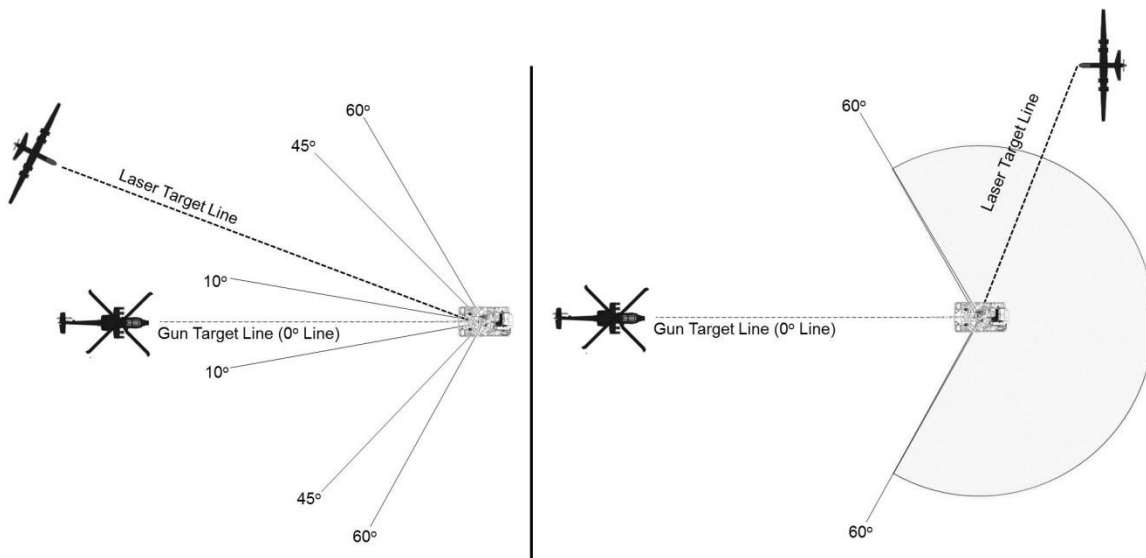
Figure 1. Laser designator positioning relative to the firing platform and target. Students must understand the process for aligning the UAS with the firing platform and target in space and time.

The geometry involves aligning the UAS in altitude and location in relation to firing platform (as seen in the left panel of Figure 1), and time-on-target in relation to laser designation (as seen in the right panel of Figure 1). The UAS altitude and location are impacted by safety considerations and missile capabilities. For example, exclusion zones, which are polyhedrons, impose restrictions on the positioning of the UAS and differ in dimensions based on the type of missile. Time-on-target, on the other hand, is related to laser designation. Based on the flight path or orbit of the UAS there is a window of time where the laser return from the target is visible to the seeker head on the missile. Lasing outside of this window could result in the missile missing the target. He identified he had difficulty communicating in an efficient and effective manner and described the use of "hand puppets" and white board drawings as a means to inform the students.

As to the second, possible training solutions, we identified that some of the knowledge necessary to successfully conduct a remote or autonomous engagement was presented during the gunnery training; however, there were no means of bringing it all together in a format that visually represented the airspace in which the students would operate. We discussed how a 4D training device could represent the airspace and players – UAS, firing platform, target, and associated exclusion zones – and provide the visuals necessary to help the students understand. We agreed that the best possible solution would include the components of three scenarios – two remote engagements and one autonomous engagement. The discussion then turned to the flexibility of the training device. Flexibility in this sense related to how the user could manipulate the models. We had identified that the GE Master Gunner had discussed multiple variations within each scenario during the classroom training, i.e., drawing models in different locations and from differing views – top down, side, and pseudo 3D. We agreed that the training device should support the instructor's ability to vary locations of the UAS, firing platforms, and the target. Lastly, we briefly discussed who would use the training device, either instructors or

students, or both. However, at this point we did not have a clear picture of how the training device would work to make an informed decision and tabled the discussion until a later date.

As to the third, gunnery specific information, the discussion turned to what objects and model capabilities were required to depict the three scenarios. To facilitate learning, the GE Master Gunner indicated that the three scenarios should replicate, as close as possible, the scenarios outlined as UAS MPLs. Therefore, each scenario should have a laser designator, a firing platform, a target, and associated graphics. Table 1 lists the initial scenario requirements.

Table 1
Scenario model and graphic requirements based on UAS GE MPLs

TC 3-04.45 MPL Scenarios	Laser Designator	Firing Platform	Required Models/Graphics	
1 – SAL* Hellfire Remote Designation for Rotary Wing (In-Line/Offset)	UAS	AWT**	• GE UAS • AWT • Target • Laser target Line (LTL)	• Gun Target Line (GTL) • Hellfire Exclusion Zone • Terminal guidance time • Designator Fan
2 – SAL Hellfire Remote Launch for Rotary Wing UAS (In-Line)	AWT	UAS	• GE UAS • AWT • Target • LTL	• GTL • Weapons Footprint • Designator Fan
3 and 4 – In-Line and Offset Autonomous Hellfire Engagement	UAS	UAS	• GE UAS • LTL/GTL • Target	• Weapons Footprint • Missile Trajectory

Note. * SAL refers to the semi-active laser (SAL) seeker in the warhead on the Hellfire missile; ** AWT is an Attack Weapons Team, which in this case is represented by two AH-64 Apache helicopters

One model that was discussed and subsequently discarded was the inclusion of different types of Hellfire missiles and the modes of flight. The GE UAS and firing platforms configured for launching Hellfire missiles have the capability to launch multiple types of Hellfire missiles in three different modes of flight – high, direct, and low. Each type of missile fired in each of the three different modes of flight has a different trajectory, that is, one missile equals three trajectory models. We agreed that developing trajectory models for each type of missile was not necessary for two reasons: (a) we did not want to include any classified data, and (b) the models for the weapons footprint and Hellfire exclusion zone would provide sufficient information in relation to missile trajectories. However, subsequent discussions with the GE Master Gunner did identify a need to develop a solution that would depict the terminal guidance time of the missile trajectory as this was a key point for discussion during the laser operations class.

The results of the needs analysis provided a path forward for the development of the training device. The device had to visually represent the airspace in which the students would operate; depict the associated models and graphics; provide instructors and/or Soldiers the ability to easily manipulate the models; and provide sufficient information to address the KSAs that GE UAS crew members must be proficient in to engage a target successfully. The next section describes the development of the 4D UAS Gunnery training device which became known as GUAVA.

GUAVA Development

Unity software and zSpace hardware was selected for the development of GUAVA. An agile software development process was utilized to develop an exemplar scenario from which common models were incorporated across scenarios in order to streamline the process and stay within the development timeline.

Unity and zSpace

Selecting Unity and zSpace stemmed from the desire to use a proven, reliable, and available system as a suitable programming environment. We discussed various other systems that used augmented virtual reality, i.e., Magic Leap and Microsoft Holo Lens, and systems that used virtual reality, i.e., Oculus Rift, Vive, and Google Cardboard, however, these choices were ruled out as suitable systems as (a) Augmented reality systems were emerging technologies and had limited availability, and (b) Virtual reality systems, i.e., goggles, were inappropriate for the large classroom target audience. We further explored the use of 3D tablets and 3D gaming solutions displayed on 2D screens, however these were ruled out as they did not provided tools to interact in real 3D space.

We choose zSpace as this system provided the following capabilities:
- zView software would display an augment reality view to an entire classroom through a 2D projector.
- zView software enabled users to view a 3D image using tracked 3D glasses.
- zSpace provided a tracked stylus user interface component that allowed user to naturally interact with the 3D space.
- zSpace was a proven and reliable system and is currently used by STEM (Science Technology Engineering and Math) programs to provide an immersive learning experience for students and supports the use of multiple development platforms (Unity3D, Ogre, Unreal, etc) to produce 2D and 3D gaming experiences.[4]

We selected the zSpace 200 system with available zView camera and camera arm, as seen in Figure 2. The zSpace 200 system consists of a high-definition immersive monitor with infrared sensors, polarized passive eyewear, and an infrared light-emitting diode (LED) stylus with three control buttons.

---

[4] More information about zSpace can be found at http://zspace.com

Figure 2. zSpace 200. The zSpace 200 system enables users to view and control graphics in Three-dimensions using polarized eyewear and stylus.

User experience is controlled with the stylus and viewed through the polarized eyewear. zSpace software provides full resolution images rendered for each eye, while the built-in infrared sensors track the viewing angle of the user and adjusts the image accordingly. zView software enables the user to project 3D images as seen in Figure 3.
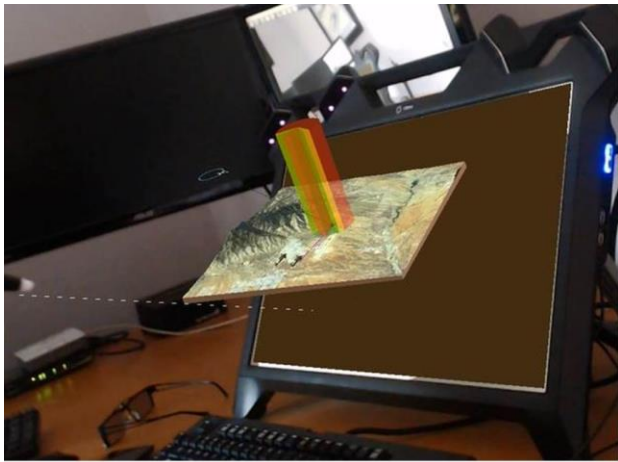
zView Augmented Reality View

Figure 3. zView augmented reality view. The zView software enables the user to project what he or she sees with the polarized eyewear on to a classroom screen.

The zSpace 200 is a monitor only system that requires an external computer, as opposed to the zSpace 300 all-in-one system. We chose the 200 system as we had yet to determine the

graphics computing power required to display a terrain backdrop and 3D geometric shapes and did not know if an all-in-one system would be sufficient.

Discussions with the GE Master Gunner identified the requirement for multiple geometric volumes rendered in three dimensions to depict safety and exclusion zones – examples are depicted in Figure 4.
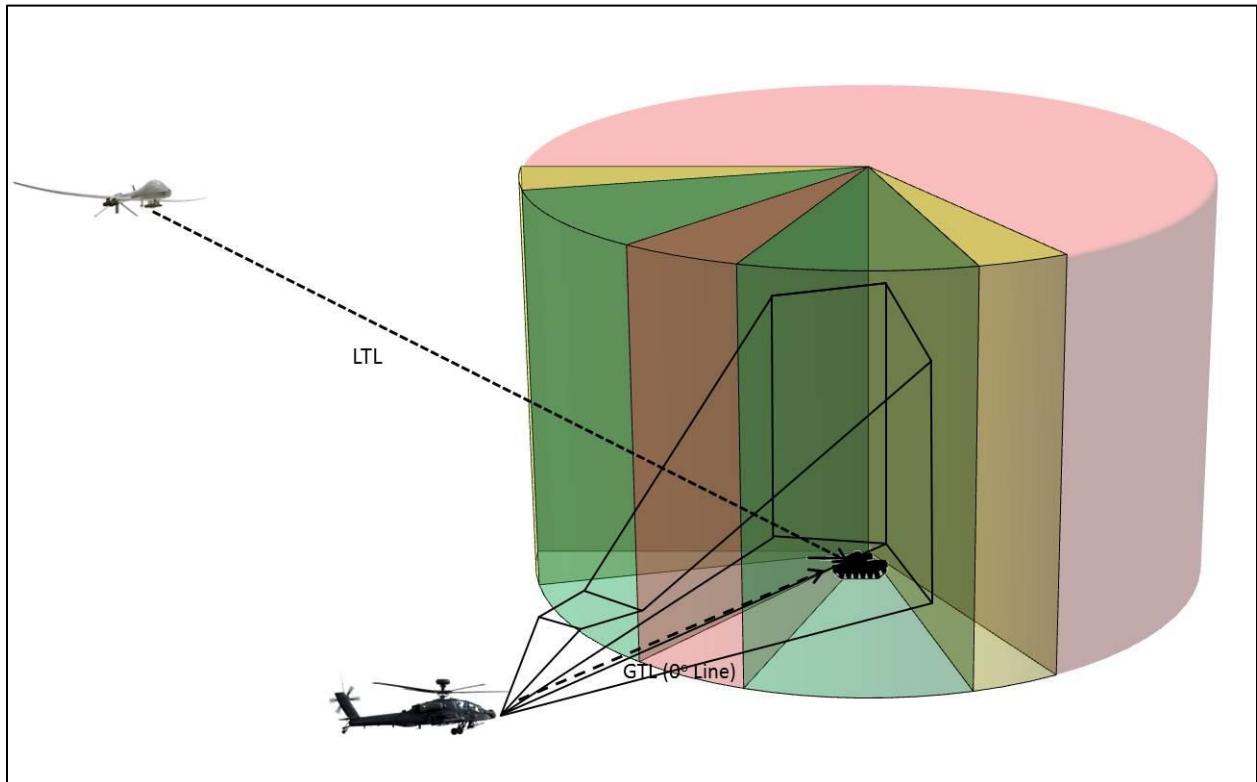
Figure 4. Example of a 3D geometric volume.

The graphics computing power required to generate these types of geometric shapes displayed on a terrain model backdrop at the required frame rates for 3D display was unknown at the time. Therefore, we erred on the side of caution, selected the zSpace 200 monitor, and added a high-end gaming computer – the Cyberpower Gamer Scorpius 9000 with an Advanced Micro-Devices (AMD) Radeon R9-390X 8GB graphics card. We selected the AMD Radeon R9 as it was recommended by the zSpace development and sales team as a graphics card used to display high-resolution medical simulations. Technical specifications can be found in Appendix A.

Technical difficulties. The use of a new system did not come without technical challenges. In this case, the challenges were centered on the use of the AMD graphics card and updated application program interfaces (APIs).

Through trial and error we discovered that the AMD graphics card works only with one specific beta version video driver. This driver was older than the default windows driver so special effort had to be made to prevent windows from replacing the driver automatically. In the

future, it is not recommended to use this specific card but instead research a video card that functions with up-to-date drivers.

Similarly, at the start of this research effort zSpace launched a new API ZCore 4.0. However, the online developer's documentation was associated with API ZCore 3.0. The updated API created a steeper initial learning curve. zSpace has now updated the developer's site and migrated the documentation to ZCore 4.0 making it easier for developers to start working right away. The entire GUAVA infrastructure is now in place which mitigates any issues with future extensions.

In order for the students to view the scenarios the instructor was manipulating, we needed to take advantage of a feature in the zView software that allows mirroring the 3D screen to a 2D projector. Unfortunately, Unity 5.3 has a bug that prevents screen overlays and user interface (UI) components from being rendered to a camera texture. zView sends the rendered camera texture as output to the 2D projector. The end result was that any heads-up display (HUD) or UI controls would not show up on the projector. The absence of a HUD and UI control was a show stopper as the initial implementation plan was to display all content on the classroom screens for the students to view. We attempted several workarounds. Traditional screen mirroring distorted the image aspect ratio, screen capture software would either slow down the frame rate or be clumsy to start, and other software methods ran into the same problems. In the end, we modified zSpace source code and added a co-routine that performed a screen capture of each frame and wrote that to the texture used by zView, while not as performance efficient as using the camera texture, it captured everything on the screen. Internal testing indicated that even with this inefficient capture process the machine and video card had plenty of power to spare.

Once we overcame these challenges, the software and hardware acted as expected and application development began. On a side note, we elected to purchase two systems to ensure that we maintained software to system compatibility. One system remained with the software developer to facilitate software updates; while the second system was deployed to Fort Huachuca after acceptance testing was completed.

Prototype Application Development

Application development followed an agile software development lifecycle of planning, requirements analysis, designing, building, and testing. Our initial needs analysis from observing the training class revealed that three different scenarios would be needed. We took the needs of the user for these scenarios and generated user stories. However, since the technology and its capabilities were new, we decided to go a step further and generate more detailed use cases. We identified similarities between the three scenarios and decided to construct an exemplar scenario as an iterative implementation.

Exemplar scenario. The exemplar scenario contained all elements found in the MPL scenario SAL Hellfire Remote Designation for Rotary Wing (In-Line/Offset). Models and graphics included the:
- GE UAS,
- AWT,

- Target,
- Laser target Line (LTL),
- Gun Target Line (GTL),
- Hellfire Exclusion Zone,
- Terminal guidance time indicator, and
- Designator Fan.

We utilized the use case process to identify all requirements for this and subsequent scenarios.

Use case process. Requirements analysis followed the use case process. This process, as defined by Jacobson, Spence, and Bittner (2011), is a process that "enables the developers to capture a set of requirements and identify all of the ways of using a system to achieve a particular goal for a particular user" (p. 4). Use cases tell stories. The stories focus on how an end user interacts with the system to achieve the desired outcome, and how to handle any problems that may occur. Each use case becomes a quality assurance document during acceptance testing.

Based on our training observations, we began by telling the story of how an instructor would use each scenario in GUAVA within the context of a gunnery class. We classified this as the scenario high-level use case and presented each use case to the GE Master Gunner for his review and concurrence before drilling down into each instructor interaction.

Each instance of instructor interaction identified a lower level or base use case. For example, when the instructor used the application to discuss exclusion zones he would toggle-on the Hellfire Exclusion Zone, move the AWT, and move the UAS in altitude and location. This interaction identified multiple base use cases as can be seen in Figure 5.

> #### 1.1.3   High level example use case
> This is high level to show an example of how the tool will be used to teach the concepts. Use Case are clickable links.
>
> 1. The instructor starts the application [Use Case 2.1.1 Start Application]
> 2. The Instructor selects scenario 1 from a list of three [Use Case 2.1.2 Select a Scenario]
> 3. The Instructor clicks load for scenario 1 [Use Case 2.1.3.2 Alternate: Scenario 1].
> 4. The instructor toggles-on the hellfire exclusion zone [Use Case 2.3.2 Toggle Hellfire Exclusion Zone] to show students the zone
> 5. The Instructor rotates the terrain [Use Case 2.3.1 Rotate Terrain] to show the zone from top-down view, side-view, and pseudo 3D-view.
> 6. The instructor moves the AWT [Use Case 2.2.1 Move AWT] to depict how the exclusion zone moves with the Shooter along the GTL.
> 7. The instructor clicks the reload button [Use Case 2.7.2 Reset Scenario Button] to return the AWT to the default position.
> 8. The instructor grabs the UAS and moves it into the exclusion zone [Use Case 2.2.2 Move] to depict and discuss the no fly zone concept.
> 9. The instructor clicks the reload button [Use Case 2.7.2 Reset Scenario Button] to return the UAS to the default position.
> 10. The instructor toggles-off the hellfire exclusion zone [Use Case 2.3.2 Toggle Hellfire Exclusion Zone].

Figure 5. An example of a high-level use case.

The high level use case was used to determine the application requirements. We identified between 25 and 28 instructor interactions with between 33 and 36 base use cases per scenario.

We next grouped common base cases as each of the three scenarios had similar functionality, i.e. Move UAS, Move AWT, Fire Missile, etc., and reduced the total number of base cases to 36. We further grouped these base use cases by like items, that is, all movement cases were grouped, as was all change view cases, which resulted in seven primary groups – Main Screen, Movement, Change View, Time Controls, User Game Controls, Simulation, and Mission Controls. These seven groups contained the main success cases in which nothing goes wrong. The next step was to identify all extension cases, that is, all alternate cases or failure cases.

The last step was to define each use case. Defining each case provides key information for the programmer, i.e. what triggers the use case, the general description, any preconditions, and the main success conditions. Figure 6 depicts an example of the format followed for defining each use case.

> **2.2.1   Move AWT**
> *2.2.1.1   Base Case*
> **Trigger:** User Initiated
>
> **Description:** The user grabs the AWT with the stylus and moves the AWT and anchored GTL and Hellfire Exclusion Zone along horizontal and vertical axes
>
> **Preconditions:** Use Case Select Scenario completed
>
> 1. User grabs the AWT with the stylus
> 2. Reset Fire Use Case
> 3. User moves AWT a fixed height above the terrain
> 4. AWT rotates to remain facing target
> 5. AWT pair remain together
> 6. Reset Scenario button is enabled, since initial state has now changed
> 7. Associated elements update with AWT (see alternate courses)
> 8. User releases the AWT

Figure 6. Base use case format. Defining a use case as specific as possible provides key information to the software programmer.

We defined each use case in this manner to identify a complete list of requirements for the application. We compiled the use cases into a single document and added the associated geometric shape graphics. The document was reviewed one final time and became the foundation for the application development. The full use case document can be found in Appendix B.

We determined that it was critical to spend a large amount of effort upfront developing the use case document for two reasons – one, to mitigate as many programming issues on the back-end as we could, and two, to define the scope of the application and managing expectations. The use case document provided the input to craft a development timeline and sequence the incremental builds. The development timeline for the exemplar scenario spanned 12-weeks.

While upfront analysis is more typical of a waterfall approach, the new technology and expected capabilities required a more iterative process. Small incremental functionality was demonstrated and reviewed to inject feedback into the development process. Initially a second zSpace system was not available at the customer site, therefore, iterations were delivered in the form of screen shots, video captures, and a user video. Table 2 lists the incremental deliveries, each iteration relied on user input that fed back into the development cycle.

Table 2
Examples of GUAVA incremental builds

Incremental Build	Screen Shots	Video	Software
Terrain rotate/manipulation		X	
Transparent models	X		
Time controls		X	
UAS orbit		X	
Main menu	X		
GTL/LTL rendering		X	
Designator fan	X		
Hellfire exclusion zone		X	
GTL/LTL rendering	X		
Exemplar scenario		X	X
Complete alpha version			X

The incremental review, in the form of screen shots and video capture, provided research team members and the GE Master Gunner a view of how the technology worked in real life and enabled incremental feedback rather than providing feedback at the completion of the scenario.

Designing and building models and graphics. This section addresses design and development challenges encountered for a sub-set of the required elements of the application.

Terrain and model scale. We selected the terrain model based on the student's location, Fort Huachuca. We sized the terrain model at 20km by 20km to enable instructors to place the models (UAS, AWT, and the Target) in a variety of positions. However, when it came time to place the models on the terrain, we realized that at normal scale (1:1) it became difficulty to see, let alone select, the models. While the solution was to increase the scale of the models 100 fold and surround them with opaque bubbles, this impacted laser occlusion, and subsequently UAS positioning. The issue was that as the model was scaled up the terrain size stayed the same, i.e., a building that dwarfs a tank at a 1:1 scale is now dwarfed by the tank at 100:1 scale.
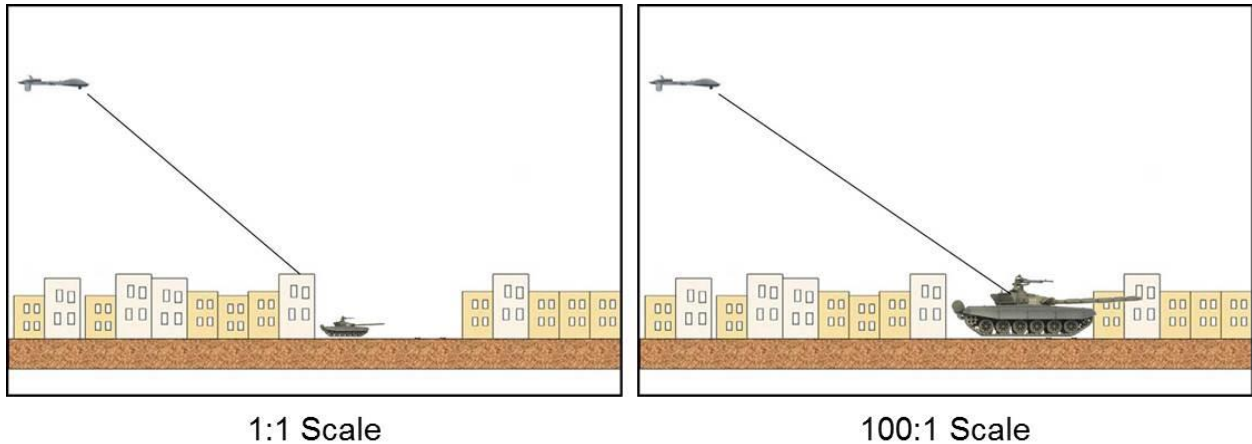
Figure 7. Comparison of 1:1 versus 100:1 scales. Increasing the scale of the model to enable instructors to select the model gave a false impression of lasing capabilities and UAS positioning.

Laser occlusion occurs when the laser beam intersects an object, a building in the above case, and does not reach the target. In GUAVA, the scenario depicted in the left panel of Figure 7 (1:1 scale) would result in a missile impact on top of the building not on the target, which reflects the incorrect positioning of the UAS. However, scaling up the target to 100:1 (approximation for illustration only), as seen in the right panel, would result in a missile impact on the target, but can be misleading as to the correct positioning of the UAS to provide a good laser return from the target.

The solution required a tradeoff. We kept the model size at 100:1 scale to enable the instructors to select and position the model as appropriate; the tradeoff would be in vignette pre-conditions. During instructor train-up, we would emphasize that when discussing laser occlusion, the instructor would have to place the target behind a terrain feature that was greater in elevation than the height of the target, and position the UAS in such a way that decreased the payload elevation angle which would induce laser occlusion.

