Electromagnetic launch modification to C3 launcher for increased velocity NLV-018-21, Year 1 of 3

Cameron Hawkins(PI)[1], Russel Howe[1], James Majdanac[1], Michael Blasco[1], Sarah Thomas[1], T. Greg Engle[2], Seth Hartman[3], Erik Timpson[3]

[1]Mission Support and Test Services, LLC; [2]University of Missouri; [3]Kansas City National Security Campus

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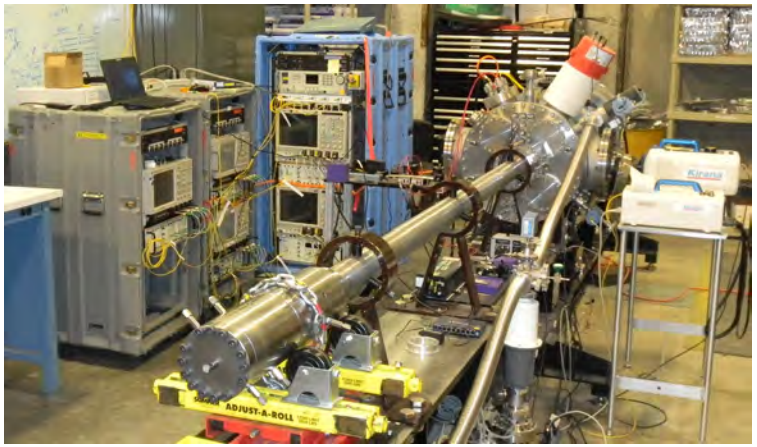
Challenge

Create a new capability to execute mission-critical Stockpile Stewardship investigations

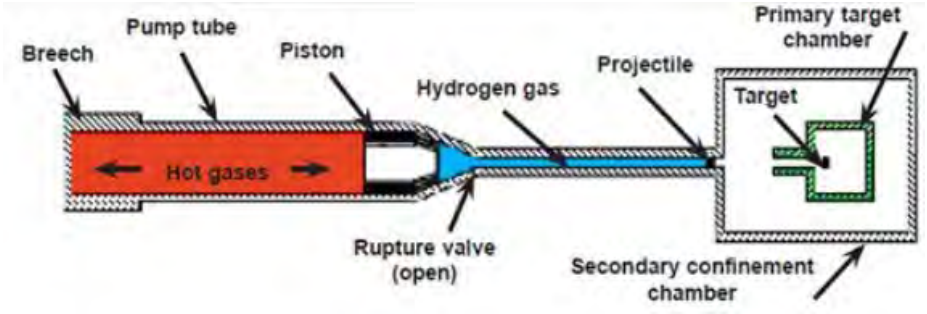
- Develop a hybrid electric-gas launcher to perform large bore experiments at high velocities with good repeatability.
- To be incorporated into the existing C3 launcher platform to prove the capability before moving this new capability to the JASPER platform.
- This solution has the potential to
  - Reduce operational cost and improve experimental cadence and repeatability at JASPER
  - Provide a high velocity large bore (3-inch) launcher platform at C3.

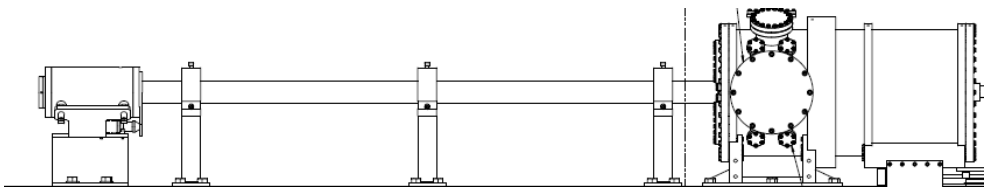


- Higher performance launcher(s) could
  - Provide opportunities to pursue a wider range of weapons-relevant science
  - Improve ability to perform diagnostic shakeouts on MSTS systems before delivery/use at other locations/lab customers
  - Improve our ability to flesh out designs for our JASPER/LLNL customers.

Innovation

- The C3 launcher will be used to conceptualize/model/flesh out the proposed hybrid electric-gas launcher prototype design, which will prove the technology at the end of the project.
  - Typically available technologies: powder guns, single-stage gas guns, two-stage light gas guns.
- This is a completely novel approach to two-stage gas gun operation and will position MSTS as a clear innovator in this competitive and challenging field of study.
- Our key partnerships with the KSNSC and MU Electrical Engineering laboratories will complement expertise at MSTS and provide this project with the complete technical skill set required to execute its objective.
- At the end of this 3-year study, we plan to have designed, built, and tested the new launcher system.



