DEPARTMENT OF THE ARMY
Holston Army Ammunition Plant
4509 West Stone Drive
Kingsport, TN 37660

April 01, 2019

Ms. Michelle Walker Owenby, Technical Secretary
Tennessee Department of Environment and Conservation
Division of Air Pollution
William R. Snodgrass Tennessee Tower
312 Rosa L. Parks Ave, 15th Floor
Nashville, TN 37243

Dear Ms. Owenby,

Holston Army Ammunition Plant (HSAAP) is pleased to present the "Thermal/Non-Thermal Solutions to Open Burning" (Open Burning Phase 2) report for your records. The purpose of this report is to present a detailed summary of the site specific research conducted by HSAAP on potential alternative technologies. This report concludes the second phase of a four-phased approach, established by HSAAP, to seek alternatives to open burning.

My point of contact for any questions is Laura Peters at phone: (423) 578-6193 or email: laura.l.peters15.civ@mail.mil.

Sincerely,

Luis A. Ortiz
Colonel, U.S. Army
Commanding

DISTRIBUTION STATEMENT A. APPROVED FOR PUBLIC RELEASE

FINAL REPORT

Thermal/Non-Thermal Solutions to Open Burning Holston Army Ammunition Plant (HSAAP)

Publically Releasable Version
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LIST OF ACRONYMS

ALARP	As Low as Reasonably Practicable
APC	Air Pollution Control (equipment)
ARDEC	Armament Research, Development and Engineering Center
BAE-OSI	BAE Systems, Ordnance Systems Inc.
CAA	Clean Air Act (and amendments)
CBC	Contained Burn Chamber
CBF	Car-Bottom Furnace
CDC	Contained Detonation Chamber
CO_2	Carbon Dioxide
CONUS	Continental United States
COTS	Commercial Off-the-Shelf
CWA	Clean Water Act
CWP	Contaminated Waste Processor
DAVINCH	Detonation of Ammunition in a Vacuum-Integrated Chamber
DDESB	Department of Defense Explosives Safety Board
DoD	Department of Defense
DoDI	Department of Defense Instruction
EA	Environmental Assessment
FBI	Fluidized Bed Incinerator
FF	Flashing Furnace
FOD	Foreign Object Debris
GAO	United States Government Accountability Office
GIS	Geographic Information System
GPCR	Gas Phase Chemical Reduction
HEW	Hazardous Explosive Waste
HMX	High Melting Explosive
HSAAP	Holston Army Ammunition Plant
HWC	Hazardous Waste Combustor
IBD	Inhabited Building Distance
ILD	Intraline Distance
IMD	Intermagazine Distance
IMX	Insensitive Munitions Explosives
IPT	Integrated Project Team
iSCWO	Industrial Super-Critical Water Oxidation
JMC	Joint Munitions Command
LBP	Lead-based paint
MBR	Moving Bed Reactor
MDAS	Material Documented as Safe
MDEH	Material Documented as an Explosive Hazard
MPF	Metal Parts Furnace
MPPEH	Material Potentially Presenting an Explosive Hazard
NAAQS	National Ambient Air Quality Standards

NASEM	National Academies of Sciences, Engineering, and Medicine
NDA	Non-Disclosure Agreement
NDI	Non-developmental items
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NEW	Net Explosive Weight
NHCW	Nonhazardous Combustible Waste
NHNCW	Nonhazardous Noncombustible Waste
NPDES	National Pollution Discharge Elimination System
OB	Open Burning
OBG	Open Burning Grounds
PCB	Polychlorinated biphenyls
PDJS	Project Director Joint Services
PEP	Propellant, Energetic, and Pyrotechnic Materials
PHA	Process Hazard Analysis
PPE	Personnel protective equipment
PTRD	Public Traffic Route Distance
QD	Quantity-Distance
RCRA	Resource Conservation and Recovery Act
RDX	Research Department Explosive
RFI	Request for Information
RKI	Rotary Kiln Incinerator
SDC	Static Detonation Chamber
SME	Subject Matter Expert
SOP	Standard Operating Procedure
TDEC	Tennessee Department of Environment and Conservation
TNT	2,4,6-Trinitrotoluene
TPY	tons per year
TRL	Technology Readiness Level
TSCA	Toxic Substances and Control Act