Hellfire exclusion zone. For the most part, information provided by the GE Master Gunner drove the design and build process. For example, we were provided with the dimensions of the Hellfire exclusion zone (as seen on the left side of Figure 8) and from these built the 3D polyhedron (as seen on the right side of Figure 8). The dimensions of the zone are based on missile low, high, and direct trajectory data. The zone is depicted to illustrate the area in front of the launching platform that the designating platform must stay clear of in order to remain protected from inadvertently becoming a target for the launched missile.
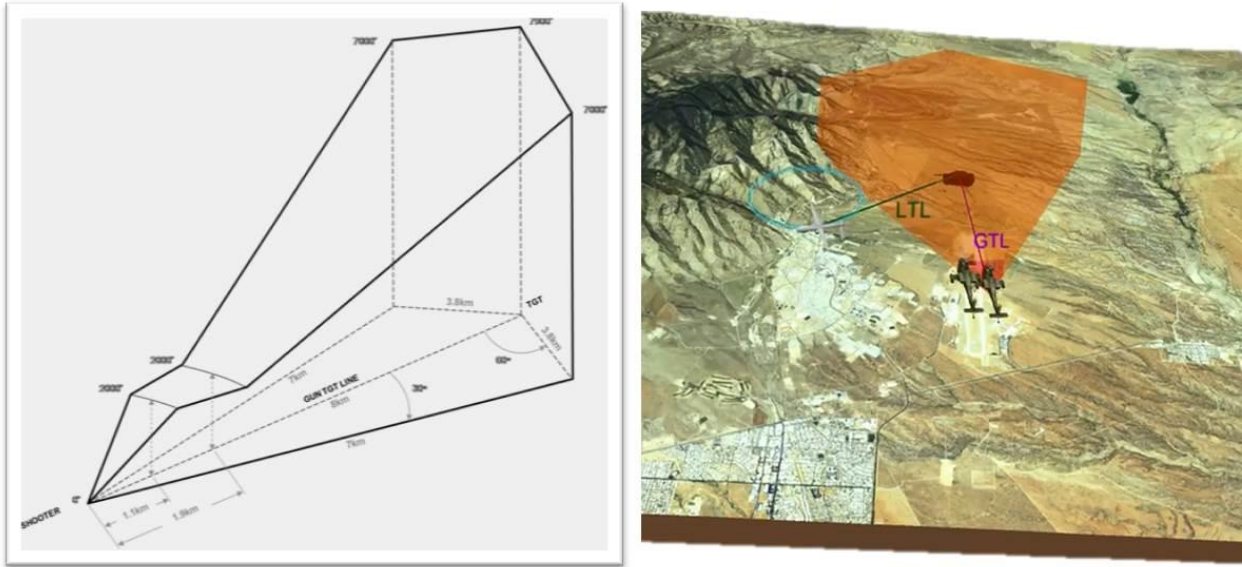
Figure 8. Model and graphic design examples. Information provided by the GE Master Gunner enabled the developers to build models, capabilities, and functions for each scenario.

In addition to building the polyhedron we added three separate functions, one based on design parameters and two requested by the GE Master Gunner. The design parameter required the narrow end of the Hellfire exclusion zone be anchored to the nose of the firing platform and move as the instructor moves the firing platform. The requested functions related to the missile trajectories. As stated previously, the GE Master Gunner did not want to depict an actual missile flyout, but still wanted an indication of the missile moving towards the target. Additionally, he identified the need to illustrate the last 10 seconds of time of flight (TOF) as this is the terminal guidance time before the missile impacts on the target and would be discussed in the classroom during the laser operations class.
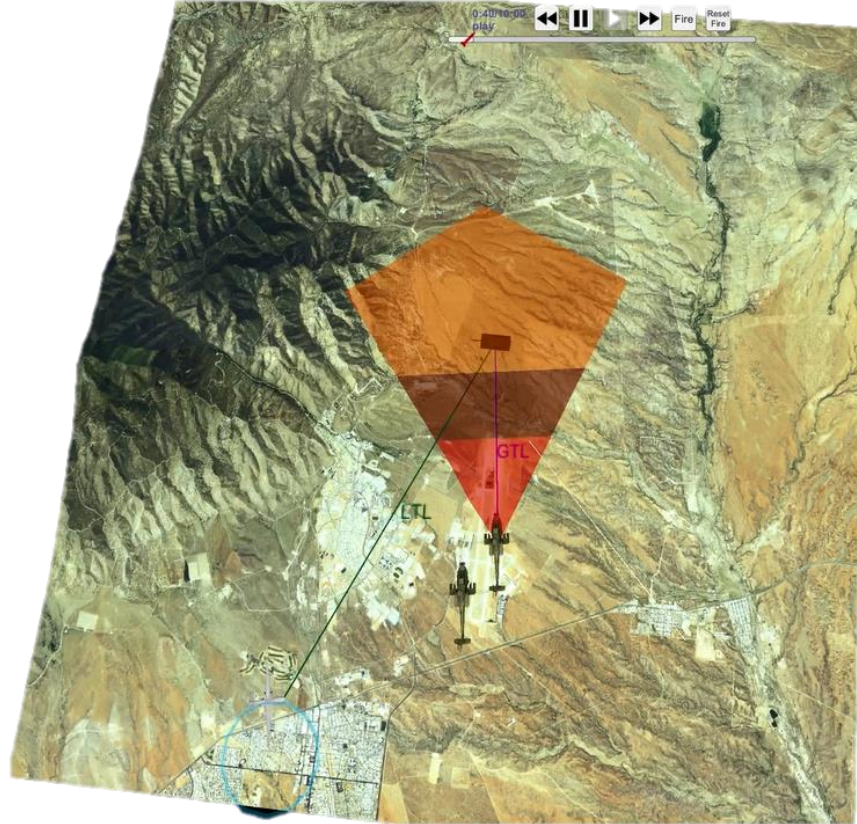
Figure 9. Missile flyout and terminal guidance time solution. Incrementally filling the Hellfire exclusion zone with two different colors illustrated the missile flyout and terminal guidance time.

To this end, we elected to depict the missile flyout by filling the Hellfire exclusion zone with the brighter shade of red, as seen in Figure 9. Fill rate was based on a missile TOF table found in TC3-04.45 *Combat Aviation Gunnery*: TOF is based on the range to target from the firing platform. The change in color to a darker shade illustrated the terminal guidance time – the last 10 seconds of TOF.

   Weapons footprint. Similarly, we were required to build a weapons footprint. In this instance not only were dimensions important, but functionality as well. The weapons footprint illustrates the maximum engagement limits of the Hellfire missile; the size, shape, and color change as the UAS altitude, angle, and range to the target changes. The challenge was in replicating these changes. We were not provided the mathematical formulas for calculating or producing the Weapons footprint and did not have enough information to build a fully accurate missile telemetry model.
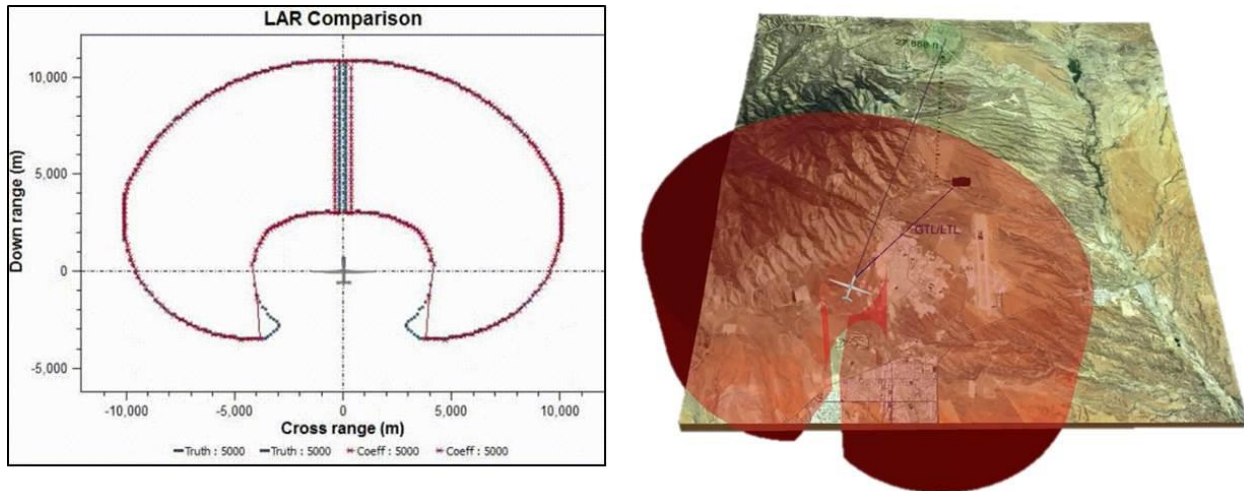
Figure 10. Weapons footprint graphic. Replicating the functionality of the weapons footprint required a complex mathematical algorithm.

However, we were provided a video showing the weapons footprint on a graph (left side of Figure 10). Our solution to achieve this shape was to generate two limacons, one representing the outer edge, the second representing the inner "hole". We used the formulas for a standard parameterized limacon and created additional variables:

- Standard formulas
    - $x = (b + a \cos t) \cos t$
    - $y = (b + a \cos t) \sin t$
- Standard formulas with additional variables
    - $x = ((b + a \cos t) \cos t) * scale * squashx + shiftx$
    - $y = ((b + a \cos t) \sin t) * scale * shifty$

Scale provided for the correct size and *squashx* enabled us to produce the correct aspect ratio. The resulting limacon could then be *shifted* to place the UAS in the correct location. We used the same variables to produce the inner limacon but with an additional *shift* since it needed to line up precisely with the outer limacon. To join the inner and the outer limacons for a given value T we switched from plotting the outer limacon to the inner limacon. The inner limacon would also only plot for a range of T values.

We identified the correct parameters for our new formula by overlaying our mathematical representation on a single frame of the provided video showing the correct footprint. We then manually adjusted the values of our formula until the formulaic graph matched the provided source imagery. However, this provided only a single frame of the outline of the weapons footprint; therefore we applied the overlay on key frames of the video every 5,000 feet to generate the necessary data: this data was then entered into the game. Using only these key frames, every 5000 feet, would create jarring image changes rather than a smooth transition. To provide a smooth transition between key frames we used a linear interpolation of the parameters, for example, at a height of 1,100 feet the parameters will be 20% in between the parameters at 1,000 feet and the parameters at 1,500 feet. This linear interpolation enabled the game to generate an approximation of the weapons footprint outline at any given altitude. These values were used in-game to generate a dynamic mesh that shifted the location of the 3D points to conform to the locations for the altitudes specific to the limacon characterization. This was done

twice, once for the top of the weapons footprint "cylinder" and once for the bottom while the two remained connected to create a solid extrusion of the weapons footprint shape. The resulting changes happen smoothly as the user grabs the UAS and moves it up and down in real-time.

   Common controls. In addition to geometric shapes scenario control buttons and functions were built. Control buttons were depicted with familiar symbols and provided recognized responses, i.e. Play, Pause, etc. These included:
- Play/Pause,
- Rewind/Fast Forward, and
- Exit.

In addition to the above control buttons, we developed five additional control buttons:
- Fire,
- Reset Fire,
- Reset Scenario,
- Disconnect/Connect, and
- Standard/Augmented Reality.

Fire and Reset Fire controls gave the instructor the flexibility to launch or reload a missile from or to the UAS or AWT any time while the scenario was running. Reset Scenario enabled the instructor to reset to the default settings without having to re-load the scenario. Disconnect/Connect enabled the instructor to display the view on a 2D projector, and Standard/Augmented Reality enabled the instructor to toggle between a standard view and an augmented reality view. These controls are depicted in Figure 11.
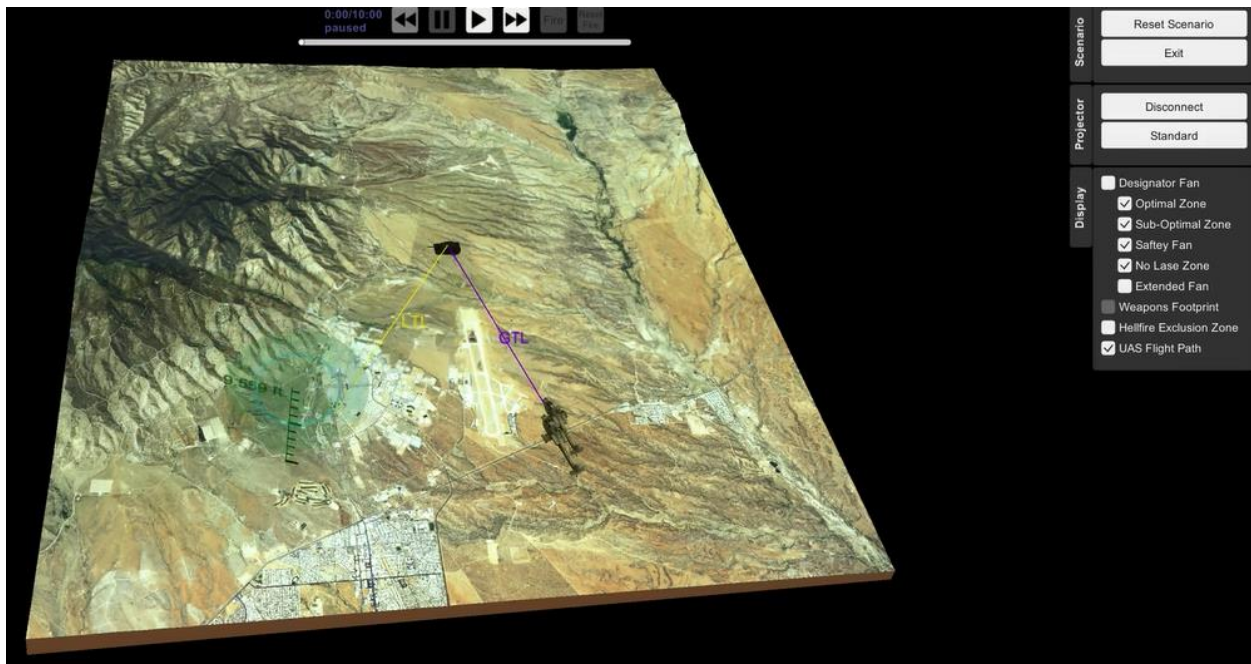

Figure 11. GUAVA Alpha version scenario controls and menu items. Common controls are depicted at the top and upper right of the image, while menu items are depicted on the right of the image. Items are grayed-out if they do not apply to the scenario.

Menu items. Menu items were specific to each scenario. Menu item selection enabled the instructor to toggle-on/off 3D geometric shapes, as depicted in Figure 12, as a representation of the 2D graphics displayed in the course POI. In addition to the Hellfire exclusion zone and the weapons footprint, 3D geometric shapes representing the designator fan were designed and built.
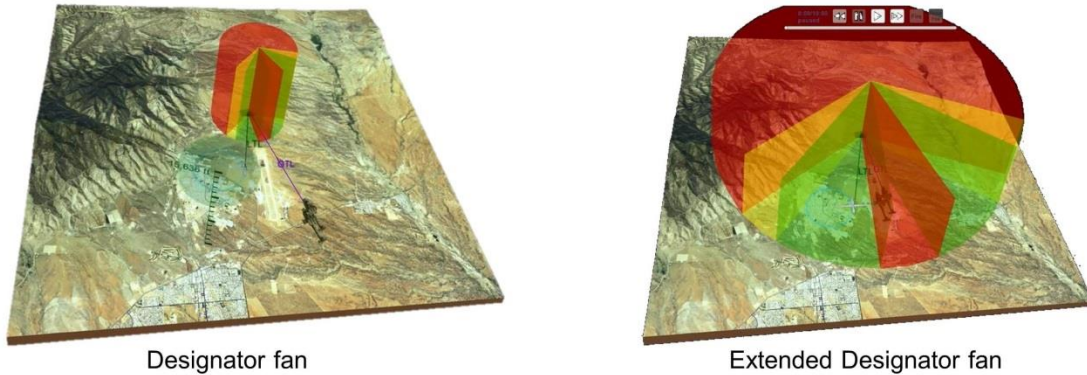

Designator fan   Extended Designator fan

Figure 12. Examples of 3D shapes. The 3D shapes enabled the instructor to discuss gunnery concepts, i.e. offset angles, associated with each scenario.

The designator fan is used to depict the optimum and sub-optimum LTL zones in relation to the firing platform gun target line. The fan depicts the required offset angles for the designating platform. The optimum zone is depicted in green between 10 and 45 degrees on either side of the gun target line (0 degree line), while the sub-optimum zone is depicted in yellow between 45 and 60 degrees on either side of the gun target line. Lasing through these zones will maximize the effectiveness of the missile at impact (DA, 2014a, p. 14-56). The fan also depicts the 240 degree no-laze zone in red. Lasing through this zone would result in the laser return from the target not being detected by the missile seeker head. The safety zone, 10 degrees on either side of the gun target line (depicted by the small red wedge), indicates a no missile release zone. The extended version was requested by the GE Master Gunner to assist in illustrating the increase in airspace at different ranges from the target.

We completed the design and build steps for each elements of the exemplar scenario. We then incorporated all elements into the exemplar scenario and began testing.

Testing. We used the use case document to guide testing and ensure all content and functionality identified in the requirement analysis was present.

We stepped through each use case to identify deficiencies and anomalies. For example, after loading the exemplar scenario we stepped through the below alternate use case (Figure 13) to determine if the default set-up contained all models and menu items.
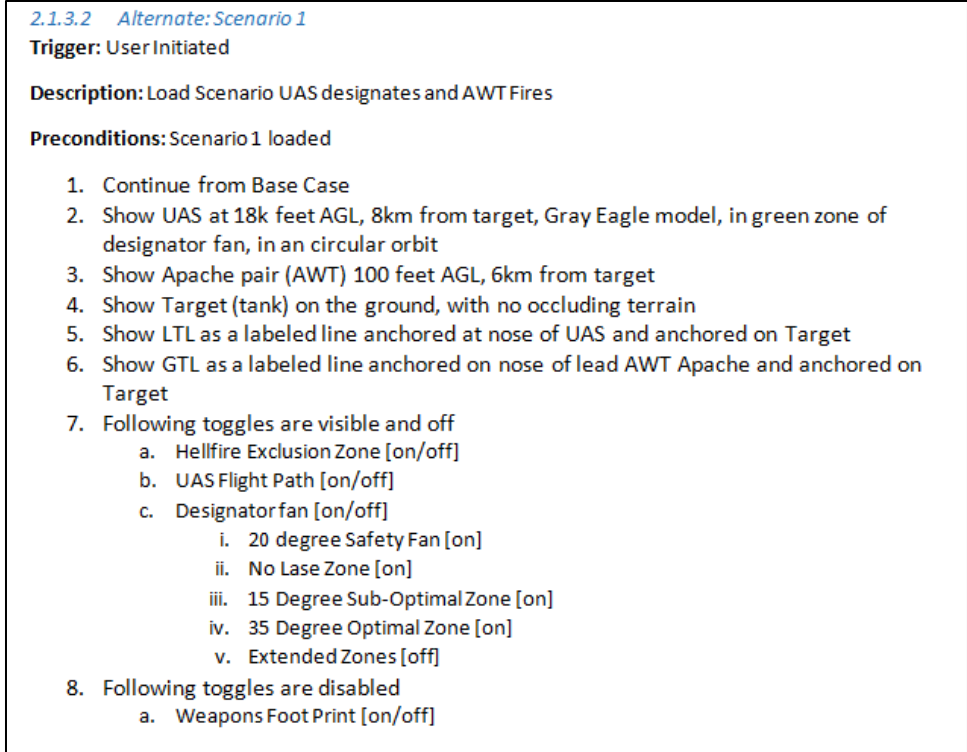
```
2.1.3.2   Alternate: Scenario 1
Trigger: User Initiated

Description: Load Scenario UAS designates and AWT Fires

Preconditions: Scenario 1 loaded

    1.  Continue from Base Case
    2.  Show UAS at 18k feet AGL, 8km from target, Gray Eagle model, in green zone of
        designator fan, in an circular orbit
    3.  Show Apache pair (AWT) 100 feet AGL, 6km from target
    4.  Show Target (tank) on the ground, with no occluding terrain
    5.  Show LTL as a labeled line anchored at nose of UAS and anchored on Target
    6.  Show GTL as a labeled line anchored on nose of lead AWT Apache and anchored on
        Target
    7.  Following toggles are visible and off
            a.  Hellfire Exclusion Zone [on/off]
            b.  UAS Flight Path [on/off]
            c.  Designator fan [on/off]
                    i.   20 degree Safety Fan [on]
                    ii.  No Lase Zone [on]
                    iii. 15 Degree Sub-Optimal Zone [on]
                    iv.  35 Degree Optimal Zone [on]
                    v.   Extended Zones [off]
    8.  Following toggles are disabled
            a.  Weapons Foot Print [on/off]
```

Figure 13. Load exemplar scenario use case example. We utilized each use case as a guide for testing.

We continued this process for each use case associated with the exemplar scenario. Deficiencies or anomalies were documented, solutions were implemented, and re-testing was accomplished. Once we determined that the exemplar scenario functioned as required we began the process of building the remaining two scenarios.

The remaining two scenarios were built in the same manner as described above. Scenario specific elements were designed and built and incorporated into the game along with the common elements from the exemplar scenario. Testing was conducted utilizing the use cases associated with each scenario until all deficiencies or anomalies were identified and corrected. Once complete, the training device, GUAVA – alpha version, was ready for deployment to, and review by, research team members.

GUAVA – alpha version. The alpha version of GUAVA (Figure 14) met all scenario functionality and content requirements outlined in the use case document. As a general description, GUAVA scenarios are not static or "canned" scenarios that are played and repeated, rather, GUAVA provides the user with the flexibility to manipulate models to demonstrate and reinforce multiple concepts of UAS gunnery. GUAVA provided three scenarios – two remote and one autonomous – with associated graphics.

Figure 14. GUAVA alpha version splash screen. GUAVA was deployed and review by research team members for acceptance testing.

Research team members reviewed each scenario, (a) to verify content and functionality, and (b) to provide an initial user experience review. During the review process team members identified one additional design issue – menu item selection.

Additional design issue. The design issue discovered was menu item selection. When we observed research team members interacting with an alpha version of GUAVA we noticed that their ability to repeatedly select buttons or controls was impeded by the size of the controls and by the users shaky hands, which subsequently increased their frustration and impacted their user experience (UX). While the age of research team members was well above those of the instructor target audience, we erred on the side of caution and increased the size of the buttons. In this instance, the solution worked but reduced screen real-estate. If more functions had to be added then a separate method of interacting with the screen would need to be designed.

We needed to document any similar UX challenges with the GE instructors. Therefore, we included UX observation questions in our protocols for use when demonstrating the beta version of GUAVA to the GE Instructors.

Final acceptance testing was conducted by the research team members to ensure all content was present and all functionality worked before deployment. The final beta version was deployed to Fort Huachuca for a demonstration of proof of concept. GE subject matter experts (SMEs) were asked to interact with the training device, review the scenario content and functionality, and provide feedback.

Gray Eagle Instructor Feedback

Feedback is an essential element of application development. In this case, feedback from the GE Instructors was deemed even more essential than usual as we expected the instructors to use the training device within the GE gunnery POI as part of this effort. Therefore we structured our sessions as a demonstration of capabilities coupled with an opportunity for the instructors to validate content and provide feedback. To this end, ARI coordinated with the supervisor of the Grey Eagle Operator Training section to provide SMEs for each session. The outcome of each session was documented by members of the research team for consideration in the further development of the training device.

Participants

A combination of 17 Noncommissioned Officers (NCOs) and GE Instructors participated in the feedback sessions. Table 3 lists the participant groups and provides a compilation of their indicated level of experience in UAS operations.

Table 3

GE Instructor UAS experience

	Number of Participants	Time as an Instructor (range)	Participant Indicated Level of Experience		
			Simulated Training	Live Training	Combat
NCOs	3	2 days to 2 months	66%	33%	100%
Grey Eagle Instructors	14	1 to 12 years	79%	57%	43%

The NCOs who attended the sessions brought with them a wealth of operational experience as they were recently assigned to Fort Huachuca as GE instructors after completing a tour of duty as UAS operators and UAS Platoon Sergeants in support of ongoing combat operations. Similarly, the GE Instructors, while Department of the Army Civilians or contractors, were former Hunter, Shadow, and Gray Eagle UAS operators with experience supporting ground operations in OEF and OIF. For example, in response to the instructor questionnaire one NCO indicated that within the last year he had operated the MQ-1C as either an AO or PO on more than 58 combat missions.

Data Collection Instruments

Two data collection instruments were developed to facilitate collecting feedback – the GUAVA Observation form and the Instructor Questionnaire. The data collection instruments were developed, reviewed, and revised internally within the research team. Both forms can be found in Appendix C and D.

GUAVA observation form. This form was developed for use in a one-on-one hands-on session. The form was crafted to document the instructor's feedback regarding the utility of GUAVA for teaching GE gunnery concepts and capture any usability challenges observed during the instructor's initial interaction with the 3D environment.

GE Instructor questionnaire. This form was developed for use after the one-on-one hands-on session. The form contained two sections: the first section contained questions relating to the instructors UAS experience; the second section contained questions relating to the applications ease of use and usefulness and was based on Davis' (1989) technology acceptance model (TAM).

Data Collection Procedures

Data was collected over a 2-day timeframe. Participants were scheduled in hourly segments in order to provide instructors with as much time as possible using GUAVA before conducting a follow-on session. Data collection was conducted in two phases for each instructor. During phase one the instructor was provided an opportunity to use GUAVA, review each of the three scenarios, and provide content and functionality feedback to a research team member. During this time the research team member observed the instructor to document any issues using the 3D technology. During phase two the instructor was asked to provide information on their UAS experience and then complete the perceived ease of use and usefulness questions.

Results

Data collection results are aggregated across all participants with no single participant's responses outweighing others. 3D user experience (UX) challenges, TAM questionnaire results, and content and functionality feedback are presented below.

3D UX challenges. Previous research conduct with zSpace identified UX usability challenges such as navigating depth and rotating objects (Essex, 2016). We were interested in determining if these challenges were replicated with first time users in this research effort. To that end, a research team member observed each participant while he interacted with the system to determine if there were any challenges in two categories – physical discomfort and interaction issues.

Only one instance of physical discomfort was recorded, in this case the user complained of sore eyes and kept taking the glasses off. However, we did find similarities concerning navigating in a 3D environment. Similar to Essex's (2016) findings, some of our participants had difficulty rotating objects and navigating depth. The most common observations were centered on using a stylus to interact with the terrain and models. Participants did not intuitively realize that they could manipulate the terrain along three axes by grabbing the terrain with the stylus and twisting their wrists or zoom-in by pulling the terrain model closer to their eyes – more participants were inclined to move their heads towards the terrain model to "zoom-in". These observations resulted in prompting by the observer in order to facilitate the session.

On a separate note, most participants, to include this research team member, had difficulty grabbing small objects or selecting controls with the stylus due to shaky hands. Participants were observed using two hands to steady the stylus while selecting controls and that pressing the top button on the stylus (to activate the control) resulted in the infrared beam being pushed down off the control icon. The difficulty of manipulating small objects led to an additional design change that increased the size of the control icons[5] and added hot keys as an alternate method of selecting controls. Examples of hot keys are depicted in Figure 15, the complete list of hot keys are found in Appendix F.

Toggle On/Off	
F1	Toggle Designator Fan
F2	Toggle Optimal Zone
F3	Toggle Sub-Optimal Zone
F4	Toggle Safety Zone
F5	Toggle No Lase Zone
F6	Toggle Extended Fan
F7	Toggle Weapons Footprint
F8	Toggle Exclusion Zone
F9	Toggle Flight Path
F10	Toggle Color
F11	Toggle HUD

Figure 15. Example of GUAVA hot keys. Hot keys were added as an alternate method for selecting buttons and controls.