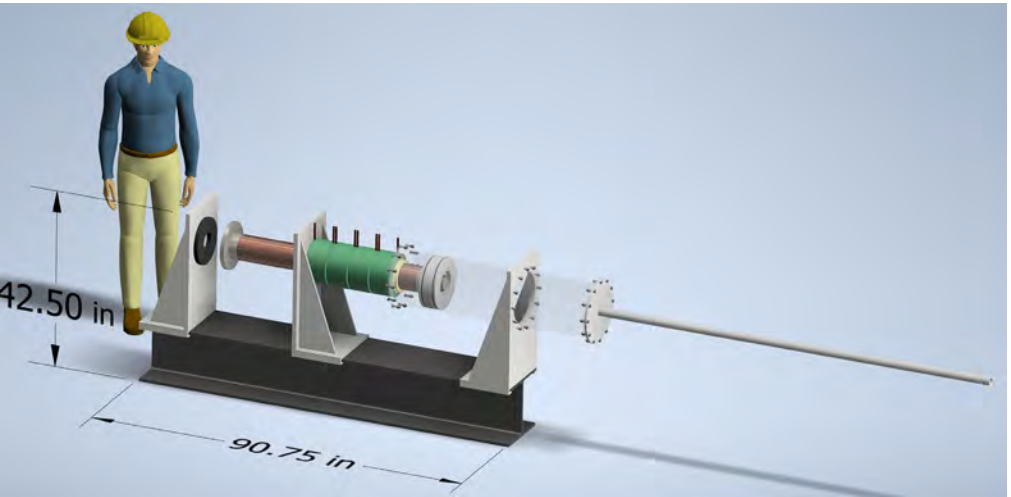


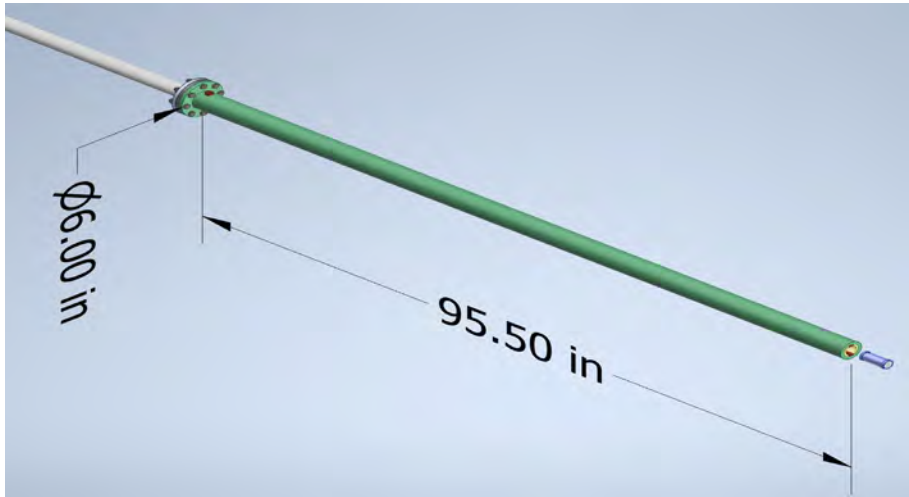
Technical Approach

- Late start to the project this year due to MU Task Order and Non-disclosure Agreement required by KCNSC.
- Conducted kickoff meeting with MSTS/KCNSC/MU in March.
- MU conducted research/prelim design of EML by first conducting a study of pre- vs. post-stage to the C3 launcher and then further refining chosen design path.
- KCNSC funded through their PDRD (providing a unique partnership and significant cost savings to SDRD) began work on the development of the pulsed power and pulse forming network that will ultimately be paired with the C3 launcher to prove this new technology.
- MSTS team began design of interface components for the HEML to the C3 launcher and began calculations/analysis of the platform for the increased pressure/velocity.

Technical Approach

- During FY21, we determined what EML technology was most suited to the launcher (pre- or post-stage).
- Two options were evaluated and considered:
  - Post-stage railgun – Higher risk because it requires extensive modifications to the C3 launcher and its projectiles and because it needs to accelerate a projectile initially traveling at ~1000 m/s to an even higher velocity. Railguns not only require much larger currents than helical launchers but have well-known performance issues at ~1000 m/s and greater.
  - Pre-stage helical – Requires fewer modifications to the existing C3 launcher and its projectiles as well as having a lower risk and higher performance for this application compared to the railgun.



