"THE PASSAGE OF GREAT RIVERS IN THE PRESENCE OF THE ENEMY IS ONE OF THE MOST DELICATE OPERATIONS IN WAR." - FREDERICK THE GREAT

Army Relevance: Deliberate wet gap crossing in real-world instances poses several challenges; one is the need for extensive communication between multiple, potentially decentralized, military entities and personnel to design and implement a customized strategy in "real time". The difficulty of this challenge is exacerbated as it must be executed an enemy decisive point [2] in the presence of enemy forces and over distances that exceed 20 meters [1]. Current solutions to performing deliberate wet-gaps crossings includes the assembly and implementation of floating bridge sections that are subsequently used to transport military vehicles, supplies and personnel across bodies of water [1]. Based on the assigned tasks, communication challenges, and imposed threats, *the 2019-2020* CCDC HBCU/MSI Undergraduate Student Design Competition challenges participants to provide novel and innovative solutions to problems presented by deliberate wet gap crossing focusing on the fundamentals of gap crossing: *surprise, extensive preparation, flexible planning, traffic control, organization and speed[1].*

Surprise: Utilizing the element of surprise, we propose to implement threat elimination strategy as our first design element.

Design Goal 1: Tank Design and Threat Elimination

- For this process one of the three wheeled robots, designated for the 'tank' will be retrofitted to accommodate a pistol seat and trigger mechanism for the nerf jolt turret (see figure 1). The gun is positioned upside-down to accommodate ease of reloading and attachment and allow moving parts of the weapon to operate unobstructed. The holster adjustment will be designed in Autodesk Fusion 360 and 3D printed using PLA/ABS filament to be attached to the Nvidia Kaya robot.
- To fire the weapon, a solenoid will be attached to the trigger of the turret and connected to a vertical solenoid that will be instantiated via the 'fire at enemy' command developed in the Jetson Nano development kit (see Figure 1).
- Programmatically the algorithms for 'return for reload', 'fire at enemy', and 'cross the bridge' will all employ use of *isaac.navigation.LocalizeBehavior* methods to remain on the Ground area while concurrently implementing *isaac.perception.AprilTagsDetection* to locate April tags placed on Threats and at reload area. Once AprilTag goals are identified the tank will instantiate the *isaac.navigation.GoTo* function to travel to that location and orient itself to a designated state. The tank should make use of obstacle detection and avoidance capabilities.

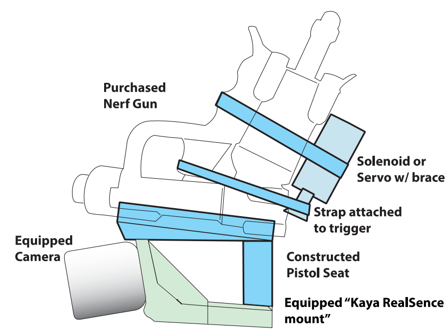

Figure 1. Threat Elimination Tank Modification

Extensive Preparation, Organization and Flexible Planning: Our ground vehicle and tank to work autonomously requires our team to carefully map out and test our algorithms and map layouts prior to implementation. Additionally, the implementation of an autonomous plan of action allows our solution to be agile enough to continue working if the threat has not been eradicated early in the maneuver.

Design Goal 2: Ground Vehicle and Tank Autonomy

- The ground vehicle will only function using two commands 'place bridge section in water' and 'cross bridge'. The ground vehicle will sit in a rest state until it receives a notification signal from the boat. The boat can send two commands to the ground vehicle
  - 'all clear': to instantiate the 'place bridge section in water' when the previous section has been moved away from the edge and the water loading area is clear to receive the next section.
  - 'crossing available': to prompt the ground vehicle to return to embarkment point and cross the bridge.
  - The ground vehicle, upon bridge dis-embarkment will send an 'all clear' message to the tank to complete the same pathway to the other side of the wet-gap.
- The 'place bridge section in water' algorithm will make use of *Yolo TensorRT Inference* to train the ground vehicle and boat locate the nearest bridge pieces in order to move them into places identified in our bridge assembly plan.

Traffic Control and Speed: Gap crossings often require a bottlenecking of resources as it traverses temporary bridging. Control of traffic through the gap is a feature provided in Design Goal 3 as the boat serves as the facilitator of triggers to the other vehicles in play when the area is clear for movement. Applying magnetic connectors to our bridge pieces will significantly decrease the time it will take to assemble and maneuver the bridge into place.