These UX challenges were not insurmountable. Participants were provided 30 to 45 minutes on the system and by the time the session was over most had grasped the concepts of interacting with the terrain and models and could easily navigate through the three scenarios.

TAM questionnaire feedback. Participants were asked to rate GUAVA on two measures related to the acceptance of technology – perceived usefulness and perceived ease of use. As defined in Davis (1989), perceived usefulness relates to "the degree to which a person believes that using a particular system would enhance his or her job performance" and perceived ease of use relates to "the degree to which a person believes that using a particular system would be free of effort" (p. 320). In this case, we asked the participants to complete a questionnaire that related to how useful GUAVA could be to UAS Gunnery Instructors when performing their job and how easy it was to use. The questionnaire results are provided in Tables 4 and 5.

---

[5] The size of the icons was increased after the alpha version was reviewed. This similar observation resulted in increase the size of the icons again.

Table 4
Participant responses to perceived usefulness questions

n = 17	LIKELY						UNLIKELY
	extremely	quite	slightly	neither	slightly	quite	extremely
Using GUAVA in my job would enable me to accomplish tasks more quickly.	**6** **(35.3%)**	**8** **(47.1%)**	2 (11.8%)	1 (5.9%)			
Using GUAVA would improve my job performance.	**8** **(47.1%)**	**7** **(41.2%)**	2 (11.8%)				
Using GUAVA in my job would increase my productivity.	**7** **(41.2%)**	**7** **(41.2%)**	2 (11.8%)	1 (5.9%)			
Using GUAVA would enhance my effectiveness on the job.	**8** **(47.1%)**	**5** **(29.4%)**	4 (23.5%)				
Using GUAVA would make it easier to do my job.	**8** **(47.1%)**	**4** **(23.5%)**	5 (29.4%)				
I would find GUAVA useful in my job.	**10** **(58.8%)**	**6** **(35.3%)**	1 (5.9%)				

In general, the instructors indicated that GUAVA was quite useful to extremely useful for their job as a UAS gunnery instructor with 70% (*n/N* = 12/17) or more indicating that the tool would enable them to accomplish tasks more quickly, improve their job performance, increase their productivity, and enhance their effectiveness. Similarly, 70% or more of the instructors responded that GUAVA was quite easy to extremely easy to use.

Table 5
Participant responses to perceived ease of use questions

n = 17	LIKELY						UNLIKELY
	extremely	quite	slightly	neither	slightly	quite	extremely
Learning to operate GUAVA is easy for me.	**6** **(35.3%)**	**6** **(35.3%)**	4 (23.5%)			1 (5.9%)	
I find it easy to get GUAVA to do what I want it to do.	**4** **(23.5%)**	**10** **(58.8%)**	2 (11.8%)			1 (5.9%)	
My interaction with GUAVA is clear and understandable.	**5** **(29.4%)**	**11** **(64.7%)**		1 (5.9%)			
I find GUAVA to be flexible to interact with.	**9** **(52.9%)**	**7** **(41.2%)**		1 (5.9%)			
It is easy for me to become skillful at using GUAVA.	**11** **(64.7%)**	**5** **(29.4%)**		1 (5.9%)			
I find GUAVA easy to use.	**8** **(47.1%)**	**8** **(47.1%)**				1 (5.9%)	

The initial responses to the perceived ease of use and usefulness questionnaire indicated that the instructors saw value in GUAVA as 4D GE gunnery training device.

Content and functionality feedback. Instructor content and functionality feedback resulted in the identification of 43 items that could improve GUAVA. Examples of feedback items are:

- Add HUD information,
    - Aircraft (A/C) heading
    - PO azimuth relative to A/C
    - Height above target (HAT)
    - Slant Range to target
    - Time of flight (missile)
    - Payload elevation scale
- Add moving target,
- Make it easier to select controls, and
- Add function to change flight path.

The feedback was initially sorted by frequency count to identify commonly requested items. At the second look, items were grouped into three categories by research team members to facilitate a selection/ranking process. Category one items were related to improving student learning of basic gunnery concepts, category two items were related to improving the usability of the tool, and category three items were related to advanced gunnery knowledge.

An iterative ranking process was conducted to select items for inclusion in the final version of GUAVA. Items were selected for inclusion based on the initial design parameters, that is, a tool that would augment classroom POI GE gunnery training. Therefore, most items related to advanced gunnery knowledge were eliminated in favor of items related to improving student understanding of basic gunnery concepts as taught during initial POI gunnery training, as well as items that would increase usability thereby increasing instructor confidence in their ability to use the tool to conduct training. Table 6 lists the results of the ranking process that identified 11 items for inclusion in the final version of GUAVA. A complete list of items can be found in Appendix E.

Table 6

Eleven items included in the final version of GUAVA

Priority of Work	GUAVA Feedback

1	• Add HUD information
	    o A/C heading
	    o PO azimuth relative to A/C
	    o Height above target (HAT)
	    o Slant Range to target
	    o Time of flight (missile)
	    o Payload elevation scale
	    o Payload elevation

2	• Add reset view button
3	• Show range from AWT to target • Add AWT altitude • Show AWT LTL degrees (scenario 2 only) • Show AWT GTL degrees (scenario 1 only)
4	• Change target from M1 Abrams to non-US Army vehicle
5	• Add laser occlusion (by terrain)

6	• Hot keys to
	    o change altitude (250 or 500 meter increments)
	    o Select options from menus (toggles)

7	• Allow flight path to remain flat in scenario 2 and 3
8	• Add button to disable colors of LTL and GTL
9	• Click scenario name to load scenario
10	• Change flight path color from light blue to dark blue
11	• Add degrees to designator fan

The 11 items were prioritized based on the perceived impact on student learning and the level of effort required to make the changes. The final version of GUAVA included all of the above additions.

One additional piece of feedback was provided by the instructors concerning the zView augmented reality view. Most instructors stated that transitioning from a standard view to the augmented reality view did not provide additional value as a teaching aid as it was difficult to manipulate the terrain model into a position that afforded a clear view. Figure 16 depicts a comparison of augmented vs. standard views. To this end, we determined that for the purpose of the GE gunnery instruction the instructors would not use the augmented reality view.
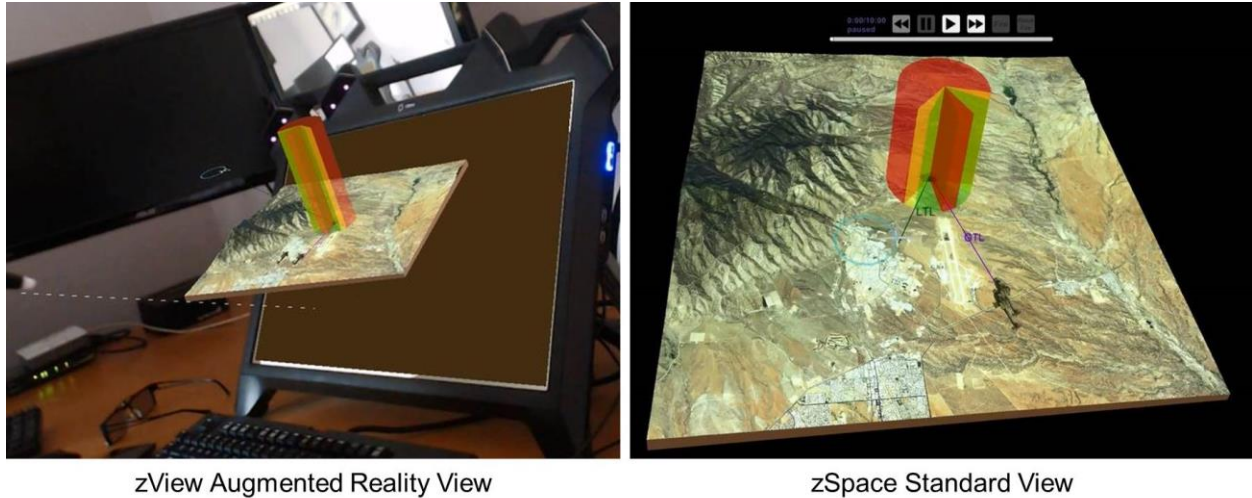
zView Augmented Reality View   zSpace Standard View

Figure 16. Comparison of augmented reality and standard views. The instructors stated that the augmented reality view did not provide additional value as a teaching aid.

The instructor feedback was essential to the development of GUAVA as a final product. Initial development was primarily focused on providing a view of the airspace and associated scenario models, the goal being to enable the instructors to discuss the geometry of offset angles and laser designation issues. However, by gaining feedback from the instructors, we identified a key piece of information was missing that could enable the students to construct a mental model of the three-dimensional space in which they operate. This information, when displayed, could enable the students to make the connection between what they see in GUAVA to information provided in the GE UAS GCS. The heads-up display (HUD) information provided in GUAVA (depicted in green text in Figure 17) is the same type of information the AO and PO see in the GCS. The HUD information provides the AO and PO with situational awareness of the UAS heading, payload offset, payload elevation, UAS altitude, and range and bearing to the target. As the instructor moves the aircraft in 3D space the HUD information changes, enabling the instructor to relate UAS positioning in the airspace to information provided in the GCS.
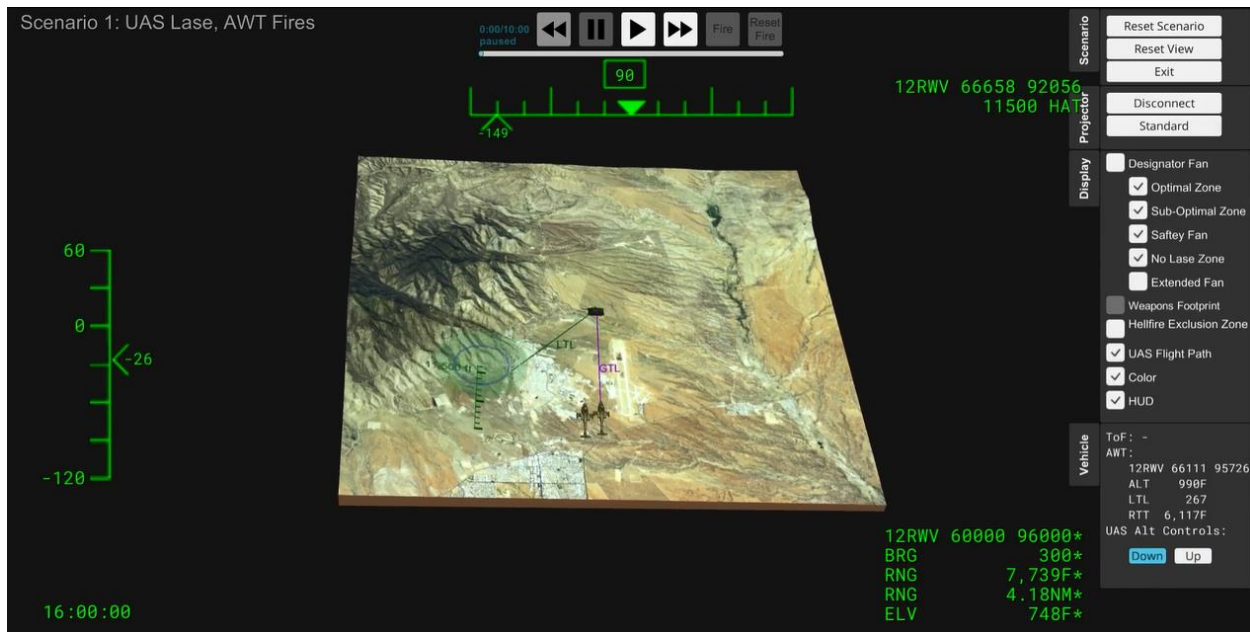
Figure 17. GUAVA HUD display. The HUD information in the final version of GUAVA could enable students to connect the images seen in GUAVA to the information provided in the GE UAS GCS.

The instructor feedback was incorporated into the final version of GUAVA. Software updates were developed, loaded, and verified before delivery of the final products.

Final Products

We provided the GE instructors with the GUAVA hardware and software, user's guide with hot key sheet, and the instructional guide. Upon delivery, our UAS SME conducted a train-the-trainer session to re-familiarize the instructors with GUAVA highlighting the updates that they had requested. The delivery of the system led to the next phase of this effort, which was determining the effectiveness of GUAVA on the GE UAS Operators understanding of gunnery concepts. The results of the training effectiveness assessment are captured in ARI research report titled: *Unmanned Aerial System (UAS) Four-Dimensional Gunnery Training Device: Training Effectiveness Assessment* (James & Miller, in press).

Discussion and Recommendations

Combat Aviation gunnery requires aircrews to have an understanding of the 3D airspace, in which they work independently or as part of a team, in order to maneuver safely, effectively employ their weapons, and survive on the battlefield. Aircrews of manned aircraft, i.e., the AH-64 Apache helicopter, have the distinct advantage of being in that space and seeing it through their cockpit windows. On the other hand, UAS operators are limited to the stovepipe view from the aircraft payload and looking outside of their ground control station does not improve airspace situational awareness. The challenge was to depict this airspace for GE UAS operators in order to help them build a mental model.

GE UAS Operators are tasked to support ground combatant commanders in the reconnaissance, surveillance, target acquisition, and direct fire roles, either autonomously (by themselves) or teamed with a manned firing platform. If called upon, they will designate a target to be shot at, or they will shoot themselves. Aircrews who have a thorough knowledge of system capabilities coupled with doctrinal employment methods and techniques can effective employ their weapons (DA, 2014a, p. 1-1). GUAVA was developed to aid instructors in communicating these methods and techniques.

The purpose of GUAVA was to provide GE instructors with a visual training device to aid in communicating UAS gunnery concepts to students. The aim of GUAVA was to supplement the GE Operator POI by either incorporating the training device within the lesson plans, or for use as a bridge between classroom and simulator training.

GUAVA provides three scenarios – two remote (UAS designating/AWT launching and UAS launching/AWT designating) and one autonomous (UAS designating and launching) – with associated models to visually depict minimum/maximum engagement ranges, offset angles, and safety zones which were identified as essential components for understanding gunnery concepts. Scenarios are flexible, that is, the instructor can set-up a typical or non-typical engagement scenario, ask the students to determine if the engagement criteria (offset angle, clearance of exclusion and safety zones, engagement ranges, etc.) have been met, and play the scenario to its endstate – hit or miss. Instructors can pause, replay, or fast forward as necessary to highlight key points.

Initial instructor feedback was positive in that GUAVA would provide a means to visually display and discuss UAS gunnery geometries as they relate to UAS doctrine minimum proficiency levels. However, the true value of a training solution is determined by the impact on student learning. To this end we coordinated for a training effectiveness assessment to be conducted with students in three GE UAS Operator training classes. The results are documented in an ARI research report titled *Unmanned Aerial System (UAS) Four-Dimensional Gunnery Training Device: Training Effectiveness Assessment* (James & Miller, in press).

Technical Recommendation

Initial technical exploration identified compatibility issues between the selected graphics card and video drivers in zSpace. The zSpace 200 and desktop configuration was selected to maximize performance. After completion of the software and looking at system load, it is recommended that the zSpace 300 all-in-one system be used in the future. While the zSpace 300 is not as performant as a desktop configuration, it is sufficient for running the GUAVA application or similar applications. The reduced form factor would make it easier to insert into limited classroom space. Additionally, no issues with hardware compatibility will arise as it is an integrated system.

Future Research

GUAVA was developed as an instructor driven training device. Initial discussions considered use as a student driven training device, however, at the time the idea was tabled as the endstate of the application was unknown at the time. Now, however, ease of use data indicates that novice users would have little difficulty manipulating the training device. As such, it is feasible that in a one-on-one or one-on-crew instructor/student environment, with the instructor providing problems and the student manipulating the scenarios and providing solutions, that student understanding of gunnery concepts and the development of mental models could be greater than in just an instructor driven environment.

Additional target audiences for future research with GUAVA are the fledging pilots and gunners of the armed weapons team (AWT). Operating in a manned unmanned teaming (MUM-T) role, pilots and gunners of the AWT have to coordinate positioning of designating or launching assets. GUAVA, albeit with minor modifications, could be used to help illustrate these processes.

References

Capri, F. (2014). UAS gunnery standardization. *Aviation Digest, 2*(3), 19-20.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319-340.

Essex, B. (2016). The UX of digital 3-D interaction. Retrieved from https://blinkux.com/blog/ux-digital-3-d-interaction/.

Department of the Army. (2014a). *Combat aviation gunnery* (TC 3-04.45). Washington D.C.: Author.

Department of the Army. (2014b). *MQ-1C unmanned aircraft system commander's aircrew training program and aircrew training manual* (TC 3-04.63). Washington, D.C.: Author.

Jacobson, I., Spence, I., & Bittner, K. (2011). Use-Case 2.0: The guide to succeeding with use cases. Retrieved from https://www.ivarjacobson.com/publications/white-papers/use-case-ebook.

Leipold, J. D. (2010) Grey Eagle weaponized UAS slated for Afghanistan. Retrieved from https://www.army.mil/article/44688/grey-eagle-weaponized-uas-slated-for-afghanistan/

U.S. Army Unmanned Aerial System Center of Excellence. (2010). *"Eyes of the Army": U.S. Army roadmap for the unmanned aircraft systems 2010-2035*. Fort Rucker, AL.

Whittle, R. (2015). Hellfire meets predator. *Air and Space Smithsonian, 29*(7) 22-27.

Acronyms and Abbreviations

2D	Two-Dimensional
3D	Three-Dimensional
4D	Four-Dimensional
A/C	Aircraft
AMD	Advanced Micro Devices
AO	Aircraft Operator
API	Application Program Interface
ARI	U.S. Army Research Institute
AWT	Armed Weapons Team
DIDEA	Detect, Identify, Decide, Engage, Assess
ERMP	Extended Range Multi-Purpose
GCS	Ground Control Station
GE	Gray Eagle
GT	Gunnery Table
GTL	Gun Target Line
GUAVA	Gunnery Unmanned Aerial Vehicle Application
HAT	Height Above Target
HUD	Heads-up Display
KSA	Knowledge Skills and Abilities
LED	Light Emitting Diode
LTL	Laser Target Line
MPLs	Minimum Proficiency Levels
NCO	Noncommissioned Officer
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
PO	Payload Operator
POI	Program of Instruction
RSTA	Reconnaissance Surveillance and Target Acquisition
SAL	Semi-active Laser
SME	Subject Matter Expert
STEM	Science, Technology, Engineering, Math

TAM	Technology Acceptance Model
UAS	Unmanned Aerial System
UI	User Interface
UX	User Experience

Appendix A

zSpace Technical Specifications

Hardware

This section lists the required hardware to setup up one UAS Gunnery Training Station

Computer

Developed on/for
- http://www.cyberpowerpc.com/system/Gamer_Scorpius_9000
- Windows 10 Home
- AMD FX-9590 Processor
- 16GB DDR3/1600MHz RAM
- AMD R9-390x 8GB Graphics Card
- Gigabyte 990FXA-UD3 R5 MB
- 2TB SATA3 7200 RPM HD

Recommended
- Windows 10 Home
- AMD FX-9590 Processor (or better, or intel equivalent)
- 16GB DDR3/1600MHz RAM (or better)
- AMD R9-390x 8GB Graphics Card **(Must be this card, compatibility with ZSpace and specific driver issues)**

The ZSpace system, below, is very specific about which video cards can be used. Additionally this requires a special driver supplied by ZSpace.

ZSpace list specific video card requirements and specific setup instructions if using a different video card.
https://support.zspace.com/hc/en-us/articles/204780645-zSpace-Supported-Graphics-Cards-GPUs-

Mouse & Keyboard

ZSpace 200

This includes:
- 1 – ZSpace 200 3D Display
- 1 – Tracked 3D Glasses
- 1 – Clip-on Tracked 3D Glasses, to be worn over corrected glasses
- 1 – Polarized Glasses, for second viewer, non-3D
- 1 – Display Port/USB Hub Cable, to connect the ZSpace to the Computer
- 1– Power Cable
- 1– Power Brick
- 1– ZSpace Stylus

ZView Hardware Kit

This is only needed if you intended to display the application on a second monitor/projector. You will also need to purchase a ZView Software Application licenses

This includes:
- 1 - Logitech C920 HD Pro Web Cam (Currently you cannot calibrate with the often shipped Microsoft LifeCam Studio due to updated drivers)
- 1 - VESA Mounting Bracket
- 4 – Screws for mounting bracket
- 1 – lock washer
- 1 – Camera Arm Adaptor, L Bracket
- 1 – Flexible Camera Arm
- 1 - Display port HDMI/DVI/VGA adaptor (only needed if your ZView source is not Display port)
- 1 - Assembly Instructions

Secondary Monitor/Projector
This can be any Monitor or Projector, currently ZView is configured to output at 1080p, (1920 x 1080)

Appendix B

UAS Gunnery Use Cases

Revisions

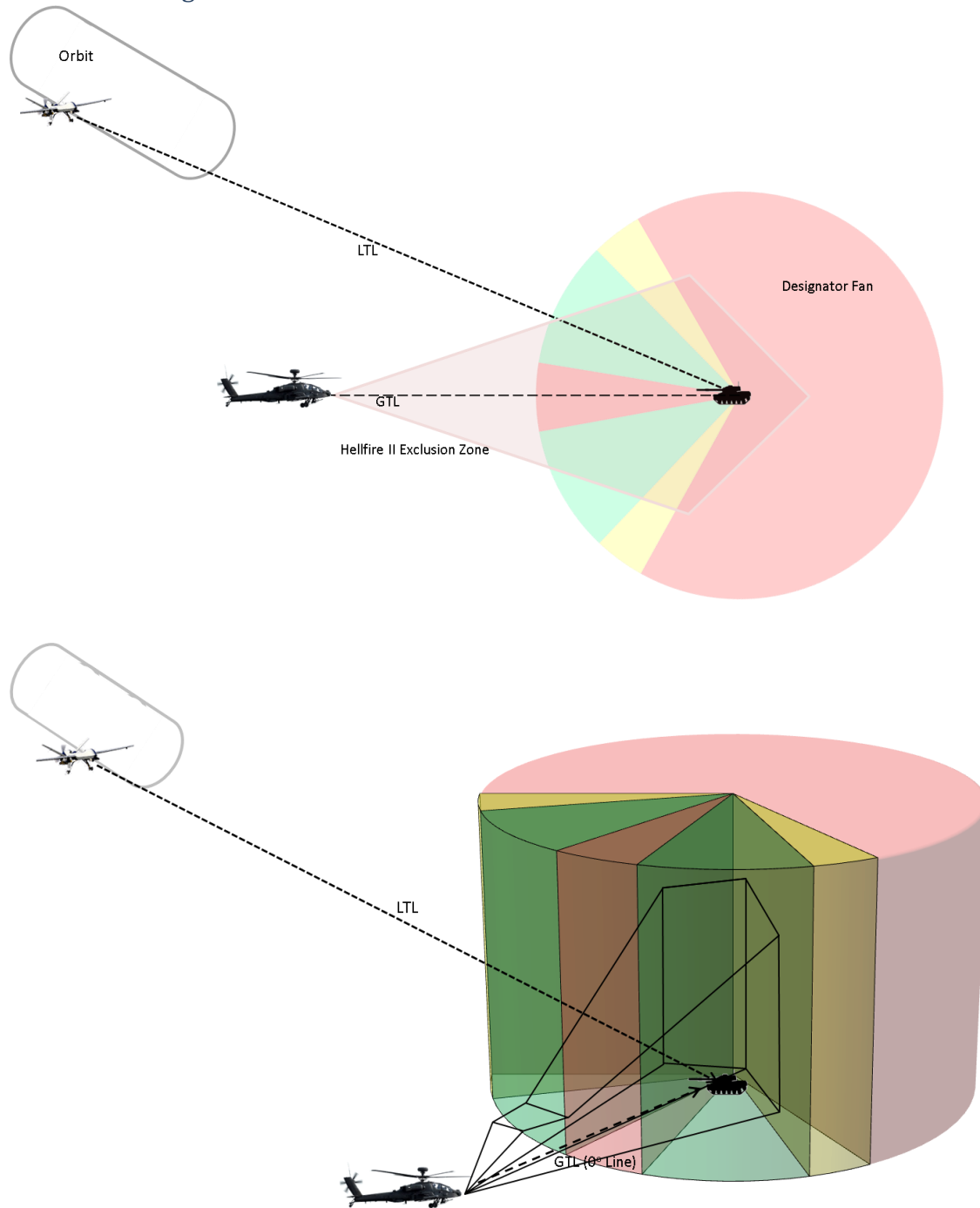| Author	Revision MM-DD-YY	Description

1 Scenario Overview and Descriptions

This section describes the scenarios and what elements are contained in them.

1.1 Scenario 1 (Remote Engagement) – UAS (Designator) AWT (Shooter)

This Scenario has the UAS designating with a laser while an AWT fires a missile.