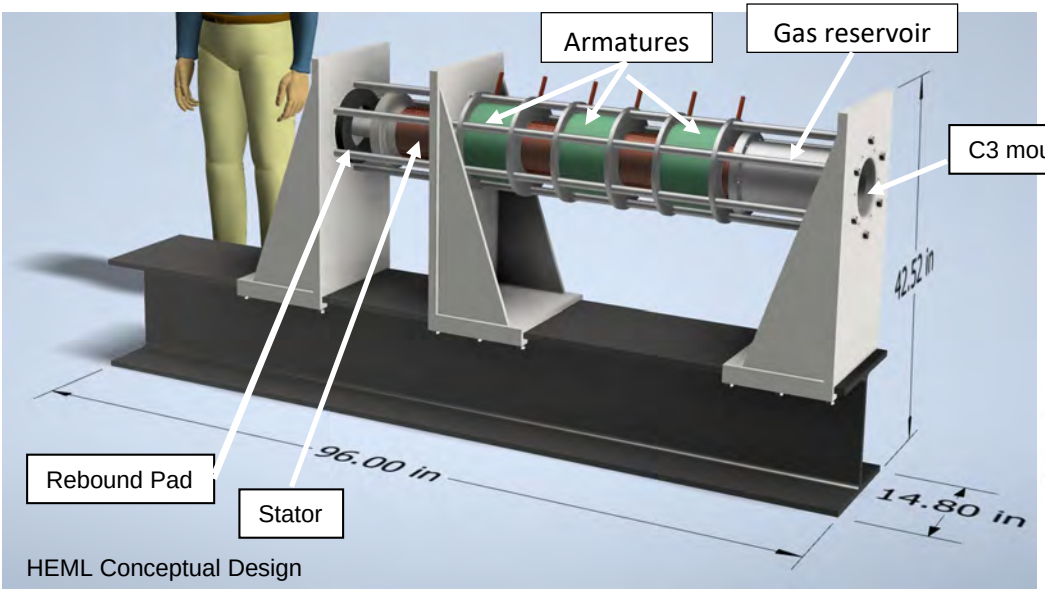


Results

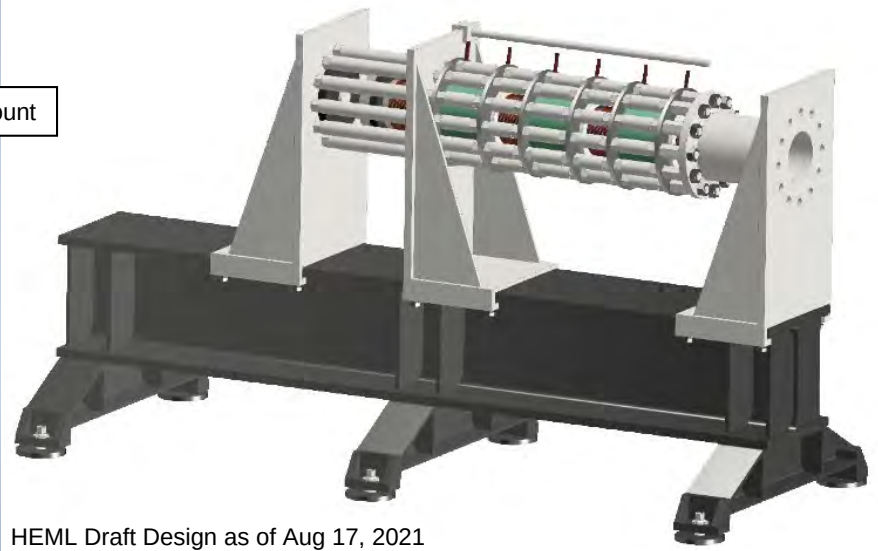
- Add a second pre-stage (Helical EML) to the C3 launcher
  - Three subsystems: a driver stage, a pulse forming network to provide the specific electrical impulse, and a control system to operate the puled power unit, triggering systems, and diagnostics.
- Helical EML systems
  - Use pulsed power drivers to achieve reliable, controllable electrical power to enable high shot-to-shot consistency.
  - High impedance devices that can generate a given force at significantly lower currents in comparison to railguns.
  - Relatively small footprint, compatibility with the existing control system, easy maintenance and long lifetime, and a high degree of worker safety via engineering and administrative controls.

Results

- This new helical pre-stage will compress helium from a lower pressure to a higher pressure.
  - First pressurize the HEML reservoir (for example, 3ksi).
  - Power is then applied to the HEML armatures, causing the stator to push the piston forward (~100s of milliseconds) and compress the gas to the desired ratio (for example, 9ksi).
  - Then the projectile is launched when the petal valve burst pressure is reached.
- Models of the pre-stage helical launcher indicate
  - A 1600 V capacitive PFN supplies power with a 10kA peak current pulse.
  - Tentative stator diameter of 6 in. and a length of about 6 ft.
  - Three armatures used to push the stator (and piston) to compress the helium in the reservoir.