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EXECUTIVE SUMMARY

The Holston Army Ammunition Plant (HSAAP) currently open burns explosive waste and potentially explosive contaminated waste generated on-site. These wastes are generally characterized into one of three categories:

- Hazardous explosive waste (HEW) (open burned in pans)
- Non-hazardous combustible waste (NHCW) (open burned in cages or pile)
- Non-hazardous non-combustible waste (NHNCW) (open burned in a pile)

In 2015 the United States Army (U.S. Army) and BAE Systems, Ordnance Systems, Inc. (BAE OSI) began a phased program to evaluate and potentially implement alternatives to open burning. The first phase was a waste identification and quantification effort to ensure alternative technologies could be fully evaluated against site-specific waste streams and volumes. The second phase, which began in September 2017, was an evaluation of mature thermal and non-thermal technologies against the waste materials identified in Phase 1 and current waste material volume projections. This report is a deliverable for Phase 2.

The objective of the Phase 2 project was to evaluate Commercial Off-the-Shelf (COTS) / Non-Developmental Item (NDI) alternative thermal and non-thermal treatment solutions to reduce and/or eliminate open burning of the above-listed waste streams. BAE OSI compiled a multidisciplinary Integrated Project Team (IPT) to assist with project execution. The BAE OSI team includes engineering disciplines (process/chemical, mechanical, electrical, and civil), safety, environmental, project management representatives (supported by Contracting and Subcontracting assistance), and a subject matter expert (SME) with extensive experience in the treatment of energetic wastes. The U.S. Army was represented on the IPT by individuals from the Office of the Project Director Joint Services (PD JS), the Armament Research, Development and Engineering Center (ARDEC), Joint Munitions Command (JMC), and the local HSAAP Army Staff.

Project tasking included communicating with commercial vendors who provide potential thermal and non-thermal treatment alternatives to open burning (OB), establishing evaluation criteria, establishing current and anticipated volumes of HEW/NHCW/NHNCW, evaluating commercial treatment technologies against the waste volumes and evaluation criteria, reporting on each specific technology, and generating a final report. Requests for Information (RFIs) were sent to potential technology vendors to initiate the data collection effort. Based on the responses received, the IPT identified promising vendors to gather additional information from and to visit. BAE OSI used all the gathered data to evaluate the technologies against Threshold Criteria, which determined if a technology was potentially viable for implementation at HSAAP. Technologies meeting or exceeding Threshold Criteria were further evaluated against Modifying Criteria and compared to each other.

After evaluating twenty-five separate technologies, BAE OSI, with IPT input, concluded five thermal technologies were potentially viable for application at HSAAP. While these technologies are considered potentially suitable for application at HSAAP, no single solution will treat all of the generated waste streams and each also has specific constraints to the unique challenges at HSAAP. The five potentially viable technologies are:

- Flashing Furnace (also referred to by other industry names)
- Contained Burn Chamber (CBC)
- Static Detonation Chamber (SDC)
- Moving Bed Reactor (MBR)
- Rotary Kiln Incinerator (RKI)

Vendors of the latter four technologies recommended combining a Flashing Furnace with their respective technology to treat the waste streams generated by HSAAP. Except for the Flashing Furnace and RKI, each of the three other technologies has one major supplier who is typically responsible for the design and construction of their technology. The systems are generally proprietary.

BAE OSI developed this report summarizing the assessment of the treatment systems inclusive of technical maturity, safety, environmental permit attainability, facility siting, operational feasibility, and commercial availability. Capital and operating expenditures were also reviewed, but not used as evaluation criteria. Until technology(s) are selected, designed, approved, installed, and commissioned, OB practices to treat HEW, NHCW, and NHNCW must continue at HSAAP in compliance with all environmental regulations and permits.