1.1.1 Drawing

1.1.2   List of relevant elements
- UAS
- UAS LTL
- UAS Flight Path
- Designator Fan
- AWT Team (two Apaches)
- AWT GTL
- AWT Hellfire Exclusion zone
- Target

1.1.3   High level example use case
This is high level to show an example of how the tool will be used to teach the concepts. Use Case are clickable links.
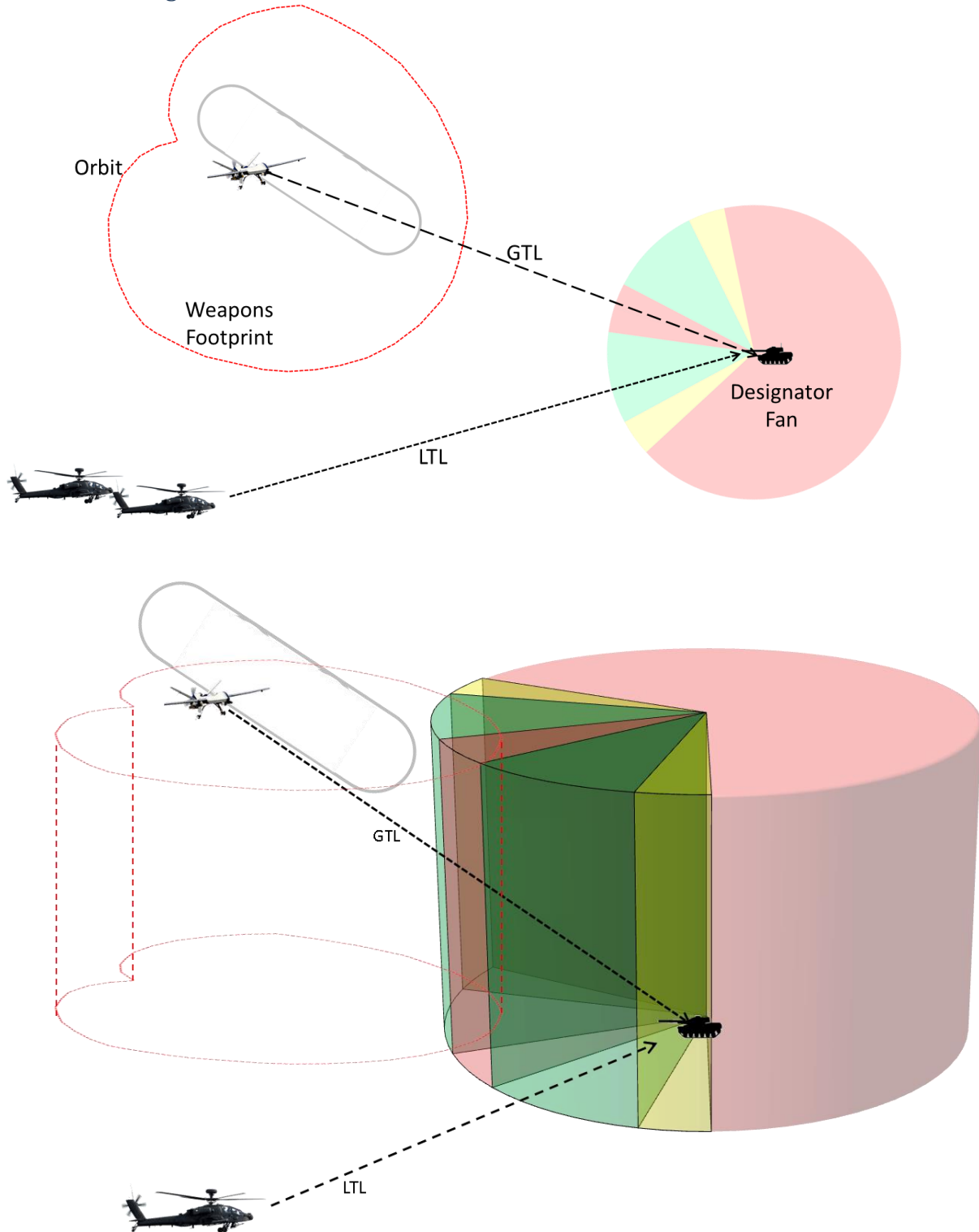
1. The instructor starts the application [Use Case 2.1.1 Start Application]
2. The Instructor selects scenario 1 from a list of three [Use Case 2.1.2 Select a Scenario]
3. The Instructor clicks load for scenario 1 [Use Case 2.1.3.2 Alternate: Scenario 1].
4. The instructor toggles-on the hellfire exclusion zone [Use Case 2.3.2 Toggle Hellfire Exclusion Zone] to show students the zone
5. The Instructor rotates the terrain [Use Case 2.3.1 Rotate Terrain] to show the zone from top-down view, side-view, and pseudo 3D-view.
6. The instructor moves the AWT [Use Case 2.2.1 Move AWT] to depict how the exclusion zone moves with the Shooter along the GTL.
7. The instructor clicks the reload button [Use Case 2.7.2 Reset Scenario Button] to return the AWT to the default position.
8. The instructor grabs the UAS and moves it into the exclusion zone [Use Case 2.2.2 Move] to depict and discuss the no fly zone concept.
9. The instructor clicks the reload button [Use Case 2.7.2 Reset Scenario Button] to return the UAS to the default position.
10. The instructor toggles-off the hellfire exclusion zone [Use Case 2.3.2 Toggle Hellfire Exclusion Zone].
11. The instructor then toggles-on the 35° Optimal (Green) portions [Use Case 2.3.6 Toggle Optimal Zones] of the designator fan to depict the best angle for lasing targets.
12. The instructor then toggles-on the 15° sub-optimal (Yellow) portions [Use Case 2.3.5 Toggle Sub-Optimal Zone] of the designator fan to discuss how and why this zone can be used to illuminate the target but is not the preferred zone.
13. The instructor toggles-on the 20° Safety Zone (Red) portion [Use Case 2.3.3 Toggle Safety Zone] of the designator fan to depict the area that should be avoided for weapons release unless the situation necessitates;
14. The instructor then toggles-on the 240° No Lase (Red) portion [Use Case 2.3.4 Toggle No Lase Zone] of the designator fan to depict the area where and why the laser will be ineffective on the target.

15. The instructor toggles-on the extended view of the designator fan [Use Case 2.3.7 Toggle Extended Designator Fan] to depict how the angles expand at distance.
16. The instructor toggles-off all designator fans [Use Case 2.3.3] [Use Case 2.3.4] [Use Case 2.3.5], except the 35º Optimal portions.
17. The instructor toggles-on the UAS orbit [Use Case 2.3.9 Toggle UAS flight path],
18. The Instructor then rotates the terrain [Use Case 2.3.1 Rotate Terrain] to show the UAS orbit within the designator fan Optimal zone.
19. The instructor toggles-off the 35º Optimal portions [Use Case 2.3.6 Toggle Optimal Zones] and extended designator fan [Use Case 2.3.7 Toggle Extended Designator Fan].
20. The instructor toggles-on the hellfire exclusion zone [Use Case 2.3.2 Toggle Hellfire Exclusion Zone]
21. The Instructor clicks the play button [Use Case 2.4.2 Play Button], the UAS moves along its orbit with the attached LTL [Use Case 2.6.8 FLY UAS on Orbit].
22. When the appropriate time is reached the Instructor clicks fire activates [Use Case 2.5.1 Fire Button], and the hellfire exclusion zone begins to fill [Use Case 2.6.4 Fill Hellfire Exclusion Zone] depicting the flight of the missile.
23. When the missile reaches terminal guidance (last 10 secs) the hellfire exclusion zone fill color changes, the instructor clicks the pause button [Use Case 2.4.1 Pause Button] and talks about laser movement on the target during the last 10 seconds of flight.
24. The instructor clicks the play button again [Use Case 2.4.2 Play Button] and the scenario continues until the missile flight path depiction reaches the target and the target is destroyed [Use Case 2.6.1 Destroy Target].
25. The instructor has the choice to rewind/fast forward/pause [Use Case 2.4 Time Controls], reload [Use Case 2.7.2 Reset Scenario Button], Reset [Use Case**Error! Reference source not found. Error! Reference source not found.**], Exit [Use Case 2.7.1 Exit Scenario], or manipulate the view [Use Cases 2.3 Change View].
26. The Instructor exits the scenario [Use Case 2.7.1 Exit Scenario].
27. The instructor returns to the scenario selections screen
28. The instructor exits the application [Use Case 2.1.4 Exit Application].

1.2 Scenario 2 (Remote Engagement) – UAS (Shooter) AWT (Designator)

This Scenario has the UAS Shooting while an AWT lases

1.2.1 Drawing

1.2.2 List of relevant elements
- UAS
- UAS GTL
- UAS Flight Path
- UAS Weapons footprint
- Designator Fan
- AWT Team (two Apaches)
- AWT LTL
- Target

1.2.3 High level example use case
This is high level to show an example of how the tool will be used to teach the concepts. Use Cases are clickable links.
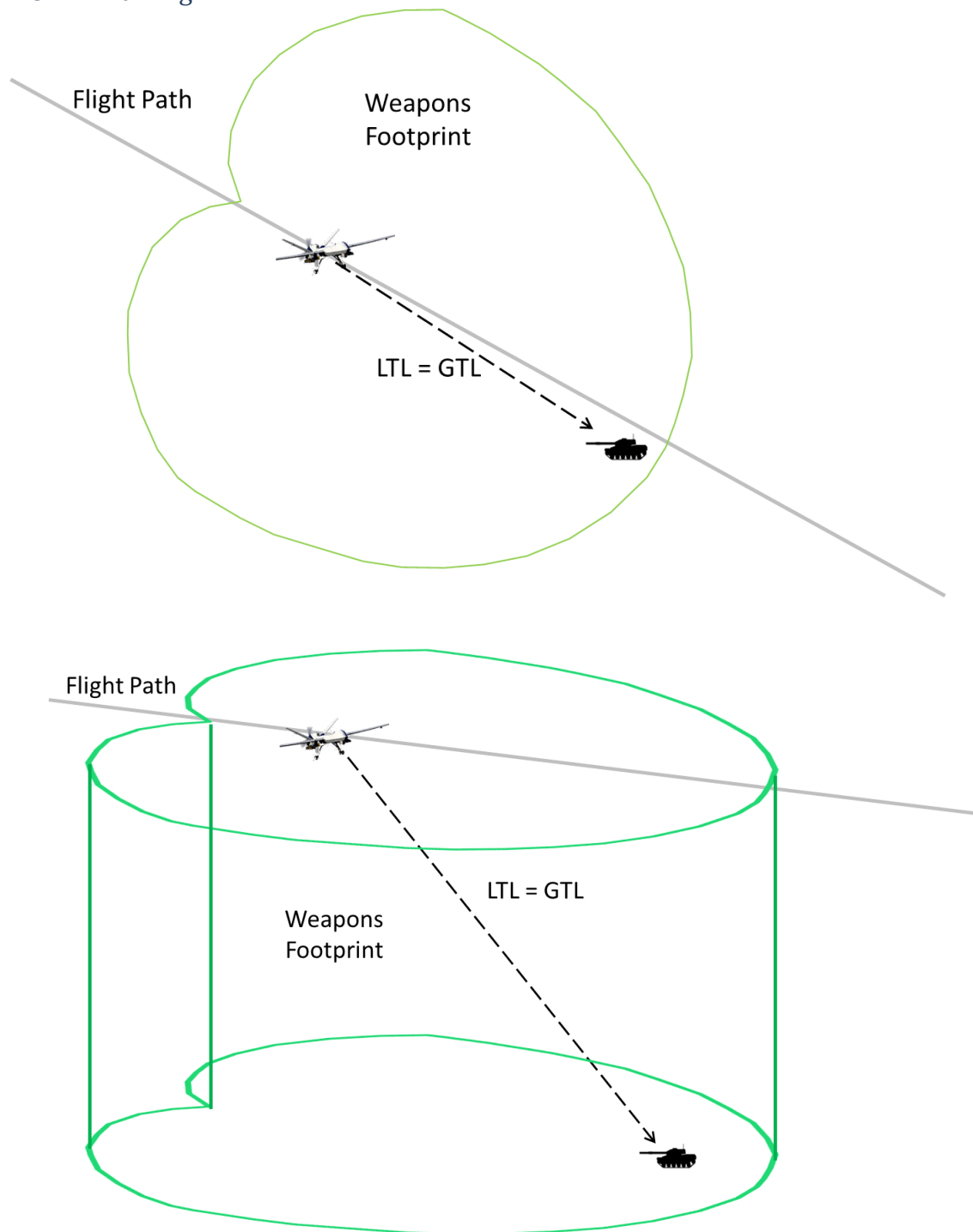
1. The instructor starts the application [Use Case 2.1.1 Start Application]
2. The instructor selects scenario 2 from a list of three [Use Case 2.1.2 Select a Scenario]
3. The instructor clicks the load button [Use Case 2.1.3.3 Alternate: Scenario 2]
4. The instructor toggles-on the UAS weapons footprint [Use Case 2.3.10 Toggle UAS Weapons Footprint] and rotates the terrain [Use Case 2.3.1 Rotate Terrain] to show the footprint from top-down view, side-view, and pseudo 3D-view.
5. The instructor moves the UAS [Use Case 2.2.2 Move] to depict how the footprint moves with the UAS.
6. The instructor clicks the reload button [Use Case 2.7.2 Reset Scenario Button] to return the UAS to the default position.
7. The instructor grabs the AWT and moves it to depict how the LTL moves with the AWT [Use Case 2.2.1 Move AWT]
8. The instructor clicks the reload button [Use Case 2.7.2 Reset Scenario Button] to return the AWT to the default position.
9. The instructor toggles-off the weapons footprint [Use Case 2.3.10 Toggle UAS Weapons Footprint].
10. The instructor then toggles-on the 35° Optimal (Green) portions [Use Case 2.3.6 Toggle Optimal Zones] of the designator fan to depict the best angle for lasing targets.
11. The instructor then toggles-on the 15° sub-optimal (Yellow) portions [Use Case 2.3.5 Toggle Sub-Optimal Zone] of the designator fan to discuss how and why this zone can be used to illuminate the target but is not the preferred zone.
12. The instructor toggles-on the 20° Safety Zone (Red) portion [Use Case 2.3.3 Toggle Safety Zone] of the designator fan to depict the area that should be avoided for weapons release unless the situation necessitates;
13. The instructor then toggles-on the 240° No Lase (Red) portion [Use Case 2.3.4 Toggle No Lase Zone] of the designator fan to depict the area where and why the laser will be ineffective on the target.
14. The instructor toggles-on the extended view of the designator fan [Use Case 2.3.7 Toggle Extended Designator Fan] to depict how the angles expand at distance.

15. The instructor toggles-off all designator fans [Use Case 2.3.3] [Use Case 2.3.4] [Use Case 2.3.5], except the 35º Optimal portions.
16. The Instructor then rotates the terrain [Use Case 2.3.1 Rotate Terrain] to show the designator fan and AWT location within the Optimal zone.
17. The instructor toggles-off the 35º Optimal portions [Use Case 2.3.6 Toggle Optimal Zones] and the extended designator fan [Use Case 2.3.7 Toggle Extended Designator Fan].
18. The instructor toggles-on the weapons footprint [Use Case 2.3.10 Toggle UAS Weapons Footprint]
19. The instructor clicks the play scenario button [Use Case 2.4.2 Play Button]
20. The UAS moves along its orbit with the attached GTL and weapons footprint [Use Case 2.6.8 FLY UAS on Orbit].
21. The UAS weapons footprint moves over the target the footprint changes from red to green [Use Case 2.6.5 Change Weapons Footprint Color] indicating the target is within range and location for the UAS to engage.
22. The Instructor decides the appropriate distance from target is reached the Instructor clicks the fire button fire [Use Case 2.5.1 Fire Button]
23. The hellfire flight path [Use Case 2.6.6 Simulate Hellfire Flight Path] is depicted until impact on the target.
24. The target is destroyed [Use Case 2.6.1 Destroy Target].
25. The instructor has the choice to rewind/fast forward/pause [Use Case 2.4 Time Controls], reload [Use Case 2.7.2 Reset Scenario Button], Reset [Use Case**Error! Reference source not found. Error! Reference source not found.**], Exit [Use Case 2.7.1 Exit Scenario], or manipulate the view [Use Cases 2.3 Change View].
26. The Instructor exits the scenario [Use Case 2.7.1 Exit Scenario].
27. The instructor returns to the scenario selections screen
28. The instructor exits the application [Use Case 2.1.4 Exit Application].

1.3 Scenario 3 (Autonomous Engagement [Inline and Offset]) – UAS (Designator/Shooter)

This scenario depicts the UAS designating and shooting the target in either an inline or offset engagement.

1.3.1 Drawing

Flight Path

Weapons Footprint

LTL = GTL

Flight Path

LTL = GTL

Weapons Footprint

1.3.2 List of relevant elements
- UAS
- UAS LTL/GTL
- UAS Weapons footprint
- UAS Flight Path
- Target

1.3.3 High level example use case

This is high level to show an example of how the tool will be used to teach the concepts. Use Cases are clickable links

1. The instructor starts the application [Use Case 2.1.1 Start Application]
2. The instructor selects scenario 2 from a list of three [Use Case 2.1.2 Select a Scenario]
3. The instructor clicks the load button [Use Case 2.1.3.3 Alternate: Scenario 2]
4. The instructor toggles-on the UAS weapons footprint [Use Case 2.3.10 Toggle UAS Weapons Footprint] and rotates the terrain [Use Case 2.3.1 Rotate Terrain] to show the footprint from top-down view, side-view, and pseudo 3D-view.
5. The instructor moves the UAS [Use Case 2.2.2 Move] to depict how the footprint moves with the UAS.
6. The instructor grabs the UAS and changes the altitude [Use Case 2.2.2 Move] to depict how the weapons footprint resizes.
7. The instructor clicks the reload button [Use Case 2.7.2 Reset Scenario Button] to return the UAS to the default position.
8. The instructor clicks the play button [Use Case 2.4.2 Play Button] and the UAS moves along the designated flight path [Use Case 2.6.7 FLY UAS on straight path] with the weapons footprint adjusting to the direction of travel.
9. The instructor clicks the pause button [Use Case 2.4.1 Pause Button] to discuss inline engagements.
10. The instructor clicks the play button [Use Case 2.4.2 Play Button] to resume the scenario
11. The UAS moves towards the target, the weapons footprint changes from red to green [Use Case 2.6.5 Change Weapons Footprint Color]
12. When the weapons footprint moves over the target and the instructor clicks the fire button [Use Case 2.5.1 Fire Button]
13. The missile flight path is depicted [Use Case 2.6.6 Simulate Hellfire Flight Path] until impact on target [Use Case 2.6.1 Destroy Target].
14. The instructor resets the scenario defaults by clicking the reload button [Use Case 2.7.2 Reset Scenario Button]
15. The instructor moves the target [Use Case 2.2.4 Move Target] to a position on a line greater than 10° from the flight path.
16. The instructor clicks the play button [Use Case 2.4.2 Play Button] and the UAS moves along the designated flight path [Use Case 2.6.7 FLY UAS on straight path] with the weapons footprint adjusting to the direction of travel.
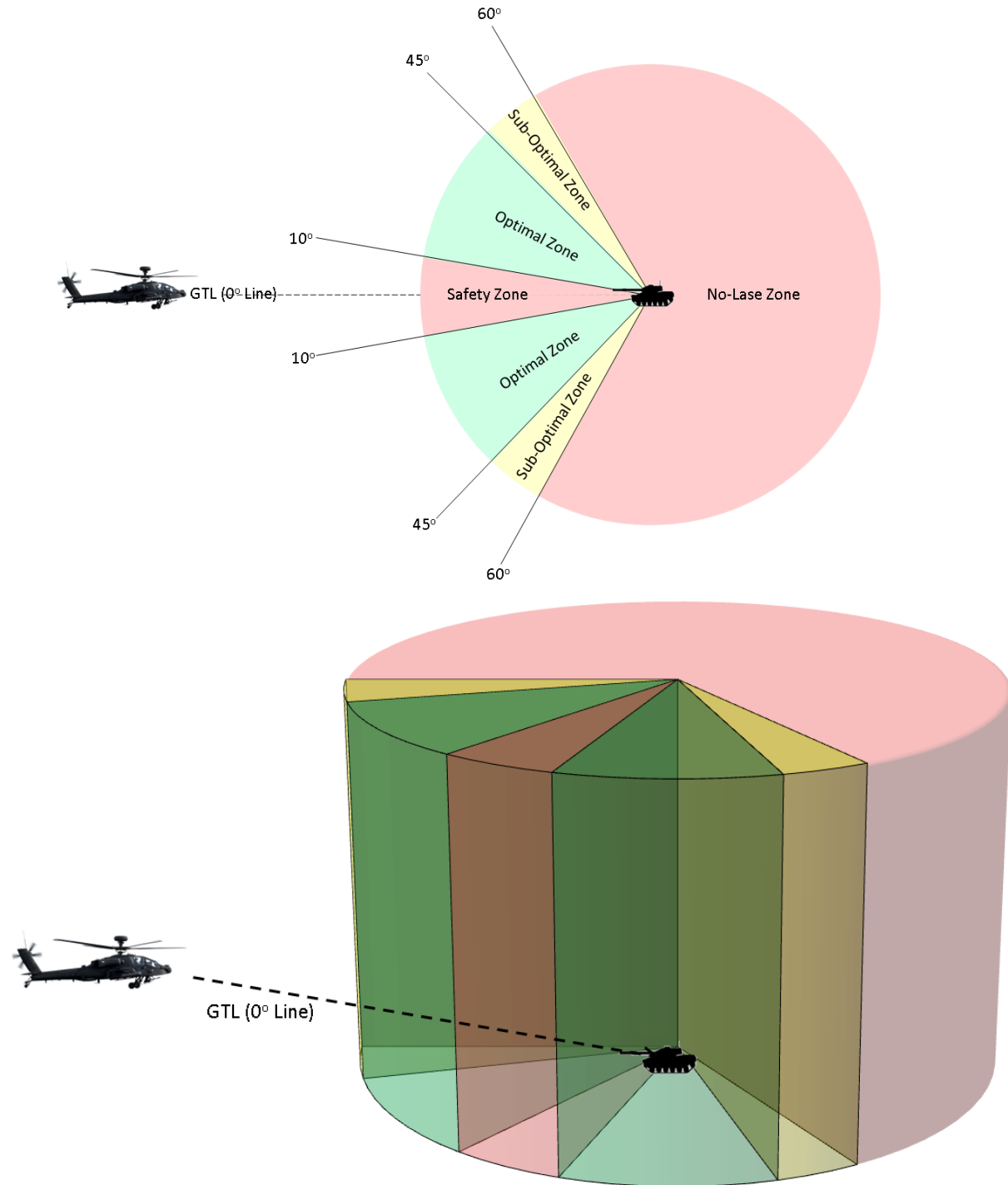
17. The instructor clicks the pause button [Use Case 2.4.1 Pause Button] to discuss offset engagements.
18. The instructor clicks the play button [Use Case 2.4.2 Play Button] to resume the scenario
19. The UAS moves towards the target, the weapons footprint changes from red to green [Use Case 2.6.5 Change Weapons Footprint Color]
20. When the weapons footprint moves over the target and the instructor clicks the fire button [Use Case 2.5.1 Fire Button]
21. The missile flight path is depicted [Use Case 2.6.6 Simulate Hellfire Flight Path] until impact on target [Use Case 2.6.1 Destroy Target].
22. The instructor has the choice to rewind/fast forward/pause [Use Case 2.4 Time Controls], reload [Use Case 2.7.2 Reset Scenario Button], Reset [Use Case**Error! Reference source not found. Error! Reference source not found.**], Exit [Use Case 2.7.1 Exit Scenario], or manipulate the view [Use Cases 2.3 Change View].
23. The Instructor exits the scenario [Use Case 2.7.1 Exit Scenario].
24. The instructor returns to the scenario selections screen
25. The instructor exits the application [Use Case 2.1.4 Exit Application].
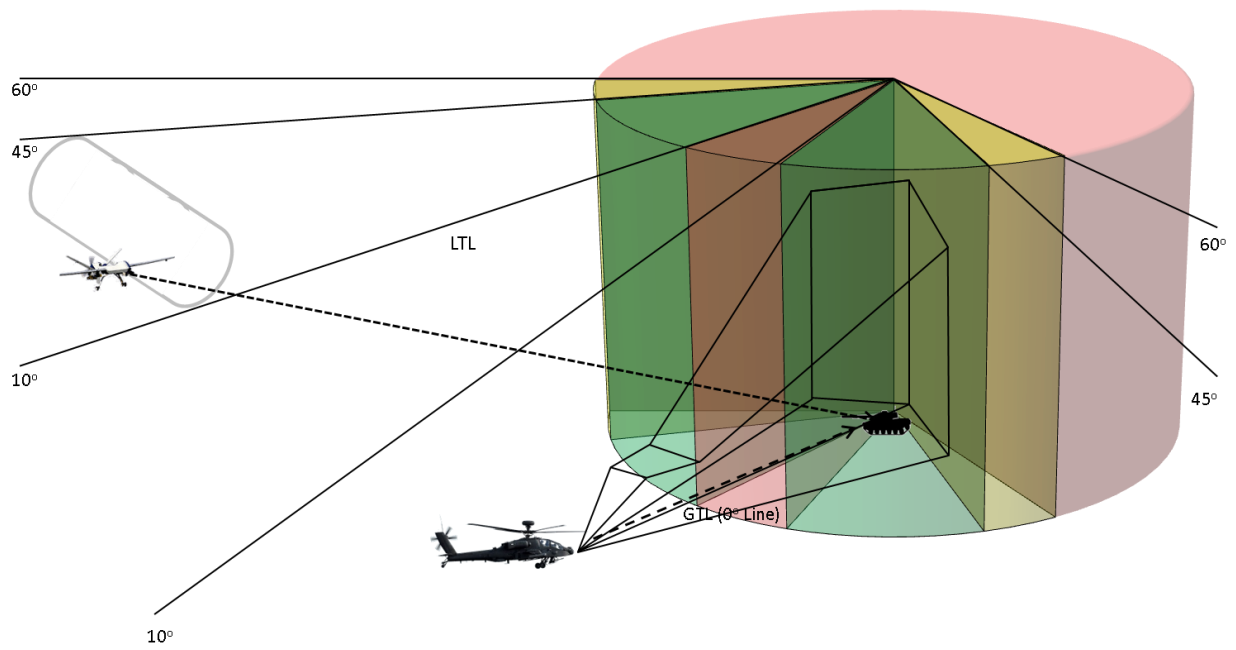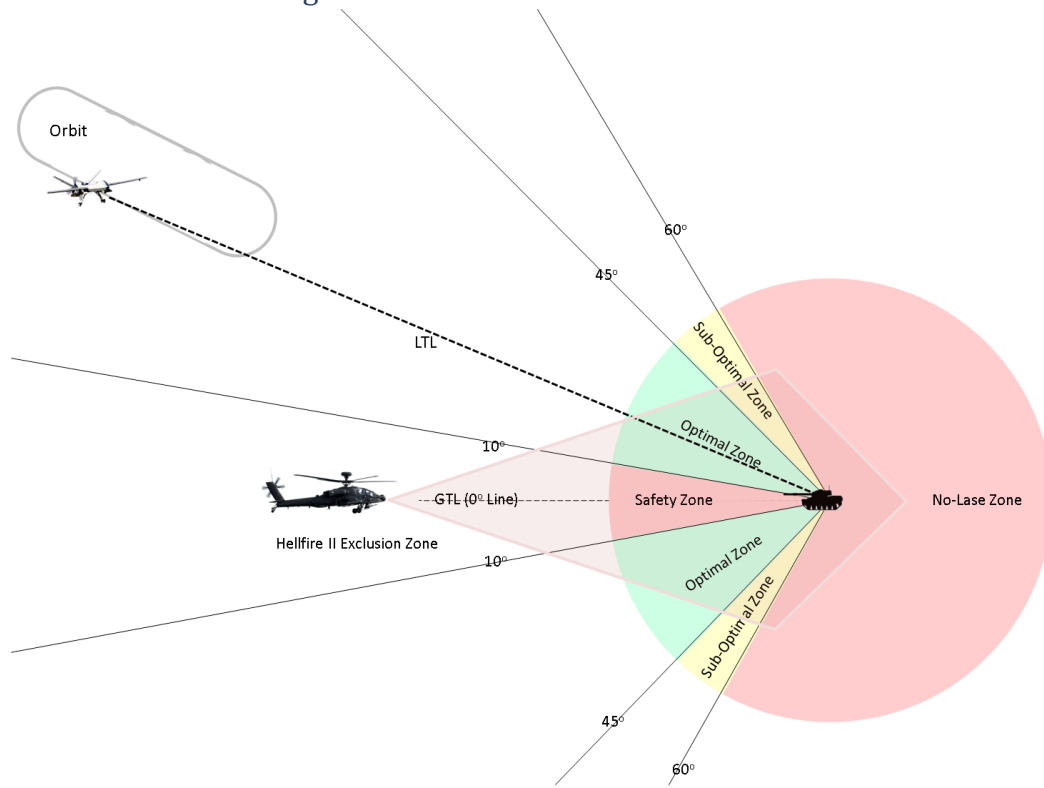
1.4 Scenario Graphics Dimensions