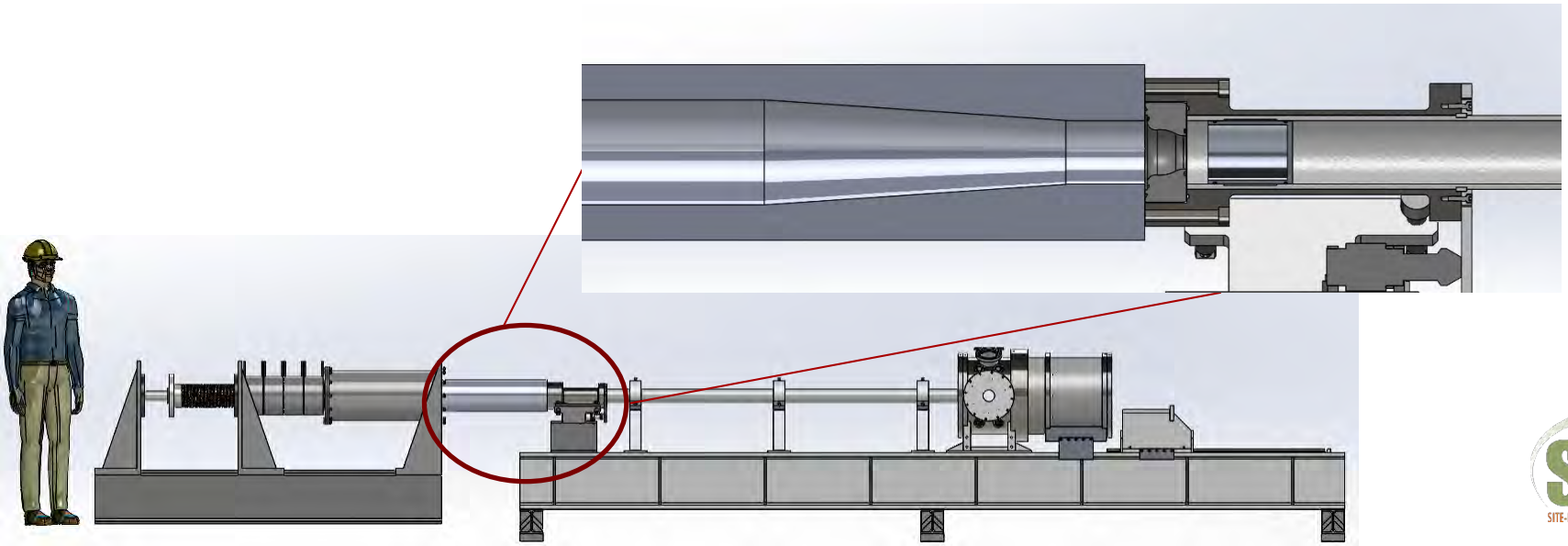


HEML Conceptual Design


HEML Draft Design as of Aug 17, 2021

Results

- To pair this new stage to the existing C3 launcher platform, a petal valve will be used in a similar fashion to JASPER.
  - This will also ease the transition of this new technology to that platform, replacing its powder stage with this newly developed HEML stage.
- Our goal is to design and build a system capable of compressing the gas at a ratio of 1:3 with a maximum of 10ksi, limited by costs and the current allowable pressure of the C3 launcher platform components.
- The petal valve will be designed to release at the requested pressure (3ksi, 10ksi, etc.), which will then propel the projectile forward down the barrel into the target in the diagnostic tank.



Summary of Results, Path Forward

- In year 1, we determined the configuration of the system, and MU designed the HEML portion. MSTS began design of the launcher interface components that will connect the C3 launcher to the HEML as well as needed calculations for the HEML system. KC began their designs on the PFN that will be used to prove the technology.
- In year 2, MU will build a mock-up of their HEML design to confirm the modeling results and then begin purchasing the components for the full HEML system so this can be assembled. MSTS will also be finishing the design of the launcher interface components, and KC will continue their design of the PFN.
- In year 3, MSTS will begin procurement of the launcher interface components and complete assembly of the full final system on the C3 launcher, including the PFN. We will then conduct experimental campaigns to prove the technology.
- The PFN will need to be procured/assembled for permanent use at C3.

Impact

- Hosted a tour of high level KCNSC personnel at C3 and JASPER
  - David McMindes — Director of Program Development
  - Dan Bowen — Chief Scientist (Sr Engineer Fellow)
  - Dan Krueger — Engineer Fellow
  - John Jungk — Chief Technology Officer
  - Seth Hartman — Sr. Electrical Engineer
  - Mitchell Morrow — Test and Measurement Center of Excellence Leader