1.0 PROJECT OVERVIEW

Spanning more than 6,000 acres in Kingsport, Tennessee, the Holston Army Ammunition Plant (HSAAP) is a major supplier of explosive materials (primarily RDX-, HMX-, and IMX-based products) to the United States (U.S.) Department of Defense (DoD). The facility is operated by BAE Systems, Ordnance Systems, Inc., (BAE OSI) and is equipped with state-of-the-art equipment and capabilities for nitration chemistry, acid handling and recovery, and other chemical processing operations. Various hazardous and non-hazardous waste streams are generated by these manufacturing operations. In addition, demolition waste is generated from ongoing facility modernization projects, maintenance, and repairs. All these wastes require treatment and/or disposal.

1.1 Project Background

HSAAP is a manufacturer of explosive materials and as such, is a generator of wastes that include secondary explosives or material that has potentially been contaminated with them. HSAAP generally categorizes these waste streams as one of the following:

- Hazardous explosive wastes (HEW) (also referred to as bulk explosives), including off-specification material and wetted explosives captured in the catch basins that are generated in the manufacturing process and can contain foreign object debris (FOD) and mixed explosive materials;
- Non-hazardous combustible wastes (NHCW), such as plastic, personal protective equipment, rubber, cardboard, and wood that are potentially contaminated with explosives; and,
- Non-hazardous non-combustible wastes (NHNCW) from modernization, demolition, or maintenance projects, such as metal, concrete, and dirt that are potentially contaminated with explosives.

The DoD classifies material that has potentially been contaminated with explosives as either Material Potentially Presenting an Explosive Hazard (MPPEH), Material Documented as Safe (MDAS), or Material Documented as an Explosive Hazard (MDEH). These terms are defined below per DoD Instruction (DoDI) 4140.62:

- MPPEH is material owned or controlled by the DoD that, before determination of its explosives safety status, potentially contains explosives or munitions or potentially contains a high enough concentration of explosives that the material may present an explosives hazard.
- MDAS is MPPEH that has been assessed and documented as not presenting an explosive hazard and for which the chain of custody has been established and maintained.
- MDEH is MPPEH that cannot be documented as MDAS, that has been assessed and documented as to the maximum explosive hazards the material is known or suspected

to present, and for which the chain of custody has been established and maintained (DoDI 4140.62, 2017).

BAE OSI currently open burns NHCW and NHNCW listed in Section 1.1 at the on-site Open Burning Grounds (OBG) in order to achieve MDAS. Under DODI 4140.62, MDAS can be achieved in one of three ways: a Department of Defense Explosive Safety Board (DDESB) approved treatment method, certified uncontaminated after a 100% visual inspection by two qualified personnel (2x100%), or the use of expert knowledge. DDESB approval for MDAS is a lengthy and detailed review/investigation into the method to ensure that in all cases the material is in fact MDAS after treatment. Any technology that is not approved by DDESB will still require all material to complete the 2x100% inspection, which is not always possible for some materials, and limits disposal of the material to the onsite landfill. Certain items have cavities that are not accessible for inspection. Any material that cannot be 2x100% inspected would still require treatment by an approved method. Considering the volume of material and the fact that 2x100% inspection is not error-free, it is not the preferred method. Use of expert knowledge by two qualified individuals allows diversion of items determined to be MDAS but is also not error-free.

HSAAP open burning (OB) operations are conducted in compliance with existing permits issued by the Tennessee Department of Environment and Conservation (TDEC). These permits dictate operating parameters (e.g., time of day, weather conditions) and set a maximum annual treatment throughput and operating time. HEW is treated on a periodic basis via OB in specially designed pans. NHCW is open burned in cages and pile, and NHNCW is open burned in a pile. After processing at the burning grounds, these materials are deemed safe for disposal in either HSAAP's landfill or sent off-site for recycling.