1.4.1 Designator Fan
4Km diameter
6Km height

1.4.2 Extended Designator Fan

Orbit

60°

45°

Sub-Optimal Zone

LTL

Optimal Zone

10°

GTL (0° Line)

Safety Zone

No-Lase Zone

Hellfire II Exclusion Zone

10°

Optimal Zone

Sub-Optimal Zone

45°

60°

60°

45°

LTL

10°

60°

GTL (0° Line)

45°

10°

B-16
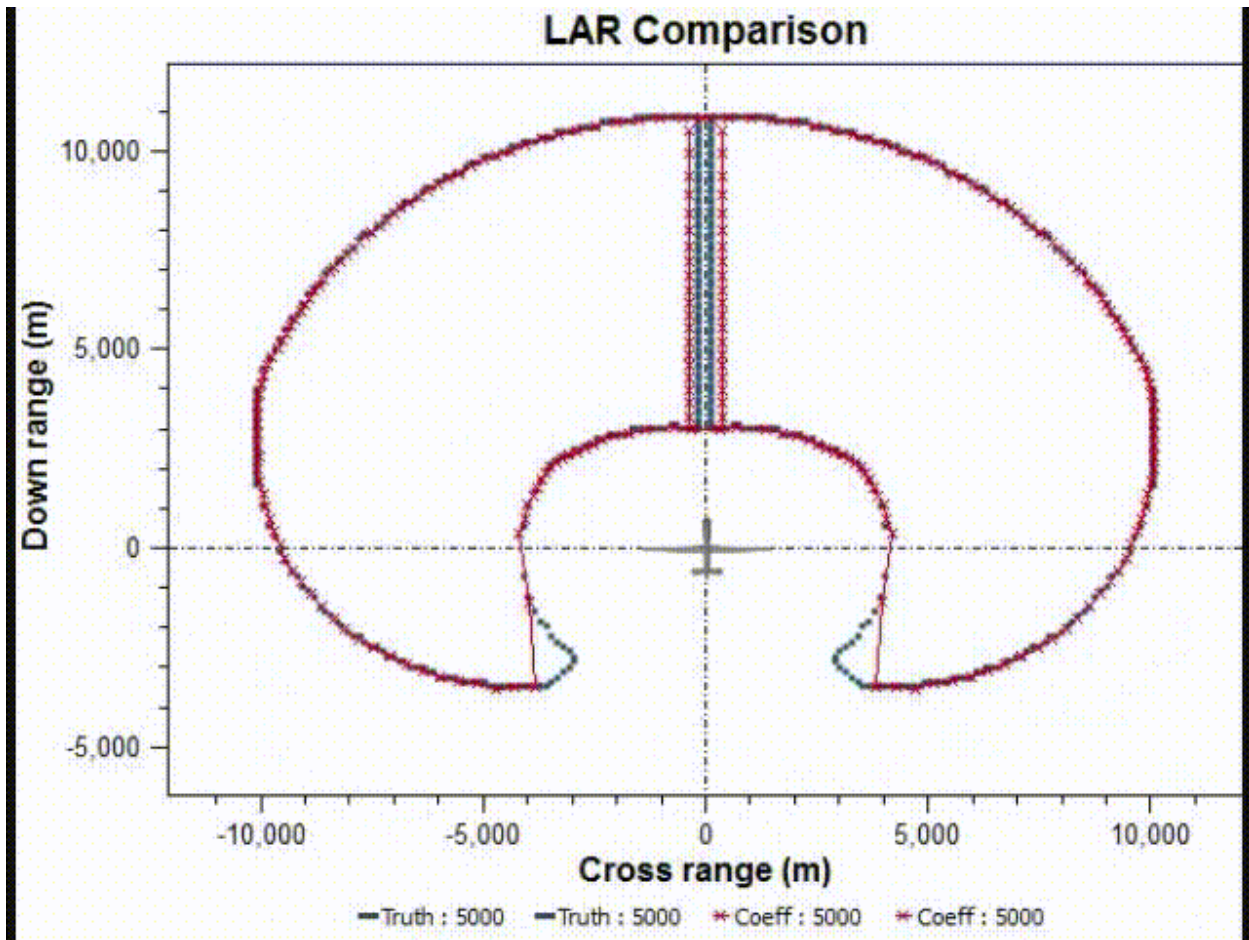
1.4.3   Hellfire Exclusion Zone
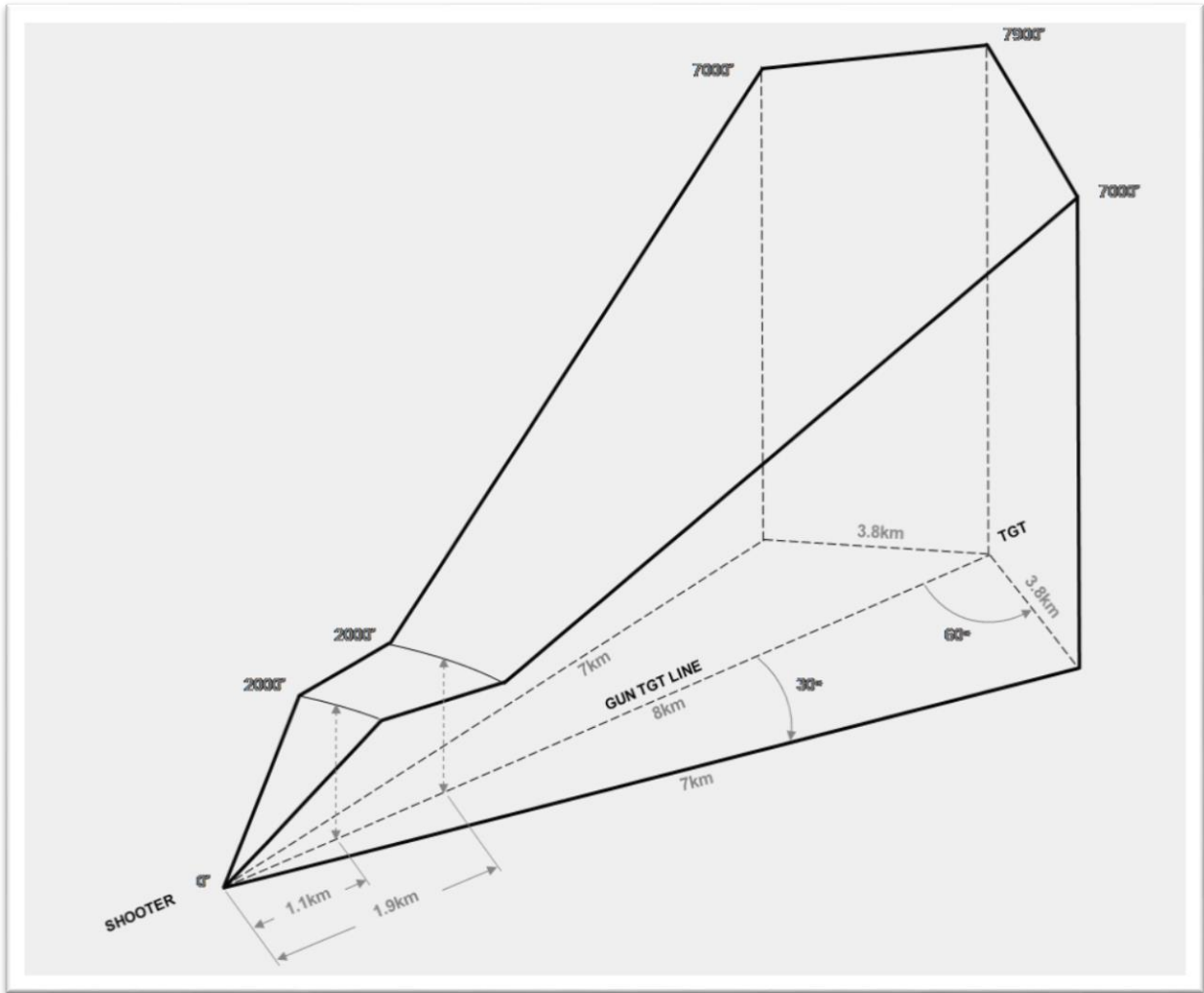
1.4.4 UAS Weapons Footprint

Direct Mode only. Below is an animated GIF showing how the weapons ground footprint changes based on UAS altitude, AGL.

1.4.5 Example of the Option Menu

- UAS/AWT Graphics
  - o Weapons Foot Print [on/off]
  - o Hellfire Exclusion Zone [on/off]
  - o UAS Flight Path [on/off]
- Designator Fan
  - o 20 degree Safety Fan [on/off]
  - o No Lase Zone [on/off]
  - o 15 Degree Sub-Optimal Zone [on/off]
  - o 35 Degree Optimal Zone [on/off]
  - o Extended Zones [on/off]
- Scenario Buttons
  - o Exit
  - o Pause
  - o Play
  - o Fast Forward
  - o Rewind (Will this be supported major design impact)
  - o Reset
  - o Reload
  - o Fire Hellfire

1.4.6 Example Timeline

This is an example to show the elements conceptually
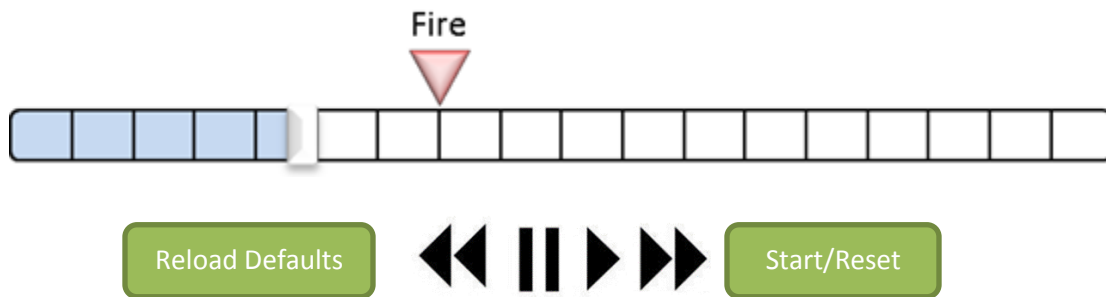
1.4.7 Example Select a Scenario Graphic

Select a Scenario

Scenario 1 – A remote engagement in which the UAS is designating a tank target for the AWT to fire upon

LOAD

Scenario 2 – A remote engagement in which the AWT is designating a tank target for the UAS to fire upon

LOAD

Scenario 3 – An autonomous engagement in which the UAS designates and fires upon a tank target

LOAD

2   Use Cases

2.1   Main Screen

These use cases are all related to the main screen, scenario selection. Starting the application is included here as well

2.1.1   Start Application
2.1.1.1   Base Case
Trigger: User Initiated

Description: The sunny day starting application

Preconditions: Machine is logged in

1. User Double clicks the app icon
2. The App starts up showing a loading screen
3. App presents user with a list of available scenarios

2.1.2   Select a Scenario
2.1.2.1   Base Case
Trigger: User Initiated

Description: The sunny day starting application

Preconditions: Use Case 2.1.1 Start Application completed

1. User is presented with 3 scenarios
2. App shows a titles of 3 Scenarios
3. User selects a scenario and a dialog is shown with a description and a LOAD button
4. User Clicks the LOAD Button for Scenario the desired scenario

2.1.3   Start Scenario
2.1.3.1   Base Case
Trigger: Application Initiated

Description: Selected scenario from Use Case 2.2 loads

Preconditions: User selected Scenario 1 from Select a Scenario

1. Show terrain, non-specific some topography
2. Show toggles on computer screen
3. Option Menu buttons are in "OFF"
4. Exit button is active , Reset Scenario button is disabled
5. Show Timeline on computer screen

6. Play button is enabled when paused
7. Pause button is disabled when paused
8. Fire button is in disabled
9. Reset Fire button is in disabled

2.1.3.2   Alternate: Scenario 1

Trigger: User Initiated

Description: Load Scenario UAS designates and AWT Fires

Preconditions: Scenario 1 loaded

1. Continue from Base Case
2. Show UAS at 18k feet AGL, 8km from target, Gray Eagle model, in green zone of designator fan, in an circular orbit
3. Show Apache pair (AWT) 100 feet AGL, 6km from target
4. Show Target (tank) on the ground, with no occluding terrain
5. Show LTL as a labeled line anchored at nose of UAS and anchored on Target
6. Show GTL as a labeled line anchored on nose of lead AWT Apache and anchored on Target
7. Following toggles are visible and off
   a. Hellfire Exclusion Zone [on/off]
   b. UAS Flight Path [on/off]
   c. Designator fan [on/off]
        i. 20 degree Safety Fan [on]
        ii. No Lase Zone [on]
        iii. 15 Degree Sub-Optimal Zone [on]
        iv. 35 Degree Optimal Zone [on]
        v. Extended Zones [off]
8. Following toggles are disabled
   a. Weapons Foot Print [on/off]

2.1.3.3   Alternate: Scenario 2

Trigger: Application Initiated

Description: Load Scenario UAS fire and AWT designates

Preconditions: Use Case 2.2 Start Scenario completed

1. Continue from Base Case
2. Show UAS at 18k feet AGL, 8km from target, Gray Eagle model, in green zone of designator fan, in an straight line path
3. Show Apache pair (AWT) 100 feet AGL, 6km from target

4. Show Target (tank) on the ground, with no occluding terrain
5. Show LTL as a labeled line anchored on nose of lead AWT Apache and anchored on Target
6. Show GTL as a labeled line anchored on nose of UAS and anchored on Target
7. Following toggles are visible and off
    a. Weapons Foot Print [on/off]
    b. UAS Flight Path [on/off]
    c. Designator fan [on/off]
        i. 20 degree Safety Fan [on]
        ii. No Lase Zone [on]
        iii. 15 Degree Sub-Optimal Zone [on]
        iv. 35 Degree Optimal Zone [on]
        v. Extended Zones [off]
8. Following toggles are disabled
    a. Hellfire Exclusion Zone [on/off]

2.1.3.4   Alternate: Start Scenario 3

Trigger: Application Initiated

Description: UAS Fires and Designates

Preconditions: Use Case 2.2 Start Scenario completed

1. Continue from Base Case
2. Show terrain, non-specific some topography
3. Show UAS at 13k feet AGL, 10km from target, Gray Eagle model, on straight flight path
4. Show Target (tank) on the ground, with no occluding terrain, outside of UAS Weapons Footprint boundary
5. Show LTL/GTL as a labeled line anchored at nose of UAS and anchored on Target
6. Following toggles are visible and off
    a. Weapons Foot Print [on/off]
    b. UAS Flight Path [on/off]
7. Following toggles are disabled
    a. Designator fan [on/off]
        i. 20 degree Safety Fan [on]
        ii. No Lase Zone [on]
        iii. 15 Degree Sub-Optimal Zone [on]
        iv. 35 Degree Optimal Zone [on]
        v. Extended Zones [off]
    b. Hellfire Exclusion Zone [on/off]

2.1.4   Exit Application

2.1.4.1   Base Case

Trigger: User Initiated

Description: The user exits the application

Preconditions: Use Case 2.1.1 Start Application completed at scenario Selection screen

1. User clicks exit
2. Application prompts the user if they are sure yes/no
3. User selects yes
4. Application exits

2.1.4.2   Alternate: Do Not Exit

Trigger: User Initiated

Description: User decides not to exit

Preconditions: Use Case 2.1.1 Start Application completed, at scenario Selection screen

1. User clicks exit
2. Application prompts the user if they are sure yes/no
3. User selects No
4. Application continues from Scenario Selection

2.2   Movement

These are use cases that move the target flight paths or the AWT team.

2.2.1   Move AWT

2.2.1.1   Base Case

Trigger: User Initiated

Description: The user grabs the AWT with the stylus and moves the AWT and anchored GTL and Hellfire Exclusion Zone along horizontal and vertical axes

Preconditions: Use Case Select Scenario completed

1. User grabs the AWT with the stylus
2. Reset Fire Use Case
3. User moves AWT a fixed height above the terrain
4. AWT rotates to remain facing target
5. AWT pair remain together
6. Reset Scenario button is enabled, since initial state has now changed
7. Associated elements update with AWT (see alternate courses)
8. User releases the AWT

2.2.1.2　Alternate: AWT is the Shooter, Scenario 1

Trigger: User Initiated

Description: The user cannot move the AWT and attached GTL and Hellfire Exclusion Zone on any axis with the stylus

Preconditions: Use Case Select Scenario 1 completed

1. Continue from Base Case step (Associated elements update with AWT)
2. GTL remains anchored to the Target and AWT
3. Anchored Hellfire Exclusion Zone
4. Hellfire Exclusion Zone remains centered longitudinally on the GTL
5. Continue to Base Case

2.2.1.3　Alternate: AWT is Designator, Scenario 2

Trigger: User Initiated

Description: The user moves the AWT and attached LTL on any axis with the stylus

Preconditions: Use Case Select Scenario 2 completed

1. Continue from Base Case step (Associated elements update with AWT)
2. LTL remains anchored to the Target and AWT
3. Continue to Base Case

2.2.1.4　Alternate: Move AWT off of terrain

Trigger: User Initiated

Description: The user tries to move the AWT outside of the terrain

Preconditions: Use Case Select Scenario completed

1. User grabs the AWT with the stylus
2. User moves AWT beyond terrain
3. AWT Does not move beyond terrain
4. AWT rotates to remain facing target
5. Reset button is enabled, since initial state has now changed
6. Associated elements update with AWT (see alternate courses)
7. User releases the AWT

2.2.2　Move Circular Orbit

2.2.2.1　Base Case

Trigger: User Initiated

Description: The user grabs the Orbit and moves it

Preconditions: Scenario is loaded

1. User grabs the Orbit with the stylus
2. Reset Fire Use Case
3. ALT line is shown indicating the Orbits current altitide
4. User moves the Orbit in 3D Space
5. UAS Remains attached to the orbit path
6. Reset Scenario button is enabled, to indicate a change to the default scenario has occurred
7. Orbit location follows stylus
8. UAS associated graphical elements move along with it (see alternate courses)
9. User releases the Orbit
10. Orbit remains at released location

2.2.2.2   Alternate: UAS has LTL (Scenario 1)
Trigger: User Initiated

Description: User moves Orbit, UAS with a LTL

Preconditions: Scenario is loaded

1. Continuing from - UAS associated graphical elements move along with it (see alternate courses)
2. LTL updates to remain from the UAS to the target

2.2.2.3   Alternate: UAS has Weapons Foot Print (Scenario 2)
Trigger: User Initiated

Description: User moves the UAS with a weapons footprint

Preconditions: Scenario is loaded

1. Continuing from - UAS associated graphical elements move along with it (see alternate courses)
2. UAS Weapons footprint move with UAS
3. UAS Weapons footprint adjusts size and shape with altitude
4. UAS Weapons footprint shape goes to the terrain, and stop at the UAS altitude

2.2.2.4   Alternate: UAS has GTL (Scenario 2, 3)
Trigger: User Initiated

Description: User moves the Orbit, UAS with a GTL

Preconditions: Scenario is loaded

1. Continuing from - UAS associated graphical elements move along with it (see alternate courses)
2. UAS moves along with Orbit
3. GTL updates to remain from the UAS to the target

2.2.2.5   Alternate: Move UAS below minimum altitude

Trigger: User Initiated

Description: The user tries to move the Orbit below the minimum altitude

Preconditions: Use Case Select Scenario completed

1. User grabs the Orbit with the stylus
2. User moves Orbit in 3D Space,
3. Orbit position is kept a minimum distance above terrain
4. Orbit and associated elements move same as other cases but limited to above terrain

2.2.2.6   Alternate: Move UAS below Terrain

Trigger: User Initiated

Description: The user tries to move the Orbit above maximum altitude

Preconditions: Use Case Select Scenario completed

1. User grabs the Orbit with the stylus
2. User moves Orbit in 3D Space,
3. Orbit position is restricted from moving a maximum distance from the terrain
4. Orbit and associated elements move same as other cases but by altitude

2.2.2.7   Alternate: Move UAS off of Terrain

Trigger: User Initiated

Description: The user tries to move the UAS off of terrain boundaries

Preconditions: Use Case Select Scenario completed

1. User grabs the Orbit with the stylus
2. User moves Orbit in 3D Space,
3. Orbit position is prevented from moving beyond the terrain boundaries
4. Orbit and associated elements move same as other cases but limited with the UAS position within terrain boundaries

2.2.3   Move Straight Flight Path

2.2.3.1   Base Case

Trigger: User Initiated

Description: The user grabs the an Endpoint of the flight path vertical axes

Preconditions: Scenario is loaded

1. User grabs one end of the flight path with the stylus
2. Reset Fire Use Case
3. Reset UAS to the beginning of the flight path
4. ALT line is shown indicating the points current altitude
5. User moves the Flight path in 3D Space
6. UAS Remains attached to the path
7. Reset Scenario button is enabled, to indicate a change to the default scenario has occurred
8. Flight Path point follows stylus
9. Flight Path stays connected between the moving point and the stationary point
10. UAS associated graphical elements move along with it (see alternate courses, of Orbit Path)
11. User releases the Point
12. Point remains at released location
13. Points are restricted like the UAS orbit to an altitude range

2.2.4   Move Target

2.2.4.1   Base Case

Trigger: User Initiated

Description: The user grabs the target and moves it on top of the terrain

Preconditions: Use Case Select Scenario 3 completed

1. User grabs the target with the stylus
2. Reset Fire Use Case
3. User moves the target, target stays "on terrain"
4. Reset Button is enabled indicating that the setup has changed from the default scenario
5. LTL and GTL lines are updated to stay with the target
6. User releases the target
7. Target remains at released location

2.2.4.2   Alternate: Move Target out of bounds

Trigger: User Initiated

Description: The user tries to move the target below the terrain

Preconditions: Scenario loaded

1. User grabs the Target with the stylus
2. User moves the target, target stays "on terrain"
3. Reset Button is enabled indicating that the setup has changed from the default scenario
4. LTL and GTL lines are updated to stay with the target
5. User continues to move the target out of the target allowable area, a rectangular region specific for each mission where the target can be moved
6. Target cannot be moved passes that point
7. Text or other indicator indicates you cannot move the target beyond this point

2.2.5   Reset Fire

2.2.5.1   Base Case

Trigger: On Button Click or whenever an object is moved

Description: The missile in flight is stopped and reset

Preconditions: Missile was fired

1. Fire and detonation event are removed from the Timeline
2. Missile Flight path is no longer visible
3. Missile is no longer visible
4. Exclusion zone is no longer visible
5. Target is not destroyed
6. Target is not on fire
7. Reset Fire Button is disabled

2.3   Change View

All of these use cases modify the view the user is seeing, these can be changed during setup, or during play. Resetting does not affect these settings.