Design Goal 3: Bridge Assembly

Our bridge assembly process will be completed in its entirety by the "boat". While it is permissible for the "ground vehicle" to assist in this process, we believe the simplest and most time efficient approach involves treating both the "tank" the "ground vehicle" as cargo. To test this theory, we generated a prototype of the boat by 3D-printing the "plow" from the NVIDIA robot and attaching it to a remote- controlled vehicle (see figure 2) and used it to test an an "all-boat" approach (see figure 3). Briefly, in our approach, the boat will move bridge piece #4 to the opposite side of

Figure 2. Boat Prototype The plow from the NVIDAI robot was 3D-printed and affixed to the front of a remoted controlled car

the water (figure 4A,B). The boat will then move bridgepiece #5 in the water, but adjacent to its initial landspace (figure 4C). Next, the boat will move bridgepiece#3 adjacent to bridgepiece#5 and the ground vehicle will move onto bridgepiece#5 (figure 4). The boat will then move bridgepiece#2 , adjacent to bridgepiece#3 and the ground vehicle will move to bridgepiece#3 (figure 3E). Next the boat will move bridgepiece #1 between bridgepieces 2&4 and the tank will enter the bridge and move to position 2 (figure 3F). Finally, the tank and the ground vehicle will complete the gap-crossing by traversing the bridge (figure 3G&H).

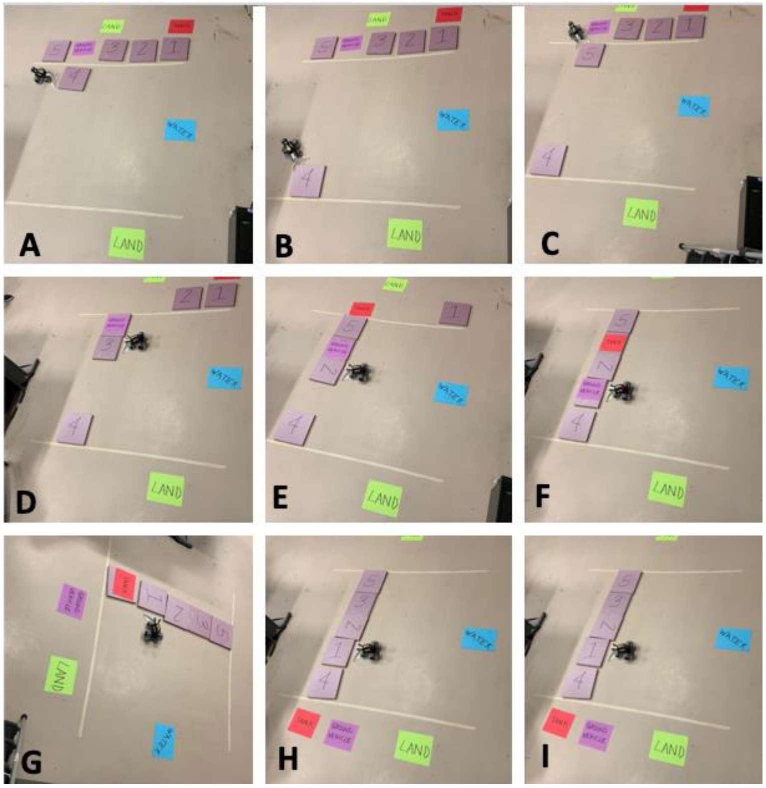

Figure 3. Bridge Assembly Approach

Past Performance: Spelman College was a proud participant in the inaugural CCDC HBCU/MSI Undergraduate Student Design Competition in April of 2019, which was held at the University of Texas at El Paso. Our participation stimulated innovation and allowed our students to engage with ARL technical and operational communities. **We are proud to share that the Spelman College Drone Team, the only all African American and all-women's team, placed fourth and was awarded a check in the amount of $2000.00.** This was a huge accomplishment for Spelman, as innovation is heavily encouraged and supported. We would also like to highlight what we consider to be another major success and benefit of our past participation in the inaugural CCDC HBCU/MSI Undergraduate Student Design Competition. **One of our Spelman team members, Ms. Ashley Townsel, a graduating senior at the time, was able to demonstrate her interest in bio-engineering and by sharing her dedication to a career in this field with ARL staff, was able to secure a Journeyman Post Baccalaureate Fellowship with ARL, which she began in August of 2019.** This was one of the most positive, yet unexpected, benefits of Spelman's participation in the CCDC HBCU/MSI Undergraduate Student Design Competition. One that we hope to see more of in the future as we attempt to continue to nurture our relationship with ARL and expose our students to ARLs staff and technical challenges.

References

[1.] Operations, C. A. G. C. (2008). Field Manual No FM 3-90.12/MCWP 3-17.1 (FM 90-13). *Headquarters Department of the Army Washington, DC*, *1*.

[2] Army Doctrine and Reference Publication 3-0. Unified Land Operations. Washington, DC: Government Printing Office, 2012