Current and projected quantities of these materials were estimated by BAE OSI, with input from the U.S. Army, from updated waste tracking methods and the most current volume data available. Projections are based on planned increases to manufacturing capacities and associated waste generation. These estimates are subject to variation based on changes in production rates and types of materials, and on-site activities such as renovation/demolition of buildings. These quantities were used to estimate location and technology throughput parameters during this study.

1.2 Objectives

This project is the second of a planned, four-phased approach to determine whether safe treatment alternatives that fit within the constraints of the installation exist to address HSAAP waste streams currently treated through OB. The first phase determined the types and quantities of materials currently being open burned at HSAAP. The second (current) phase of the project investigated alternatives to open burning at HSAAP. If any potentially viable alternatives are selected for implementation, the planned third and fourth phases of the project are to design and build the OB alternative(s) at HSAAP.

Under contract with the U.S. Army, BAE OSI conducted this study to evaluate alternative disposal methods to OB for HEW, NHCW, and NHNCW. The objective was to review and evaluate Commercial Off-the-Shelf (COTS) / Non-Developmental Item (NDI) alternative thermal and non-thermal treatment solutions to reduce and/or eliminate open burning of MPPEH and MDEH at HSAAP. Specific HEW, MPPEH and MDEH materials evaluated for alternatives in this study may include, but are not limited to, the following:

- Metal (tanks, process vessels, structural steel, piping, valves, flanges, ladders, etc.)
- Wood (clean, treated, manufactured, modified, plywood, etc.)
- Plastic (drum liners, bags, trash bags, used personal protective equipment [PPE], packaging, Teflon items, hose parts, etc.)
- Cardboard (fiber drums, boxes, packaging, etc.)
- Concrete (block, brick, excavated material, etc.)
- Dirt (contaminated soil, contaminated rock, contaminated gravel, etc.)
- Other (cotton: lab coats, coveralls, hats, paper towels, filters, dewatering filter socks, etc.)
- Uncharacterized (rubber hoses, tubing, etc.)
- Waste Explosives (out of specification material, catch basin explosives, etc.)
- Items contaminated with polychlorinated biphenyls (PCBs) below regulated limits
- Items contaminated with lead-based paint (LBP)

1.3 Integrated Project Team

BAE OSI compiled a multidisciplinary Integrated Project Team (IPT) to evaluate OB alternatives. This team included representatives from BAE OSI, the U.S. Army, and a subject matter expert (SME) with extensive experience in the treatment of energetic wastes. The BAE OSI members represented engineering, safety, environmental, and project management disciplines located at HSAAP. The U.S. Army was represented by members from the Office of the Project Director Joint Services (PD JS), the Armament Research, Development and Engineering Center (ARDEC), JMC, and the local HSAAP Army Staff.

2.0 APPROACH

BAE OSI's approach to the project included establishing current and anticipated volumes of HEW/NHCW/NHNCW, establishing evaluation criteria, communicating with commercial vendors who provide potential thermal and non-thermal treatment alternatives to OB, evaluating plant locations available for siting potential alternative technologies, evaluating commercial treatment technologies against the waste volumes and evaluation criteria, reporting on each specific technology, and generating a final report. Requests for Information (RFIs) were sent to potential technology vendors to initiate the data collection effort. The IPT used SME knowledge to identify vendors of technologies deemed potentially suitable for application at HSAAP. Based on the responses received, BAE OSI identified promising vendors to gather additional information from and to visit. BAE OSI used all the gathered data to assess the technologies against evaluation criteria and determined their viability for implementation at HSAAP.

2.1 Evaluation Criteria Development

The IPT developed initial requirements and evaluation criteria and then refined them over a period of several weeks at the outset of the study. The criteria discussed included safety, Quantity-Distance (QD) arc requirements for siting purposes, Technology Readiness Level (TRL) requirements, operations and maintenance impacts, a required schedule for implementation, performance, permit attainability, permit risks, impacts to the environment, and waste streams generated along with available abatement systems and ability to handle generated waste streams.