2.3.1   Rotate Terrain

2.3.1.1   Base Case

Trigger: User Initiated

Description: User grabs terrain and rotates on 3 axes

Preconditions: Use Case 2.2 Select Scenario completed, Use Cases 2.3, 2.4, 2.5 completed

1. User grabs terrain with stylus
2. User rotates terrain in 3D space

2.3.2　Toggle Hellfire Exclusion Zone

2.3.2.1　Base Case

Trigger: User Initiated

Description: The user toggles-on the hellfire exclusion zone

Preconditions: Scenario is loaded, Hellfire Toggle is enabled, Hellfire Toggle is OFF

1. User clicks on hellfire exclusion zone button with the stylus
2. Hellfire exclusion zone button changes to indicate it is currently ON (eg color, text, other)
3. Hellfire exclusion zone becomes visible in 3D space
4. Hellfire exclusion zone is centered longitudinally along the GTL
5. Hellfire exclusion zone is anchored to the nose of the launching platform

2.3.2.2　Alternate: Toggle-off Hellfire Exclusion Zone

Trigger: User Initiated

Description: The user toggles-off the hellfire exclusion zone

Preconditions: Scenario is loaded, Hellfire Toggle is enabled, Hellfire Toggle is ON

1. User clicks on hellfire exclusion zone button with the stylus
2. button changes to indicate it is currently Off (eg color, text, other)
3. Hellfire exclusion zone becomes invisible in 3D space

2.3.3　Toggle Safety Zone

2.3.3.1　Base Case

Trigger: User Initiated

Description: The user toggles-on Safety zone portion of the designator fan

Preconditions: Scenario is loaded, Safety Zone Toggle is enabled, Safety Zone Toggle is OFF

1. User clicks on safety zone button with the stylus
2. Safety zone button changes to indicate it is currently ON (eg color, text, other)
3. Safety zone becomes visible in 3D space
4. Safety zone originates at the target
5. Safety zone is centered along the GTL towards the Launching platform
6. Safety zone is translucent light red in color

2.3.3.2　Alternate: Toggle-off Safety Zone

Trigger: User Initiated

Description: The user toggles-off the safety zone

Preconditions: Scenario is loaded, Safety Zone Toggle is enabled, Safety Zone Toggle is ON

1. User selects safety zone option from the menu with the stylus
2. Safety zone option button changes to indicate it is currently OFF (eg color, text, other)
3. Safety zone becomes invisible in 3D space

2.3.4   Toggle No Lase Zone
2.3.4.1   Base Case
Trigger: User Initiated

Description: The user toggles-on No Lase zone portion of the designator fan

Preconditions: Scenario is loaded, No Lase Zone Toggle is enabled, No Lase Zone Toggle is OFF

1. User clicks on No-Lase Zone button with the stylus
2. No-Lase control indicates the No-Lase zone is on (color, text, checkbox etc)
3. No-Lase Zone becomes visible in 3D space
4. No-Lase Zone originates at the target
5. No-Lase Zone is centered along the GTL away from the Launching platform
6. No-Lase Zone is translucent light red in color

2.3.4.2   Alternate: Toggle-off No Lase Zone
Trigger: User Initiated

Description: The user toggles-off the No-Lase zone

Preconditions: Scenario is loaded, No Lase Zone Toggle is enabled, No Lase Zone Toggle is ON

1. User clicks on No-Lase Zone control
2. No-Lase control indicates the No-Lase zone is off (color, text, checkbox etc)
3. No-Lase Zone becomes invisible in 3D space

2.3.5   Toggle Sub-Optimal Zone
2.3.5.1   Base Case
Trigger: User Initiated

Description: The user toggles-on Sub-Optimal zone portion of the designator fan

Preconditions: Scenario is loaded, Sub-Optimal Zone Toggle is enabled, Sub-Optimal Zone Toggle is OFF

1. User clicks on Sub-Optimal Zones button with the stylus
2. Sub-Optimal Zones button changes to indicate On (eg text, color, etc)
3. Sub-Optimal Zones becomes visible in 3D space
4. Sub-Optimal Zones originate at the target
5. Sub-Optimal Zones are translucent light yellow in color

2.3.5.2 *Alternate: Toggle-off Sub-Optimal Zones*

Trigger: User Initiated

Description: The user toggles-off the Sub-Optimal Zones

Preconditions: Scenario is loaded, Sub-Optimal Zone Toggle is enabled, Sub-Optimal Zone Toggle is ON

1. User clicks Sub-Optimal Zones button with the stylus
2. Sub-Optimal Zones button changes to indicate Off (eg text, color, etc)
3. Sub-Optimal Zones becomes invisible in 3D space

2.3.6 Toggle Optimal Zones

2.3.6.1 *Base Case*

Trigger: User Initiated

Description: The user toggles-on Optimal Zones portion of the designator fan

Preconditions: Scenario is loaded, Optimal Zone Toggle is enabled, Optimal Zone Toggle is OFF

1. User clicks Optimal Zones button with the stylus
2. Optimal Zones button changes to indicate On (eg text, color, etc)
3. Optimal Zones becomes visible in 3D space
4. Optimal Zones originate at the target
5. Optimal Zones are translucent light green in color

2.3.6.2 *Alternate: Toggle-off Optimal Zones*

Trigger: User Initiated

Description: The user toggles-off the Optimal Zones

Preconditions: Scenario is loaded, Optimal Zone Toggle is enabled, Optimal Zone Toggle is ON

1. User clicks on Optimal Zones button with the stylus
2. Optimal Zones button changes to indicate Off (eg text, color, etc)
3. Optimal Zones becomes invisible in 3D space

2.3.7 Toggle Extended Designator Fan

2.3.7.1 *Base Case*

Trigger: User Initiated

Description: The user toggles-on the extended designator fan

Preconditions: Scenario is loaded, Extended Designator Fan Toggle is enabled, Extended Designator Fan Toggle is OFF

1. User clicks on Extended Zones button with the stylus
2. Extended Zones button changes to indicate On (eg text, color, etc)
3. Extended Zones become visible in 3D space
4. Extended Zones is a wire frame object
5. Designator fan Zones extend beyond the UAS and AWT locations

2.3.7.2   *Alternate: Toggle-off Extended Designator Fan*

Trigger: User Initiated

Description: The user toggle-off the extended designator fan

Preconditions: Scenario is loaded, Extended Designator Fan Toggle is enabled, Extended Designator Fan Toggle is ON

1. User clicks on Extended Zones button with the stylus
2. Extended Zones button changes to indicate Off (eg text, color, etc)
3. Extended Zones become invisible in 3D space

2.3.8   Toggle Designator Fan

2.3.8.1   *Base Case*

Trigger: User Initiated

Description: The user toggles-on the designator fan

Preconditions: Scenario is loaded, Designator Fan Toggle is enabled,

1. User clicks on Designator fan button with the stylus
2. Any of the enabled Designator fan toggles enabled will now show there parts (No Lase, Optimal, Sub-optimal, Safety, Extended)

2.3.8.2   *Alternate: Toggle-off Designator Fan*

Trigger: User Initiated

Description: The user toggle-off the designator fan

Preconditions: Scenario is loaded, Designator Fan Toggle is enabled, Designator Fan Toggle is ON

1. User clicks on Designator fan button with the stylus
2. All designator fan elements are made non visible(No Lase, Optimal, Sub-optimal, Safety, Extended)

2.3.9 Toggle UAS flight path

2.3.9.1 Base Case
Trigger: User initiated

Description: The user toggles-on the UAS flight path

Preconditions: Scenario is loaded, UAS flight path is enabled, UAS Orbit is OFF

1. User clicks on UAS flight path button with the stylus
2. UAS Orbit button changes to indicate On (eg text, color, etc)
3. UAS Orbit becomes visible in 3D space
4. UAS Orbit is attached to UAS

2.3.9.2 Alternate: Toggle-off UAS flight path
Trigger: User initiated

Description: The user toggles-off the UAS flight path

Preconditions: Scenario is loaded, UAS flight path is enabled, UAS flight path is ON

1. User clicks on UAS Orbit button with the stylus
2. UAS Orbit button changes to indicate Off (eg text, color, etc)
3. UAS Orbit becomes invisible in 3D space

2.3.10 Toggle UAS Weapons Footprint

2.3.10.1 Base Case
Trigger: User Initiated

Description: The user toggles the UAS weapons footprint

Preconditions: Scenario is loaded. UAS Weapons footprint is currently OFF (This button is only visible in Scenario 2 & 3)

1. User clicks UAS Weapons Footprint toggle
2. UAS Weapons Footprint Toggle changes to indicate On (eg text, color, etc)
3. UAS Weapons Footprint becomes visible in 3D space
    a. UAS Weapons Footprint is attached to UAS
    b. UAS Weapons Footprint has a dashed line outline
    c. UAS Weapons Footprint outline is color is based on target location see 2.6.5 Change Weapons Footprint Color

2.3.10.2 Alternate: Toggle UAS Weapons Footprint Off
Trigger: User Initiated

Description: The user toggles-off the UAS weapons footprint

Preconditions: Scenario is loaded. UAS Weapons footprint is currently ON (This button is only visible in Scenario 2 & 3)

1. User clicks UAS Weapons Footprint button
2. UAS Weapons Footprint toggle changes to indicate OFF (eg text, color, etc)
3. UAS Weapons Footprint becomes invisible in 3D space

2.4 Time Controls

All controls that directly affect the passage of time

2.4.1 Pause Button

2.4.1.1 Base Case

Trigger: User Initiated

Description: The user clicks on the pause button to freeze the scenario; the user restarts the scenario by clicking on the play icon.

Preconditions: Scenario loaded and currently playing

1. The user clicks the pause button
2. The simulation pauses
3. Aircraft stops moving,
4. Time stops progressing
5. Pause button is no longer enabled

2.4.2 Play Button

2.4.2.1 Base Case

Trigger: User Initiated

Description: The user clicks on the play button to begin the scenario animation.

Preconditions: Scenario loaded, Use Case Pre-set Automated Fire Trigger completed

1. The user clicks the play button
2. Pause button is enabled
3. Time moves forward
    a. The current time indicator progresses
    b. UAS flies along its flight path
    c. Hellfire/Hellfire exclusion zone update with time

2.4.3 Rewind Button

2.4.3.1 Base Case

Trigger: User Initiated

Description: The user clicks on the Rewind button to reverse the simulation

Preconditions: Scenario is loaded and started

1. The user clicks the Rewind button
2. Pause button is enabled
3. Time moves backwards at 1x speed of play
   a. The current time indicator regresses
   b. UAS reverse along its flight path
   c. Hellfire/Hellfire exclusion zone update with reverse time

2.4.3.2   *Alternate: User Hits Rewind multiple Times*
Trigger: Application Initiated

Description: The hellfire missile impacts the target; the target is destroyed

Preconditions: Scenario is loaded and started

1. The user clicks the Rewind button
2. Pause button is enabled
3. Time moves backwards at 1x speed of play
4. The user clicks the Rewind button
5. Time moves forward at 2x speed of play
6. The user clicks the Rewind button
7. Time moves forward at 4x speed of play
8. The user clicks the Rewind button
9. Time moves forward at 1x speed of play

2.4.4   Fast Forward Button
2.4.4.1   *Base Case*
Trigger: User Initiated

Description: The user clicks on the FF button to speed up the simulation

Preconditions: Scenario is loaded and started

1. The user clicks the FF button
2. Pause button is enabled
3. Time moves forward at 2x speed of play
   a. The current time indicator progresses
   b. UAS flies along its flight path
   c. Hellfire/Hellfire exclusion zone update with time

2.4.4.2   *Alternate: User Hits FF multiple Times*
Trigger: Application Initiated

Description: The hellfire missile impacts the target; the target is destroyed

Preconditions: Scenario is loaded and started

1. The user clicks the FF button
2. Pause button is enabled
3. Time moves forward at 2x speed of play
4. The user clicks the FF button
5. Time moves forward at 4x speed of play
6. The user clicks the FF button
7. Time moves forward at 1x speed of play

2.4.5 Maximum play time reached
2.4.5.1 Base Case
Trigger: Simulation time over maximum time for scenario

Description: The user has hit play or fast forward and allowed to run, however max time is reached

Preconditions: In any scenario and play or fast forward have exceeded max scenario play time

1. Time pauses
2. Play/Fast-forward buttons are disabled

2.5 User Game Controls
Actions simulated based on events previously setup, not direct user input

2.5.1 Fire Button
2.5.1.1 Base Case
Trigger: User Initiated

Description: User clicks fire while playing no current fire trigger events present

Preconditions: Scenario is running, Game is not in setup time is playing, no fire trigger present

1. Use clicks the fire button
2. Reset Fire Use Case
3. Fire trigger event is scheduled for now
4. Fire trigger indicator appears on time line at time now
5. Go to use case 2.6.3 Fire Event Trigger

2.5.1.2 Alternate: Fire Event Already on timeline
Trigger: User Initiated

Description: Click Fire when an event is scheduled

Preconditions: Scenario is running, Game is not in setup time is playing, fire trigger is present

1. Use clicks the fire button
2. Reset Fire Use Case
3. Old fire trigger event is removed

a. Not scheduled at old time
b. Removed from timeline Fire trigger indicator
4. Fire trigger event is scheduled for now
5. Fire trigger indicator appears on time line at time now
6. Go to use case 2.6.3 Fire Event Trigger

2.5.2   Clear Fire Button

2.5.2.1   Base Case

Trigger: Application Initiated

Description: The user clears a schedule fire, might be used if they want to fire later

Preconditions: Scenario is running

1. Use clicks the Clear Fire button
2. Reset Fire Use Case
3. No further action

2.6   Simulation

Actions simulated based on events previously setup, not direct user input

2.6.1   Destroy Target

2.6.1.1   Base Case

Trigger: Application Initiated

Description: The hellfire exclusion zone fill color reaches the target location; the target is destroyed

Preconditions: Scenario is running, Hellfire missile reached target, or hellfire exclusion zone fiil has reached target

1. The target visible explosion, fire smoke (event)
2. Flames engulf the target (continuous)
3. Smoke engulfs the target(continuous)

2.6.2   Miss Target

2.6.2.1   Base Case

Trigger: Application Initiated

Description: The hellfire exclusion zone fill color reaches end, or missile reaches the ground

Preconditions: Scenario is running, Hellfire missile/exclusion zone flies maximum distance

1. Point on ground, flash of fire and smoke
2. No long lasting continuing effect

2.6.3   Fire Event Trigger

2.6.3.1   Base Case
Trigger: Application Initiated

Description: The automated fire trigger is tripped and a fire missile event is initiated

Preconditions: Scenario where AWT is firing

1. The time matches the fire event trigger time
2. A fire missile event is initiated, goto Use Case Fill Hellfire Exclusion Zone

2.6.3.2   Alternate: UAS originated fire event (Scenario 2, 3)
Trigger: Time Controls

Description: The automated fire trigger is tripped and a fire missile event is initiated

Preconditions: Scenario where UAS is firing

1. The time matches the fire event trigger time
2. A fire missile event is initiated, goto Use Case Simulate Hellfire Flight Path

2.6.4   Fill Hellfire Exclusion Zone

2.6.4.1   Base Case
Trigger: Time Controls

Description: The hellfire exclusion Zone fills with a translucent color from the launch platform towards the target when the automated fire trigger is initiated

Preconditions: Scenario is running, AWT is firing entity, UseCase 2.6.3 Fire Event Trigger completed, AWT is between 8km and 3.5 km of target

1. The hellfire exclusion Zones fills with a translucent light red color horizontally from at a rate equivalent to time of flight of the missile for distance from AWT to target. This simulates the movement of the hellfire missile.

Table 14–13. SAL Hellfire designation times

Range	TOF from launch to impact	Laser delay time steady on	Required laser terminal guidance before impact	
Kilometers	Seconds			
	Rotary Wing			UAS
2	7	**	6	10
3	10	2-3	6	
4	14	3-6	6	
5	19	4-8	6	
6	24	4-11	6	
7	29	4-13	7	
8***	36	4-16	8	

Note.
*All times are from missile separation. Add an additional second for time from trigger pull.

**Short delay times (typically three seconds from trigger pull) may allow the missile seeker to lock onto backscatter near the aircraft.

***LOAL-LO and LOAL-HI only for all missile variants except P+ and R.
For LOAL engagements if visibility is less than 5km and/or laser delays near the recommended maximum used, than a ±5 degree offset is recommended as to allow the missile to acquire the laser energy.

2. When the simulated range of the hellfire missile, and thus the fill is at 3.5km the new fill color changes from translucent light red to translucent dark red, indicated the UAS should be lasing. So the first part closes to the AWT is light red, and closest to the target dark red

3. At 0km to trigger the use case 2.6.1 Destroy Target

2.6.4.2   Alternate: AWT Fires within 3.5km of target
Trigger: Time Controls

Description: The hellfire exclusion Zone fills with a translucent color from the launch platform towards the target when the automated fire trigger is initiated

Preconditions: Scenario is running, AWT is firing entity, UseCase 2.6.3 Fire Event Trigger completed, AWT is within 3.5km of target

1. Since the simulated range of the hellfire missile is less than the lasing time (tof at 3.5k) the fill color changes is translucent dark red and fills horizontally from the AWT to the target at the rate of the base case
2. At 0km to trigger the use case 2.6.1 Destroy Target

2.6.4.3   Alternate: AWT Fires more than 8k from target
Trigger: Time Controls

Description: The hellfire exclusion Zone fills with a translucent color from the launch platform towards the target when the automated fire trigger is initiated

Preconditions: Scenario is running, AWT is firing entity, UseCase 2.6.3 Fire Event Trigger completed, AWT is > 8k from target

1. The hellfire exclusion Zones fills with a translucent light red color horizontally from at a rate equivalent to time of flight of the missile for distance from AWT to target. This simulates the movement of the hellfire missile. (Same as base case)
2. After 8km, 36 seconds trigger the use case 2.6.2 Miss Target using a point at the end of the hellfire exclusion zone, 8km from the AWT

2.6.5   Change Weapons Footprint Color
2.6.5.1   Base Case
Trigger: Time/Target Location/Footprint location

Description: The application changes the color of the weapons footprint from red to green when the target falls within the footprint

Preconditions: Scenario is loaded, Footprint is visible, and target is within footprint

1. The UAS moves towards the target
2. The target falls within the boundaries of the weapons footprint
3. The weapons footprint changes to green

2.6.5.2   Alternate: Target Leaves Weapon Footprint
Trigger: Time/Target Location/Footprint location

Description: The application changes the color of the weapons footprint from red to green when the target falls within the footprint

Preconditions: Scenario is loaded, Footprint is visible, and target is outside footprint

1. The UAS moves towards the target
2. The target falls outside the boundaries of the weapons footprint
3. The weapons footprint changes to red

2.6.6   Simulate Hellfire Flight Path
2.6.6.1   Base Case
Trigger: Time Controls

Description: Simulate the flight of a hellfire from the UAS to the target

Preconditions: Running a scenario where the UAS fires a hellfire, the Fire Trigger event has occurred, target is inside the weapons footprint at time of fire

1. A curved line becomes visible that shows the projected simulated path of the hellfire missile, in direct fire mode

2. Hellfire missile object flies along the line path at the same rate depicted in 2.6.4 Fill Hellfire Exclusion Zone
3. Hellfire updates location along the flight path with time
4. The hellfire models impacts the target at the completion of the time of flight
5. The target is destroyed, goto the use case 2.6.1 Destroy Target

2.6.6.2 Alternate: Target is outside the weapons footprint
Trigger: Time Controls

Description: Simulate the flight of a hellfire from the UAS to the target

Preconditions: Running a scenario where the UAS fires a hellfire, the Fire Trigger event has occurred, target is outside the weapons footprint at time of fire

1. A curved line becomes visible that shows the projected simulated path of the hellfire missile, in direct fire mode
2. Hellfire missile object flies along the line path at the same rate depicted in 2.6.4 Fill Hellfire Exclusion Zone
3. Hellfire updates location along the flight path with time
4. The hellfire models impacts the terrain at the completion of the time of flight, at an edge of the exclusion zone, close to the target
5. The target is missed, goto the use case 2.6.2 Miss Target

2.6.7 FLY UAS on straight path
2.6.7.1 Base Case
Trigger: Time Controls

Description: The path

Preconditions: Use

1. The UAS starts moving along the flight path and a constant speed
2. The UAS orientation remains constant and along flight path
3. Associated graphics are updated with new position LTL, GTL, Weapons footprint
4. Movement is tied to time
5. Movement ends with time, or at the end of the flight path

2.6.8 FLY UAS on Orbit
2.6.8.1 Base Case
Trigger: Time

Description: The UAS moves along the flight path

Preconditions: Scenario loaded with a UAS orbit, Time is moving

1. The UAS starts moving along the orbit path and a constant speed
2. The UAS bank, if any, remains constant
3. The UAS heading adjusts to keep flight path in front
4. Associated graphics are updated with new position LTL, GTL, Weapons footprint
5. Weapons foot print orientation is updated matches the UAS heading
6. Movement is tied to time

2.7   Mission Controls

Controls to Reload, Reset, or quit the mission

2.7.1   Exit Scenario

2.7.1.1   Base Case

Trigger: User Initiated

Description: The user elects to exit the scenario

Preconditions: Any scenario has been loaded

1. User clicks exit
2. Application prompts the user if they are sure yes/no
3. User selects yes
4. Scenario exits to Scenario Selection screen

2.7.1.2   Alternate: User decides not to exit

Trigger: User Initiated

Description: The user elects not to exit the scenario

Preconditions: Any scenario has been loaded User clicks exit

1. User clicks exit
2. Application prompts the user if they are sure yes/no
3. User selects no
4. Scenario continues as previous

2.7.2   Reset Scenario Button

2.7.2.1   Base Case

Trigger: User Initiated

Description: The user clicks the rest button to return all models to default locations and positions

Preconditions: Scenario is loaded

1. User clicks the Reload button
2. Fire Trigger event is removed

3. Time is set to zero
4. UAS and associated elements returns to default Start X, Y, and Z coordinates
5. Any AWT and associated elements to default Start X, Y, and Z coordinates
6. Target and associated elements returns to default Start X, Y, and Z coordinates
7. Toggled settings remain unchanged

Appendix C
GUAVA Observation Form

<u>User Experience</u>

Observe the user while he/she interacts with GUAVA.

Document any challenges that the user has with the interface, i.e. selecting objects, moving objects, etc., or exhibits from interacting with the application.

Stop the user if what they are attempting to do could cause damage to the equipment, i.e. pushing on the screen with the stylus.

Challenges
Touching the screen with the stylus
Selecting controls
Navigating depth
Rotating objects
Using Augmented Reality Mode – trying to place terrain in correct position in relation to camera
Physical symptoms (headache, nausea, dizziness, etc)
Vision issues (sore eyes, eye strain, blurred vision)
Other observed challenges

<u>Content Questions</u>

Ask the user the following questions concerning the content of GUAVA

1. In general, are there sufficient objects/graphics to enable you to teach UAS gunnery tasks?

   a. If not, what would you like to see added?

2. Does the rendition of the graphics closely represent what you are currently teaching?

   a. If not, why

      i. How should the graphics be represented?

3. Do the three scenarios support the gunnery lessons you are teaching?

   a. In what way?

   b. If not,
      a. Which scenario does not support the gunnery lessons, why?
         i. Scenario 1 –Remote Engagement UAS lasing AWT launching

         ii. Scenario 2 – Remote Engagement AWT lasing UAS launching

         iii. Scenario 3 – Autonomous UAS lasing and launching

4. Will the scenario content enable you to better impart understanding of gunnery concepts to the students? (i.e. spatial relationship between UAS – AWT – Target, Optimal vs Sub-optimal lasing positons, safety, etc.)

   a. If not, why?

5. Does the movement of the objects give you sufficient flexibility to emphasize or reinforce key learning points?

    a. If not why?

6. Now that you have had some experience using GUAVA, how would you use GUAVA to teach UAS gunnery lessons/tasks?

Appendix D
Gray Eagle Instructor Questionnaire

Duty Position _____ Time in Duty Position _____

 Please describe your duties and roles regarding Grey Eagle Operator Training.

_____

Have you participated in any/all of the engagement situations described below? (Mark an "X" in the boxes that apply)

Engagement Situation	None	Simulated Training	Live Training	Combat	Role
Remote Engagement – UAS (Designator) AWT (Shooter)					UAS Pilot
					Payload Specialist
Remote Engagement – UAS (Shooter) AWT (Designator)					UAS Pilot
					Payload Specialist
Autonomous Engagement [Inline and/or Offset] – UAS (Designator/Shooter)					UAS Pilot
					Payload Specialist

For those boxes that you marked an "X" in above, please write-in the number of engagements.

Engagement Situation	Simulated Training	Live Training	Combat	Role
Remote Engagement – UAS (Designator) AWT (Shooter)				UAS Pilot
				Payload Specialist
Remote Engagement – UAS (Shooter) AWT (Designator)				UAS Pilot
				Payload Specialist
Autonomous Engagement [Inline and/or Offset] – UAS (Designator/Shooter)				UAS Pilot
				Payload Specialist

Have you certified on any other UAS airframes? (Mark an "X" in the "No" column, or write in the number of hours for training or combat on those systems you are certified on)

UAS	No	# of Hours Training	# of Hours Combat
Hunter			
Shadow			
Raven			
Puma			
Wasp			
Micro Air Vehicle (gMAV)			
Other _____			

Gunnery UAV Application Questionnaire

Please complete the questionnaire by marking an X in the appropriate box for each question. The first six items relate to perceived usefulness, the second six items relate to perceived ease of use.

1. **Using GUAVA in my job would enable me to accomplish tasks more quickly.**

LIKELY | extremely | quite | slightly | neither | slightly | quite | extremely | UNLIKELY

2. **Using GUAVA would improve my job performance.**

LIKELY | extremely | quite | slightly | neither | slightly | quite | extremely | UNLIKELY

3. **Using GUAVA in my job would increase my productivity.**

LIKELY | extremely | quite | slightly | neither | slightly | quite | extremely | UNLIKELY

4. **Using GUAVA would enhance my effectiveness on the job.**

LIKELY | extremely | quite | slightly | neither | slightly | quite | extremely | UNLIKELY

5. **Using GUAVA would make it easier to do my job.**

LIKELY | extremely | quite | slightly | neither | slightly | quite | extremely | UNLIKELY

6. **I would find GUAVA useful in my job.**

LIKELY | extremely | quite | slightly | neither | slightly | quite | extremely | UNLIKELY

1. **Learning to operate GUAVA is easy for me.**

LIKELY | extremely | quite | slightly | neither | slightly | quite | extremely | UNLIKELY

2. **I find it easy to get GUAVA to do what I want it to do.**

LIKELY | extremely | quite | slightly | neither | slightly | quite | extremely | UNLIKELY

3. **My interaction with GUAVA is clear and understandable.**

LIKELY | extremely | quite | slightly | neither | slightly | quite | extremely | UNLIKELY

4. **I find GUAVA to be flexible to interact with.**

LIKELY | extremely | quite | slightly | neither | slightly | quite | extremely | UNLIKELY

5. **It is easy for me to become skillful at using GUAVA.**

LIKELY | extremely | quite | slightly | neither | slightly | quite | extremely | UNLIKELY

6. **I find GUAVA easy to use.**

LIKELY | extremely | quite | slightly | neither | slightly | quite | extremely | UNLIKELY

Appendix E
GUAVA Instructor Feedback Table

GUAVA Feedback	Frequency Count
Terrain	

• Add urban objects
   ○ Houses
   ○ Alleys
   ○ Small town
	4

• Add environmental objects
   ○ Trees
   ○ Overhangs
   ○ Caves
	5

• Shift terrain 5km to the east	2
• Would like smaller terrain to allow better zoom	1
• Add different terrain databases	1
UAS	

• Add HUD information
   ○ A/C heading
   ○ PO azimuth relative to A/C
   ○ Height above target (HAT)
   ○ Slant Range to target
   ○ Time of flight (missile)
   ○ Payload elevation scale
   ○ Payload elevation
	8

• Add banking turns ○ To occlude laser with wings	1

• Add Payload view
   ○ Toggle on/off
   ○ Show from 200 meters in to impact
	3

• More contrast of UAV	1
• Add ability to increase/decrease A/C speed	2
AWT	
• Show range from AWT to target	3
• Add AWT altitude ○ Visible at all times	3
• Show LTL degrees (scenario 2 only)	2
• Show GTL degrees (scenario 1 only)	2
• Change AWT to Reaper in Scenario 2	1
Target	
• Change target from M1 Abrams to T-72/T-80	1
• Add moving target ○ Straight line movement	7
• Ability to rotate target to show weak zones	1

GUAVA Feedback	Frequency Count
• Add second tank target	1
• Change type of target (clusters, number of)	1
• Add friendly targets	1
Geometric shapes / lines	
• Add laser occlusion o By terrain	1
• Add location of laser reflection on target (see a spot)	5
• Add degrees to designator fan	1
• Add button to disable colors of LTL and GTL	1
• Increase size of LTL and GTL text	1
• Outline weapons footprint	1
• Add Launch Acceptability Region (LAR) at target	2
• Add Restricted Operations Zone (ROZ) o Upside down wedding cake	3
• Would like to see designator fan with max altitude at 8 km	1
UAS Flight path	
• Allow flight path to remain flat in scenario 2 and 3	1

• Add function to change flight path
    o Remove loiter, or give ability to turn-in to straight flight path to target
    o Would like option to change loiter / orbit – racetrack, straight path
    o Would like to be able to curve path – show turn in and turn away
	6

• Change flight path color from light blue to dark blue	1
Missile	
• Add missile flight path based on station (1-4) missile released from	2
• Add ability to pick station to launch missile from	1

• Would like alternate flight paths
    o High
    o Direct
    o Low
	2

• Show distribution of fragmentation of missile warhead on differing terrain	1
User Interface Controls	
• Add reset view button	1
• Click scenario name to load scenario	4
• Make it easier to select controls	7

• Allow changing scale on objects
    o Target
    o UAS
    o AWT
	1

GUAVA Feedback	Frequency Count
• Hot keys to change altitude (250 or 500 meter increments) ○ Or ability to type in	4
• Add menu of selectable airframes and munitions	1
• Add north seeking arrow	1
• Would like to see 9-line template	1

Appendix F
GUAVA Administrator's Guide

Set-up

This section lists the steps necessary to setup and connect the hardware.

zSpace Monitor

    a. Hold the zSpace monitor by the top handle and rest the bottom of the monitor on the desk.

    b. With your free hand reach behind the monitor and extend the legs to the second position.

    c. Position the monitor on the desktop.

    d. Connections (on the back of the monitor)

i. Plug the power brick into the port labeled "Power", connect the power cable to the power brick and plug it into an UPS or surge protector.

ii. Connect the Combined USB and Display Port Cable to the zSpace monitor.
   1. Insert large connector into the port labeled "Display Port". <u>The port on the back of the zSpace display is very tight, be sure to push it all the way in.</u>

   2. Insert small connector into the port labeled "USB Input".

zView Hardware

This section is only necessary to view the augmented reality view. Ensure the monitor legs are extended before attaching the flexible arm.

a. Select the side the camera should be mounted on.
   i. Mount on left side of the monitor for viewing a right-handed user's stylus/hand during operation.

   ii. Mount on right side of the monitor for viewing a left-handed user's stylus/hand during operation.

b. Put the lock washer around the threaded-end of the flexible arm then screw the flexible arm into the mounting plate.
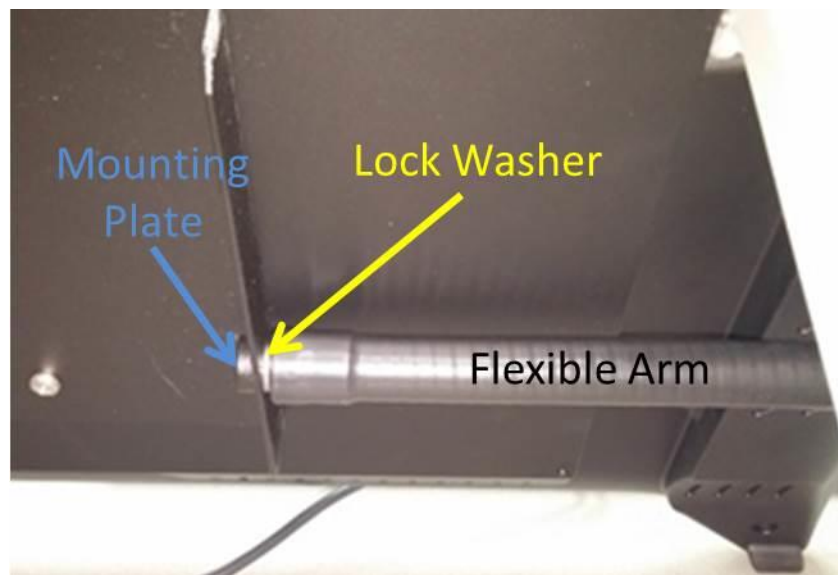
c. Screw the Camera Arm Adaptor L Bracket onto the flexible arm.

d. Screw the camera onto the Camera Arm Adaptor L Bracket.

e. Bend the flexible arm to approximate the arm position seen in the picture below. The bend should enable the camera to look at the display and user's hand; this will be fine-tuned during the zView Calibration.

Computer

a. Place the Computer on the floor nearest the side of the monitor that the camera arm is attached to.

b. Ensure the power switch on the back of the computer is in the on position – The "I" is depressed.
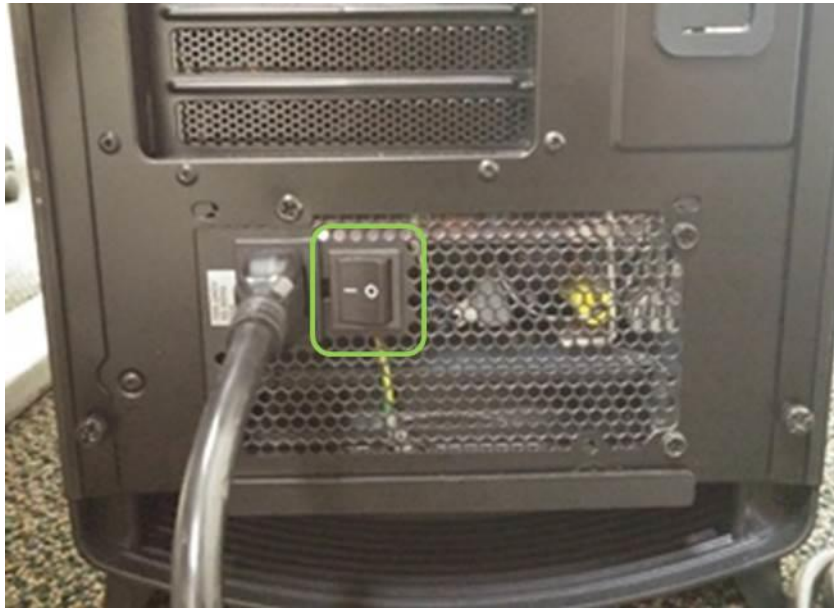
c. Connect the Combined USB and Display Port Cable from the zSpace monitor to the back of the Computer.
   i. Insert large connector into the right graphics card port.

ii. Insert small connector into either of the lower USB 2.0 **(not blue)** ports**.**

d. Plug the Computer Power Cable into a UPS or surge protector.

Peripherals

a. Mouse and keyboard
   i. Connect the USB Mouse and keyboard to the zSpace monitor using the two right side USB ports. (This is what is recommended by zSpace, you can also connect to the back of the monitor).

b. Stylus

   ii. Connect the stylus to the back of the zSpace monitor in the port labeled "Stylus 1".

c. Camera

   i. Insert the USB connector into either of the upper USB 2.0 ports **(not blue)** on the back of the computer.

d. Projector / 2nd Monitor
   i. Determine the type of connector you have on the projector or 2nd monitor.
   ii. If you have a VGA connector, use the VGA adapter.

   iii. Insert the VGA adapter HDMI connector into the graphics card HDMI slot on the back of the computer.

   iv. If you have a DVI-D connector, insert the connector into the DVI-D slot.

Power-on the System

This section lists the power-on and login steps.

1. Turn on the zSpace monitor by depressing the power button on the right side of the monitor.

2. Turn on the Computer by depressing the power button located on the top front of the computer.

3. Left click on the middle of the screen to access the GUAVA login page.

4. Login to GUAVA
   a. **Password**: UASgunnery(2016).

5. Once on the Windows™ desktop screen follow the directions in the next section to calibrate the zView camera.

Calibrating zView

This section lists the steps necessary to calibrate zView. Whenever the camera is moved zView must be recalibrated. This section is only necessary when preparing to view the augmented reality view.

1. On the Desktop Double Click **zSpace zView-2016** icon to start zView.

2. Click the **wrench** icon to begin setup
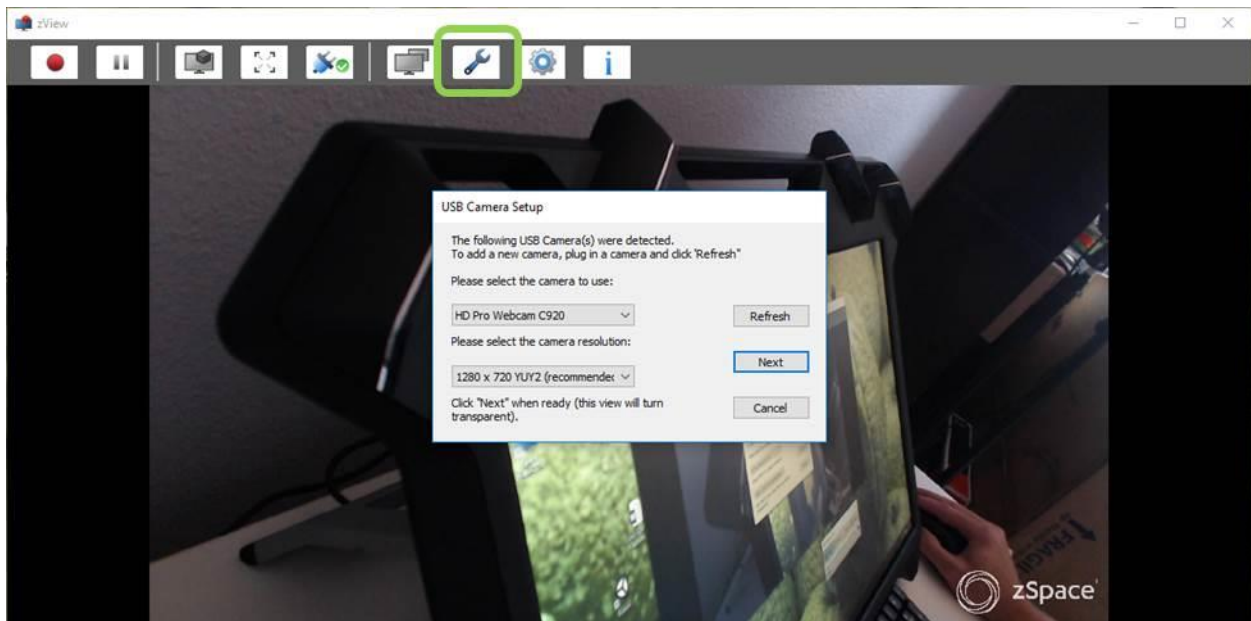
3. The Camera and Resolution will be automatically detected, you do NOT need to select from the drop-down menu, click **Next.**

4. Position the camera/arm so that the screen is in view, as instructed.
   a. Each square on the zSpace monitor will highlight in green as it is recognized.
      i. You might have to turn off the room lights to eliminate screen glare in order for the camera to recognize the squares on the screen.

   b. When all squares are green the Next button will be enabled.

5. Click **Next** to accept the camera position.
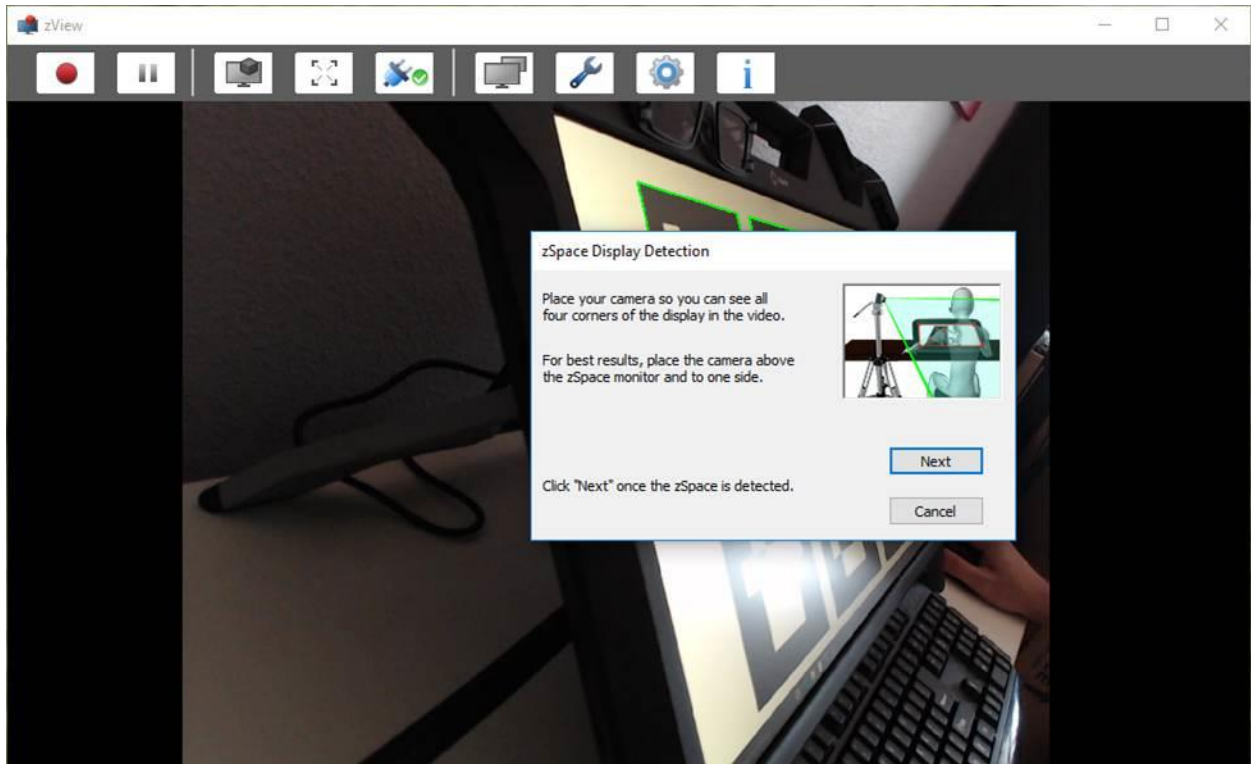
6. Click **Finish.**

7. Close zView.

Updating GUAVA

This section describes how to take an updated GUAVA delivery and install it on the machine.

1. Login as the administrative user
   a. User Name: adminroot
   b. Password: 4D-TrainerSystem
2. Close any running GUAVA instances
3. Rename **C:\GUAVA** to something like **C:\GUAVA.1** in case there are issues you can revert
4. Copy the New **GUAVA** directory to **C:**
5. Logout as administrator
6. Login as user
   a. Password: UASgunnery(2016)
7. **Double Click** the **guava** icon on the desktop to verify that it runs

GUAVA Video Capture

zView provides a video capture capability that can be used to record short videos that emphasize key gunnery concepts.

1. Launch GUAVA on a dual display. zView will launch automatically on the second display
2. Left click on the settings icon and set video resolution to 1080p.

3. Left click on the record icon to start recording. A red clock timer will be displayed in the upper right corner of zView.
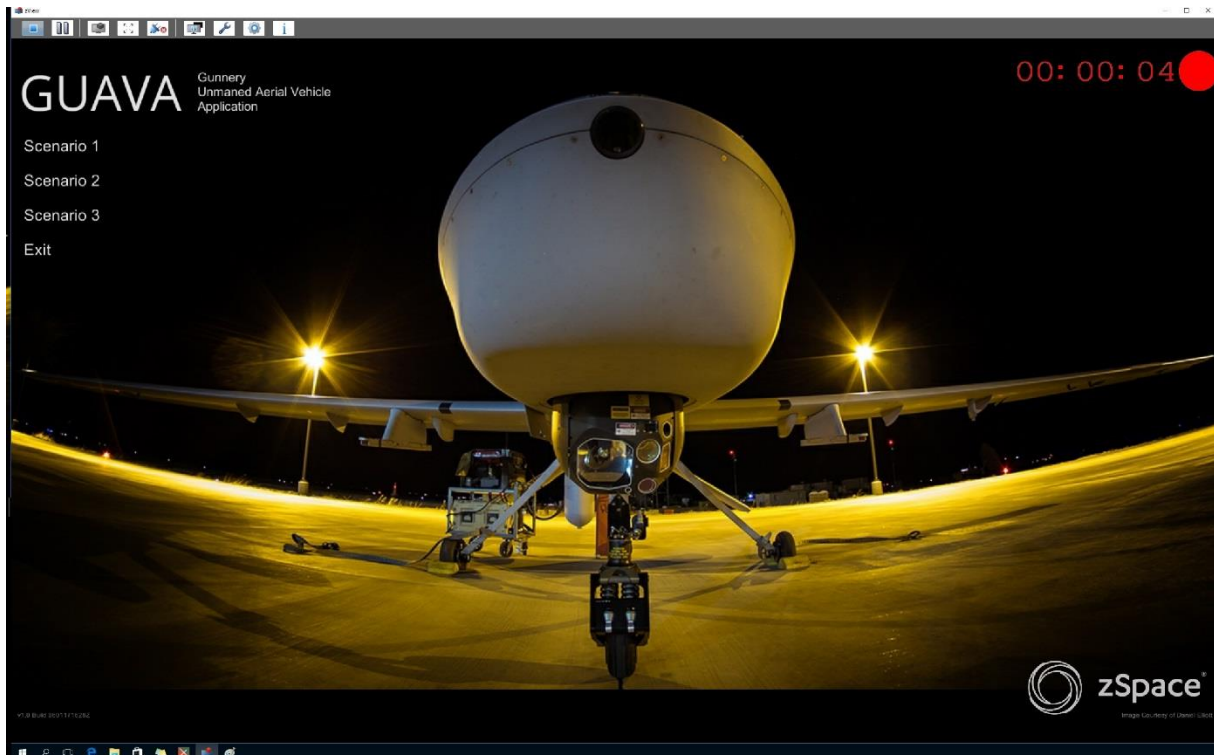
4. Select and run a scenario on the zSpace monitor.
5. Exit the GUAVA scenario when finished.
6. Left click on the record icon to stop recording.

7. Save the file

Troubleshooting Chart

Fault	Cause	Action
GUAVA will not launch. Error message is displayed	Display settings have been changed	1. Double left click on the "Fix GUAVA" icon on the desktop. 2. Restart GUAVA.
zView camera will not calibrate to squares on zSpace monitor	Screen glare	3. Turn off the room lights to calibrate
zView buttons are not visible but zView is shown in the taskbar	This can happen if the screen resolution of the projector changes to a lower resolution and the window controls become unreachable via the mouse cursor	4. Click the zview Icon on the taskbar 5. Hold the Windows Key and Press the Up arrow to maximize the window.
		OR
		1. If that doesn't work, click the zview icon on the task bar again to make sure it's in focus
		2. Hold the Windows Key and Press the Up arrow, this maximizes the window.
Machine locks up	Windows 10 freezes	1. Push and hold the power button on the computer to reset
		2. If machine locks up on boot, repeat by holding the power button until the machine resets again

GUAVA Hot Keys

This section list the hot keys associated with actions within GUAVA.

Aircraft	
Page Up	Move Flight Path up 500ft
Page Down	Move Flight Path down 500ft
Time	
Left Arrow	Rewind
Down Arrow/Spacebar	Play/Pause toggle
Right Arrow	Fast Forward
Fire	
Enter	Fire
Backspace	Reset Fire
Reset	
Insert	Reset Scenario
Home	Reset View
Toggle	
F1	Toggle Designator Fan
F2	Toggle Optimal Zone
F3	Toggle Sub-Optimal Zone
F4	Toggle Safety Zone
F5	Toggle No Lase Zone
F6	Toggle Extended Fan
F7	Toggle Weapons Footprint
F8	Toggle Exclusion Zone
F9	Toggle Flight Path
F10	Toggle Color
F11	Toggle HUD
Miscellaneous	
ESC	Exit To Main Menu

Appendix G
GUAVA User Guide

Power-on the System

This section lists the power-on and login steps.

1. Turn on the zSpace monitor by depressing the power button on the right side of the monitor.

2. Turn on the Computer by depressing the power button located on the top front of the computer.

3. Left click on the middle of the screen to access the GUAVA login page.

4. Left click on GUAVA account to login
   a. **Password**: UASgunnery(2016).

GUAVA Tutorial

The GUAVA tutorial demonstrates how to use the multitude of functions associated with the training system.

1. On the Desktop Double Left Click the video icon to view the tutorial.

Guava Tutorial 08162016c.wmv

2. Close the video before using GUAVA.

Launching GUAVA

To launch the application:

1. Double left click on the GUAVA icon.
2. Only one pair of control glasses can be used at a time. The person wearing the control glasses must continuously look at the computer screen in order <u>not</u> to distort the image being projected on the classroom screen.

Control Glasses

3. Use the control stylus to launch and control the scenario elements.
    a. To rotate the terrain either clockwise or counter clockwise press and hold either of the two buttons depicted below. Release the button to stop rotation.
    b. To grab an object or toggle on/off different elements hover the laser over the object or menu item and press the single button. Release the button to release the object.

Rotate Terrain Clockwise

Depress button to grab objects

z space

Rotate Terrain Counterclockwise
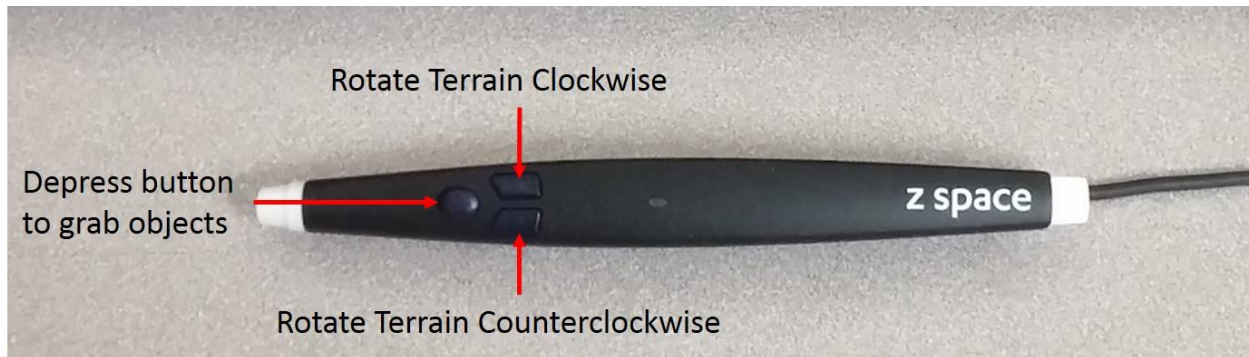
4. The alternate method for toggling on/off different menu items is to use the Hot Keys. The Hot Key reference is located at the end of this document.

Menu Items

GUAVA Scenarios

The following provides a brief description of each GUAVA scenario and the associated elements. For more information on how to incorporate the scenarios into the POI refer to the Instructor Use Case document.