To be considered potentially feasible as an alternative to OB at HSAAP, a technology had to be able to comply with the following regulatory requirements:

- DDESB Requirements
- Department of Defense Instruction (DoDI) 4140.62
- BAE OSI safety requirements and Standard Operating Procedures (SOPs)
- TDEC Air Quality Regulations
- TDEC Hazardous and Solid Waste regulations
- National Ambient Air Quality Standards (NAAQS) and attainment status
- Resource Conservation and Recovery Act (RCRA)
- Toxic Substances and Control Act (TSCA)
- Clean Water Act (CWA)
- Clean Air Act (CAA)

Other considerations for potential viability included, but were not limited to, the following:

- Availability of the technology in the commercial market.

- Requirements for procedural changes and equipment needed to safely process MPPEH and MDEH materials.
- The ability to safely site the technology including considerations for required utilities, access to fuel sources, Safety QD arcs, and site preparation requirements.
- Potential for waste to energy solutions that can be incorporated into the technology.

BAE OSI defined Threshold and Modifying Criteria based on these considerations. A Threshold Criterion is a requirement of the technology that cannot be compromised. If the technology does not meet these criterions, then it cannot be implemented at HSAAP. A Modifying Criterion is a characteristic of the technology that is preferred. Modifying Criteria are used to compare and contrast technologies to one another. The following subsections provide a detailed description of the evaluation criteria and how they were applied to the technologies.

2.1.1 Threshold Criteria

The IPT's objective was to identify mature, safe, and environmentally permittable alternative technologies for operation at HSAAP. The IPT defined threshold criteria for technical maturity, safety, and permit attainability, which are discussed below. Initial viability of a technology was determined if it met or exceeded threshold criteria.

2.1.1.1 Technology Readiness Level

The U.S. Government developed a Technology Readiness Level (TRL) scale that is used to measure the maturity of a technology or product. The scale ranges from 1 to 9, with lower rankings assigned to less developed, or lower-maturity level, technologies. Table 1 provides an overview of the TRL ratings (GAO, 2016). For this project, a waste-specific TRL was assigned to each technology. Additionally, the overall TRL assigned by the IPT reflects the technology's application to its intended waste stream as designed. The IPT assigned HSAAP waste-specific TRLs based on an evaluation of the technology's maturity for treating HSAAP's HEW, NHCW, and NHNCW. Only technologies with a HSAAP waste-specific TRL of 8 or above were considered potentially viable for near-term implementation at HSAAP. As shown in the table, a TRL 8 is assigned when an actual system has been completed and qualified through test and demonstration.

Table 1: Technology Readiness Levels (GAO, 2016)

TRL	Description
1	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples include paper studies of a technology's basis properties.
2	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.

4	Basic technological components are integrated to establish that they will work together. This is relatively low fidelity compared with the eventual system. Examples include integration of ad hoc hardware in the laboratory.
5	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements, so they can be tested in a simulated environment. Examples include high fidelity laboratory integration of components.
6	Representative model or prototype system, which is well beyond that of TRL5, is tested in its relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.
7	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requirement demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, a vehicle, or space).
8	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

2.1.1.2 Safety

The safety of the operators, suppliers, and personnel at HSAAP and the surrounding populated areas is a critical assessment criterion for any new technology or operation, especially for those involving explosive or potentially explosive materials. The current system for disposing the three waste streams by OB has proven itself a reliable and safe process for many years. HSAAP maintains a classification and management system for the control of any facility, equipment, items of property, system or land area that has been in contact with or exposed to explosives. Therefore, potential alternative technologies were evaluated against the baseline of safe operations demonstrated by the current system. The U.S. Army will not implement any technology that measurably increases risk or that has a risk that cannot be accepted (i.e., uncontained/uncontrolled explosion outside of its design limits, personnel exposure, etc.). Specific issues of concern identified during the evaluation process included:

- Pre-Processing: Most alternatives have a limit on the configuration, size, weight, density, etc., of the waste to be treated. These impact the amount of handling, size reduction, or other manipulation required for the technology to accept the various waste streams in their current and anticipated conditions. Increasing the amount of handling of MPPEH and MDEH can increase the risk to operators and material handlers. Therefore, technologies that demonstrated the ability to accept the various waste streams in a condition as similar as possible to the existing waste configurations were determined to be safer than those that required additional manipulation and handling/pre-processing. Any technology that requires preprocessing of site specific waste(s) that increases safety risks to an unacceptable level cannot be implemented.
- Feed Method: All technologies have a means to insert the pre-processed waste into the system itself. Any feed method increasing safety risks to an unacceptable level cannot be implemented.