Scenario 1 (Remote Engagement) – UAS (Designator) AWT (Shooter)

This Scenario has the UAS designating with a laser while an AWT fires a missile.
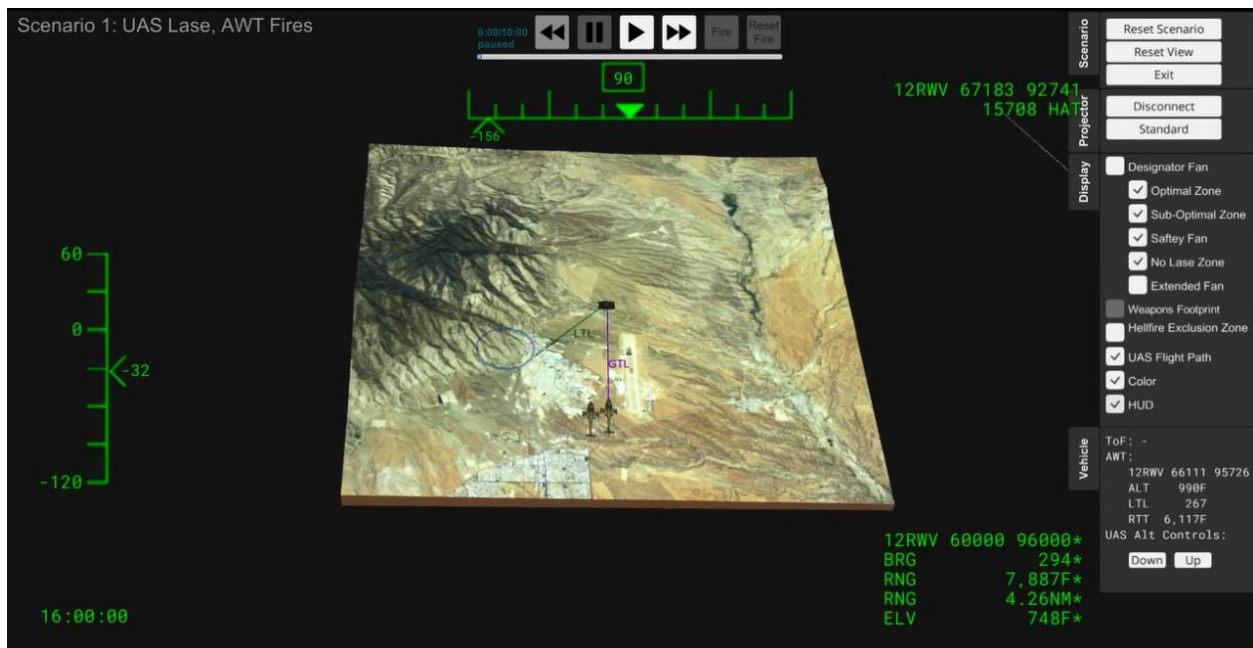
List of relevant elements

- UAS
- UAS LTL
- UAS Flight Path
- Designator Fan
- AWT Team (two Apaches)
- AWT GTL
- AWT Hellfire Exclusion zone
- HUD
- Target

Scenario 2 (Remote Engagement) – UAS (Shooter) AWT (Designator)

This Scenario has the UAS Shooting while an AWT lases
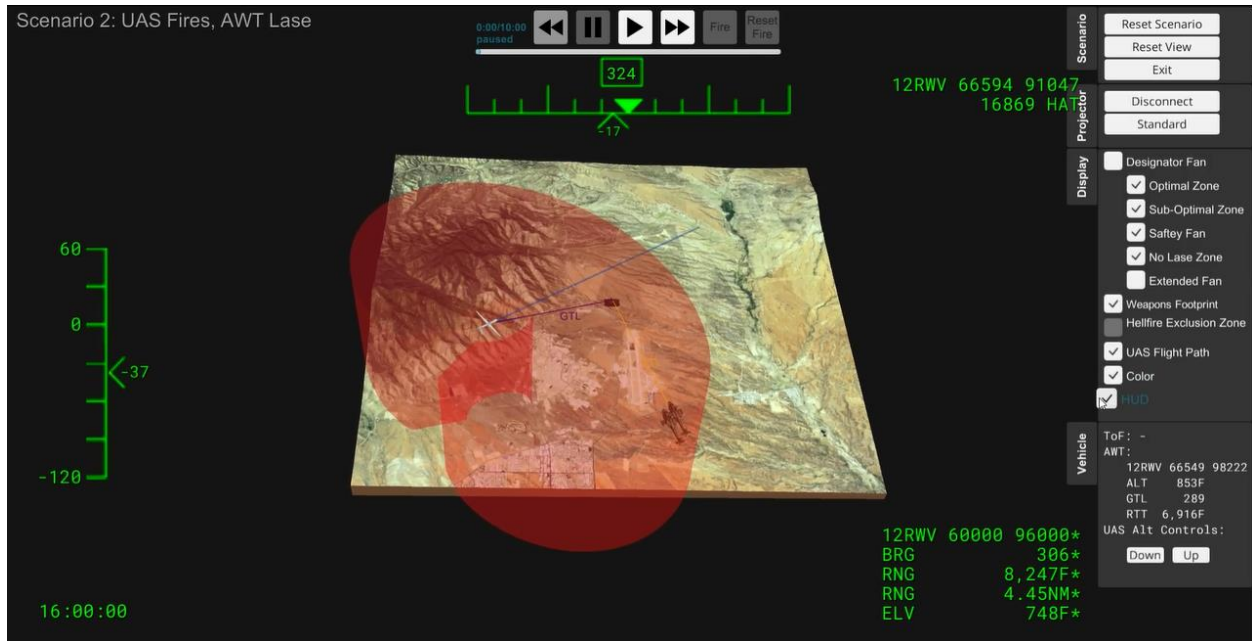
List of relevant elements

- UAS
- HUD
- UAS GTL
- UAS Flight Path
- UAS Weapons footprint
- Designator Fan
- AWT Team (two Apaches)
- AWT LTL
- Target

Scenario 3 (Autonomous Engagement [Inline and Offset]) – UAS (Designator/Shooter)

This scenario depicts the UAS designating and shooting the target in either an inline or offset engagement.
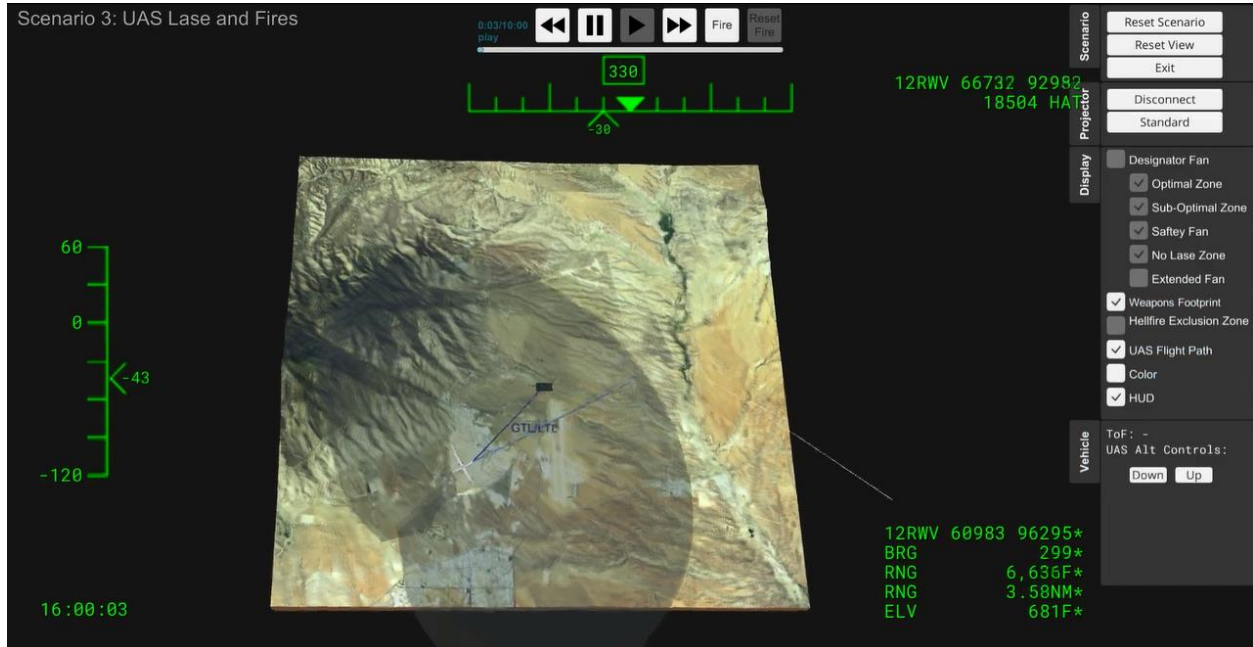
List of relevant elements

- UAS
- UAS LTL/GTL
- UAS Weapons footprint
- UAS Flight Path
- UAS HUD information
- Target

Troubleshooting Chart

Fault	Cause	Action
GUAVA will not launch. Error message is displayed	Display settings have been changed	6. Double left click on the "Fix GUAVA" icon on the desktop. 7. Restart GUAVA.
Image projected on the classroom screen is distorted or twisted	Person wearing controller glasses looking away from the computer screen	1. Person wearing the controller glasses must continuously look at the computer screen.
zView buttons are not visible but zView is shown in the taskbar	This can happen if the screen resolution of the projector changes to a lower resolution and the window controls become unreachable via the mouse cursor	1. Click the zview Icon on the taskbar 2. Hold the Windows Key and Press the Up arrow to maximize the window. OR 3. If that doesn't work, click the zview icon on the task bar again to make sure it's in focus 4. Hold the Windows Key and Press the Up arrow, this maximizes the window.
Machine locks up	Windows 10 freezes	3. Push and hold the power button on the computer to reset 4. If machine locks up on boot, repeat by holding the power button until the machine resets again

GUAVA Hot Keys

This section list the hot keys associated with actions within GUAVA.

Aircraft	
Page Up	Move Flight Path up 500ft
Page Down	Move Flight Path down 500ft
Time	
Left Arrow	Rewind
Down Arrow/Spacebar	Play/Pause toggle
Right Arrow	Fast Forward
Fire	
Enter	Fire
Backspace	Reset Fire
Reset	
Insert	Reset Scenario
Home	Reset View
Toggle	
F1	Toggle Designator Fan
F2	Toggle Optimal Zone
F3	Toggle Sub-Optimal Zone
F4	Toggle Safety Zone
F5	Toggle No Lase Zone
F6	Toggle Extended Fan
F7	Toggle Weapons Footprint
F8	Toggle Exclusion Zone
F9	Toggle Flight Path
F10	Toggle Color
F11	Toggle HUD
Miscellaneous	
ESC	Exit To Main Menu

Appendix H
GUAVA Instructor Use Case Examples

Scenario 1 (Remote Engagement) – UAS (Designator) AWT (Shooter)

This Scenario has the UAS designating with a laser while an AWT fires a missile.

List of relevant elements

- UAS
- UAS LTL
- UAS Flight Path
- Designator Fan
- AWT Team (two Apaches)
- AWT GTL
- AWT Hellfire Exclusion zone
- HUD
- Target

Instructor high level use case example

This is high level to show an example of how the tool will be used to teach the concepts.

Pre-instruction GUAVA set-up

- Assistant Instructor (AI) loads Scenario 1
- AI toggles on UAS HUD by selecting the "HUD" button
- AI turns off UAS LTL color by de-selecting "Color" button
- AI toggles off Optimal Zone, Sub-optimal Zone, and Safety Fan by de-selecting buttons
- AI moves terrain on 3 axis to best display initial content

Instructional Lead-in

"We are now going to discuss the remote engagement gunnery concepts" "This scenario depicts the remote scenario with the UAS designating and the AWT launching" "This is one of the minimum proficiency level scenarios you will be required to perform as a UAS crew during gunnery qualification at your homestation"

- Primary Instructor (PI) toggles classroom display controls to show GUAVA on the big screen
- PI orients the class to the display
  - o Libby Army Airfield
  - o UAS
  - o AWT
  - o Target
- PI explains that the images shown within the tool are not what the student will see in the GCS.
- PI asks question
  - o Q: What are the employment factors of a remote engagement which ensure proper and safe delivery of the Hellfire?
  - o A: Offset geometry, Gun to Target Line (GTL), Laser to Target Line (LTL), target location, laser codes, and launch and delivery modes (TC 3-4.45, p. 14-70, para. 14-281)
- PI states "First we are going to discuss offset geometry and the LTL and GTL"
- PI asks question
  - o Q: What is the maximum laser designation offset angle between the LTL and the GTL?
  - o A: 60 degrees on each side of the GTL or a total of 120 degrees (TC 3-4.45, p. 14-56, para. 14-237 and p.14-72, figure 14-43)

PI Actions	AI Actions
	- AI toggles on Designator Fan by selecting "Designator Fan" button
- PI discusses the offset angle between the GTL and LTL	- AI moves AWT to show how the designator fan moves with the GTL
- PI orients class to different zones within the designator fan	- AI rotates terrain to depict top-down view of designator fan
- PI discusses why lasing outside of the 120 degree offset angle impacts the delivery of the Hellfire	- AI moves UAS to depict lasing through the No-Lase Zone
- PI discusses how and why this zone can be used to illuminate the target but is not the preferred zone.	- AI toggles-on the 15° sub-optimal (Yellow) portions of the designator fan
- PI discusses why this is the best angle for lasing targets.	- AI toggles-on the 35° Optimal (Green) portions of the designator fan
- PI discusses this area as it should be avoided for weapons release unless the situation necessitates	- AI toggles-on the 20° Safety Zone (Red) portion of the designator fan

| PI Actions	AI Actions
• PI discusses how the angles expand at distance and that with the GE laser capabilities lasing from a distance provides greater airspace in which to loiter.	• AI toggles-on the extended view of the designator • AI moves UAS loiter in line with optimal zone • AI rotates the terrain to show the UAS orbit within the designator fan Optimal zone. • AI toggles-off the designator fan
• PI asks question • Q: If the GTL is 360 or 0 degrees, what should the LTL be to lase through the optimal zone? • A: Between 11 and 45 degrees or between 315 and 349 degrees	
• PI highlights BRG reading in HUD • Discusses difference between UAS heading and payload offset in HUD	• AI moves AWT until GTL = 360 or 0 degrees • AI moves UAS loiter to both optimal zones
	• AI toggles-off Designator Fan • AI moves AWT and UAS to different positions
• PI asks question • Q: Is this an acceptable position for the UAS to lase from? • Students must use information provided in UAS HUD and AWT GTL reading to determine answer	
	• AI toggles-on "Color" button • AI toggles-on "Designator Fan" button
• PI states "We are now going to discuss Hellfire launch and delivery modes in relation to this scenario"	• AI toggles "Reset Scenario" button
• PI asks question • Q: As the designating platform in this scenario, what must you conform to in order to remain protected from inadvertently becoming the target for missile launched by the AWT? • A: The Hellfire Exclusion Zone (TC 3-4.45, p. 14-70, para. 14-284)	
	• AI toggles-on the hellfire exclusion zone to show students the zone • AI rotates the terrain to show the zone from top-down view, side-view, and pseudo 3D-view.
• PI discusses that the missile will fly within the hellfire exclusion zone based on the flight mode selected by the AWT – High, Direct, or Low	

PI Actions	AI Actions
• PI discusses the dimension of the hellfire exclusion zone and how it relates to positioning of the UAS to ensure the UAS is not within the hellfire exclusion zone.	• AI moves the AWT to depict how the exclusion zone moves with the launching platform along the GTL.
• PI discusses how the missile seeker head could acquire the source of the laser rather than the return on target is the UAS is within the hellfire exclusion zone.	
	• AI clicks the Rest Scenario to return the scenario to the default position. • AI toggles-off the hellfire exclusion zone.
• PI direct the AI to click the Fire button	• AI clicks the play button the UAS moves along its orbit with the attached LTL.
• PI explains that the change in color of the hellfire exclusion zone depicts the missile in flight	
• PI directs the AI to pause the scenario when the hellfire exclusion zone changes color indicating the last 10 seconds of ToF	• AI clicks Pause button
• PI discusses the importance of the last 10 seconds of ToF and laser movement on the target	
• PI directs AI to click play, the scenario continues until the missile flight path depiction reaches the target and the target is destroyed.	• AI clicks Play button
	• AI clicks Rest Scenario button

Check on Learning

- • Q: What is the maximum laser designation offset angle between the LTL and the GTL?
- • A: 60 degrees on each side of the GTL or a total of 120 degrees (TC 3-4.45, p. 14-56, para. 14-237 and p.14-72, figure 14-43).
- • Q: What is the terminal guidance time for a UAS as the designator, why?
- • A: The last 10 seconds of missile ToF, to ensure the missile will guide to the intended target (TC 3-4.45, p. 14-45, para. 14-230 and table 14-13).

Scenario 2 (Remote Engagement) – UAS (Shooter) AWT (Designator)

This Scenario has the UAS Shooting while an AWT lases
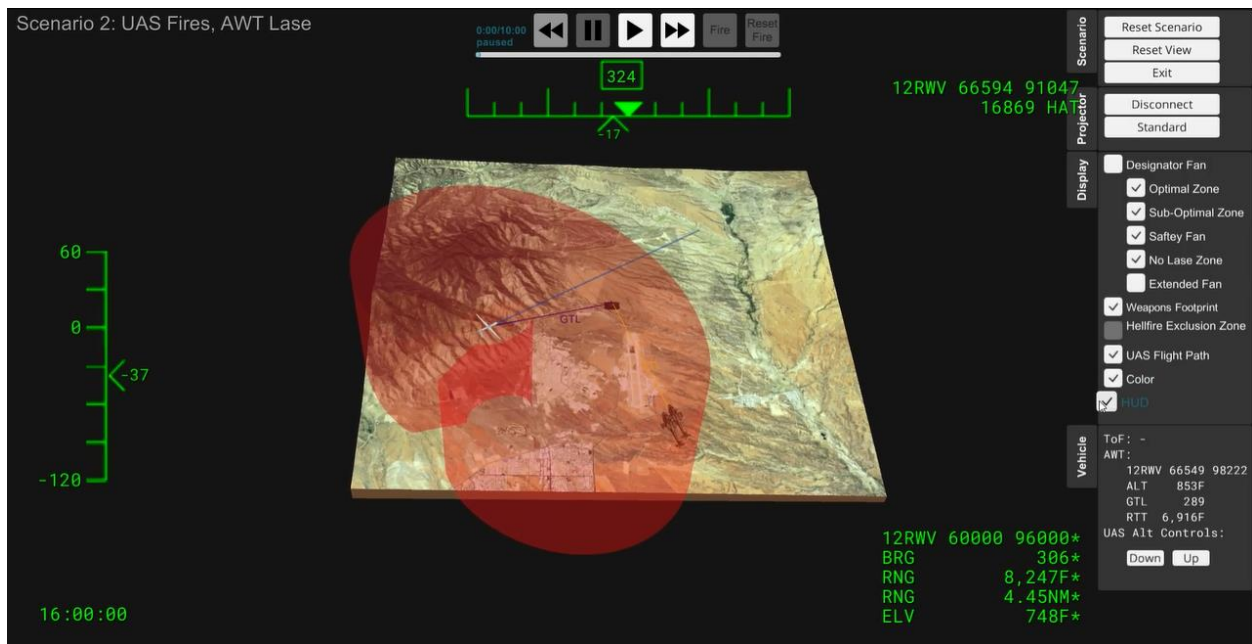
List of relevant elements

- UAS
- HUD
- UAS GTL
- UAS Flight Path
- UAS Weapons footprint
- Designator Fan
- AWT Team (two Apaches)
- AWT LTL
- Target

Instructor high level use case example

This is high level to show an example of how the tool will be used to teach the concepts.

Pre-instruction GUAVA set-up

- Assistant Instructor (AI) loads Scenario 2
- AI toggles-on the weapons footprint color by selecting Color button
- AI positions UAS to ensure that weapons footprint is red
- AI toggles-off the weapons footprint color by deselecting the Color button
- AI turns off the UAS flight path by deselecting the UAS Flight Path button
- AI moves terrain on 3 axis to best display initial content

Instructional Lead-in

"We are now going to discuss the second type of remote engagement" "This scenario depicts the remote scenario with the AWT designating and the UAS launching" "This is another of the minimum proficiency level scenarios you will be required to perform as a UAS crew during gunnery qualification at your homestation"

- PI toggles classroom display controls to show GUAVA on the big screen
- PI orients the class to the display
  - Libby Army Airfield
  - UAS
  - AWT
  - Target
- PI explains that the images shown within the tool are not what the student will see in the GCS.
- PI asks question
  - Q: What are the differences between this remote engagement and the one we just discussed?
  - A: UAS launching, AWT designating, no hellfire exclusion zone, weapons footprint, designator fan now aligned with UAS not AWT.

| PI Actions	AI Actions
• PI states that the GTL and LTL offset requirements are the same as previously discussed	• AI toggles-on the designator fan
• PI discusses how the designator fan moves with the GTL from the launching platform	• AI grabs UAS and moves it on the terrain
• PI discusses how designating and firing platforms have to move to align themselves into the optimum positions	• AI grabs the AWT and moves it to depict how the LTL moves with the AWT
	• AI clicks the Reset Scenario button to return the scenario to the default position.
• PL asks question • Q: As the launching platform, what does the GCS display provide that enables you to determine if the target is within range of the missile based on your altitude and location? • A: The horizontal weapons engagement zone or commonly referred to as the weapons footprint.	
	• AI toggles-on the weapons footprint
• PI discusses how the weapons footprint shape also changes based on the missile flight mode – High, Direct, and Low	• AI rotates the terrain to show the footprint from top-down view, side-view, and pseudo 3D-view.

PI Actions	AI Actions
• PI discusses what impacts the weapons footprint, i.e. slant range	• AI moves the UAS to depict how the footprint moves with the UAS.
	• AI changes UAS altitude to display how the weapons footprint changes shape
	• AI clicks the Reset Scenario button to return the scenario to the default position.
	• AI toggles-on the weapons footprint
• PI directs AI to click the play scenario button	• AI clicks Play button
• The UAS moves along its orbit with the attached GTL and weapons footprint.	
• The UAS weapons footprint moves over the target the footprint changes from red to green indicating the target is within range and location for the UAS to engage.	
• PI directs the AI to click the fire button	• AI clicks Fire button
• PI discusses R9 message sent to missile	
• The target is destroyed.	
	• AI clicks Reset Scenario button**Error! Reference source not found.**.

Check on Learning

- Question: What is the purpose of the weapons footprint?
- Answer: To inform the UAS crew when the target is within range of the missile
- Question: What color is the weapons footprint when the target is out of range of the missile
- Answer: Red

Scenario 3 (Autonomous Engagement [Inline and Offset]) – UAS (Designator/Shooter)

This scenario depicts the UAS designating and shooting the target in either an inline or offset engagement.
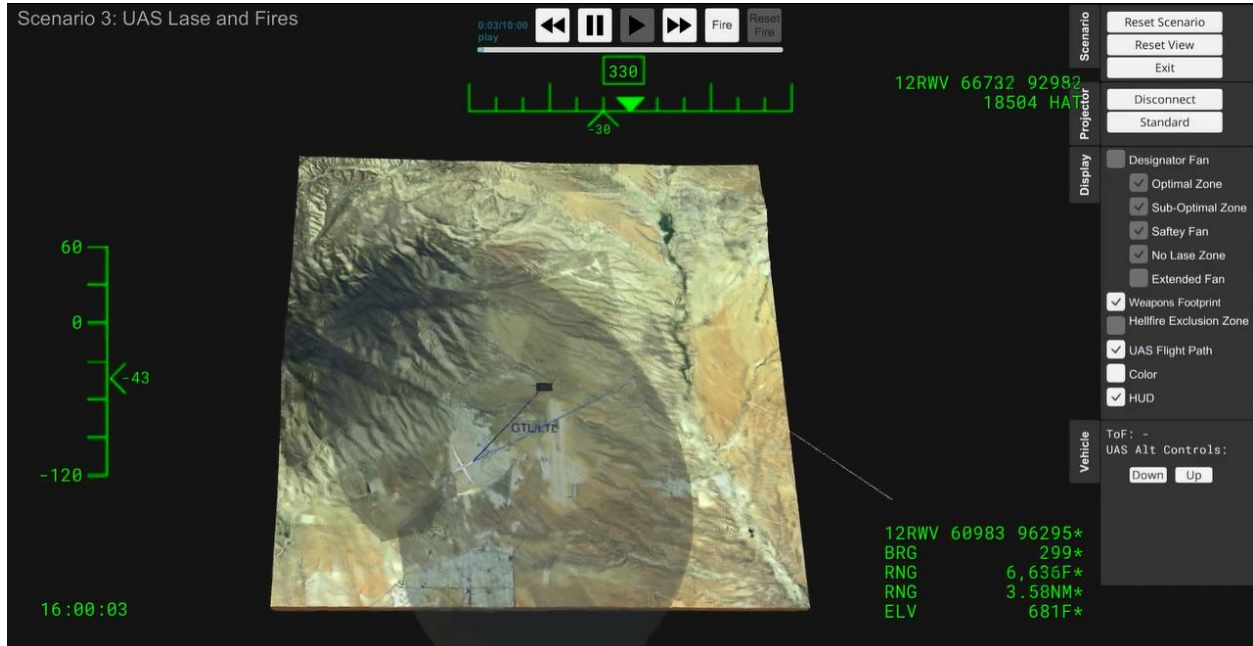
List of relevant elements

- UAS
- UAS LTL/GTL
- UAS Weapons footprint
- UAS Flight Path
- UAS HUD information
- Target

Instructor high level use case example

This is high level to show an example of how the tool will be used to teach the concepts.

Pre-instruction GUAVA set-up

- Assistant Instructor (AI) loads Scenario 3
- AI positions target from aircraft to ensure payload offset is greater than plus or minus 10 degrees
- AI positions UAS to ensure that weapons footprint is red
- AI turns off the UAS flight path by deselecting the UAS Flight Path button
- AI turns off the weapons footprint color by deselecting the Color button

- AI moves terrain on 3 axis to best display initial content

Instructional Lead-in

"The last scenario we will discuss is the autonomous engagement."

- PI toggles classroom display controls to show GUAVA on the big screen
- PI orients the class to the display
  - Libby Army Airfield
  - UAS
  - Target
- PI explains that the images shown within the tool are not what the student will see in the GCS.
- PI asks question
  - Question: "What is an autonomous engagement or autonomous laser designation?"
  - Answer: "An autonomous engagement or laser designation is when the aircraft launching the missile also provides the laser designation to guide the missile". TC 3-04.45 p. 14-53, para. 14-229.
- PI asks question
  - Question: As a GE AO and PO what are the two types of autonomous engagements you will be required to shoot?"
  - Answer: Inline and Offset. TC 3-04.45, p.7-2, Table 7-2.
- PI asks question
  - Question: What is the difference between an inline engagement and an offset engagement?"
  - Answer: In an inline engagement the seeker head is pointing within plus or minus 10 degrees off the nose of the aircraft, in an offset engagement the seeker header is pointing plus or minus 11 degrees or greater off the nose of the aircraft"

PI Actions	AI Actions
• PI asks question • Question:" What information provided on your GCS display would you use to position your aircraft and payload for an inline engagement?" • Answer: Aircraft heading and payload offset	
	• AI toggles on HUD by selecting HUD button
• PI orients the class to the HUD information	
• PI asks question • Q: What is the current payload azimuth in relation to the aircraft? • A: Read from HUD	
• PI asks question	

PI Actions	AI Actions
• Q: If the payload offset is greater than plus or minus 10 degrees, as a crew how and what do you adjust to ensure you are in line with the target? • A: UAS flight path heading	
	• AI toggles on UAS flight path by selecting UAS Flight Path button
• PI discusses how adjusting the flight path impacts the payload azimuth offset with a stationary/fixed target	• AI moves flight path to until payload offset is less than ±10 degrees from aircraft heading
• PI asks question • Q: Once you have adjusted your flight path to ensure your aircraft heading and the payload offset does not exceed ±10 degrees, how do you know whether or not you can launch the missile with a high probability of hitting the target? • A: Weapons Footprint	
• PI discusses Weapons Footprint characteristics • Color change • Size based on elevation changes • Slant range	• AI toggles-on the UAS weapons footprint and rotates the terrain to show the footprint from top-down view, side-view, and pseudo 3D-view
	• AI clicks on Color button
	• AI moves the UAS to depict how the footprint moves with the UAS.
	• AI grabs the UAS and changes the altitude to depict how the weapons footprint resizes.
	• AI clicks Reset Scenario button
• PI directs AI to play scenario	• AI clicks the play button and the UAS moves along the designated flight path with the weapons footprint adjusting to the direction of travel.
• PI directs the AI to pause the scenario	• AI clicks the pause button
• PI asks question • Q: Is this an inline or offset engagement? • A: Read from HUD	
• PI asks question • Q: When should you launch the missile • A:	
• PI discusses launch parameters	
• PI directs AI to play scenario	• AI clicks Play button
• PI directs AI to fire the missile	• AI clicks Fire button
	• AI clicks on Rest Scenario button

PI Actions	AI Actions
	• AI toggles-off HUD
	• AI moves the target to a position on a line greater than 10º from the flight path.
• PI asks question • Q: Is this an inline or offset engagement? • A: Read from HUD	
	• AI toggles-on HUD
• PI directs AI to play the scenario	• AI clicks the Play button
• PI directs AI to fire the missile	• AI clicks Fire button
	• AI clicks Reset Scenario button**Error! Reference source not found.**

Check on Learning

- Question: As a GE AO and PO what are the two types of autonomous engagements you will be required to shoot?”
- Answer: Inline and Offset. TC 3-04.45, p.7-2, Table 7-2.
- Question: What is the difference between and inline engagement and an offset engagement?”
- Answer: In an inline engagement the seeker head is pointing within plus or minus 10 degrees off the nose of the aircraft, in an offset engagement the seeker header is pointing plus or minus 11 degrees or greater off the nose of the aircraft”
- Question: If the aircraft heading is 180 degrees and the payload offset is -30, to what heading should you correct to conduct an inline engagement
- Answer: Between 140 and 160 degrees