Vendors of thermal and non-thermal technologies were asked to provide information on known safety incidents with their technologies in similar applications. This information, coupled with a preliminary safety assessment, was conducted as an initial phase of the technology review. This assessment considered standard process hazards analysis factors such as event severity and frequency of event occurrence. These preliminary assessments were combined per Military Standard 882e to provide a preliminary safety risk determination for each viable technology. The following terminology was used in categorizing the relative risk.

TABLE 2: RISK RANKING TERMINOLOGY

RISK RANKING	DESCRIPTION
Unacceptable	Risk cannot be tolerated or justified unless there are exceptional reasons for the activity to take place. Control measures to be introduced to drive risk downward.
Undesirable	Risk may be tolerated but shall only be accepted when risk reduction is deemed impracticable by senior management.
Tolerable	Risk is tolerable once demonstrated that it is as low as reasonably practicable "ALARP". For a risk to be ALARP, it must be possible to demonstrate that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained.
Acceptable	Risk is sufficiently low that it may be tolerated with the endorsement of the normal project / plant reviews.
Eliminated	Interim condition when risk is not yet categorized or is recorded but it not deemed a safety issue.

An additional consideration of the safety assessment is the determination that a safe location for a new facility within the HSAAP property can be identified. The siting of a facility of this nature is largely controlled by a number of inter-related factors including the distances dictated by the Blast Fragments Effects (Barricaded or Unbarricaded), the size of the facility and its use (e.g., the management and safe handling of Class 1.1 rated explosives), explosive content rating as expressed by the Net Explosive Weight (NEW) rating, and the personnel limits. The materials to be treated at HSAAP are primarily classified as Class 1.1 Explosives ("explosives that have a mass explosion hazard, i.e., a mass explosion will affect the entire load instantaneously") per the International Fire Code (2015).

QD arcs are established by the DoD under 4145.26M, "Contractor's Safety Manual for Ammunition and Explosives," as the primary means of mitigating damage to surrounding equipment and structures. A QD arc delineates the area around an operation likely to be affected by the destructive force of an uncontained explosion (Longuemare, 1997). Several different QD determinations must be made for siting a facility, including:

- Intermagazine distance (IMD) – This is the distance required between two different explosive storage locations, for example, the operational storage provided in the feed room and additional storage provided in a material preparation building. At this distance, personnel are expected to be seriously injured or killed and equipment is expected to be severely damaged or destroyed, but the blast is not expected to propagate to adjacent explosive storage areas.

- Intraline distance (ILD) – This is the distance required between an explosive storage location and an explosive processing operation, such as a Rotary Kiln Incinerator (RKI). Without any barricades, personnel at this location are expected to be seriously injured by fragmentation and experience a slight chance of eardrum damaged, and equipment is expected to be extensively damaged but not destroyed.
- Public Traffic Route Distance (PTRD) or K24 distance – This is the distance required between the explosive storage or processing operation and any public traffic ways, navigable rivers, and recreational facilities. At this distance, personnel are expected to experience minor to moderate injury by fragments and debris and equipment may experience minor damage.
- Inhabited Building Distance (IBD) – This is the distance required between the explosive storage or processing operation and adjacent buildings that are occupied during normal operation. At this distance, injuries are possible but only minor in nature, and adjacent equipment, while possibly damaged, are expected to remain operational. In most cases, the IBD distance will be driven by fragmentation impacts, not blast impact.

Figure 1 provides a graphical representation of how these QD distances compare in terms of impact on structures and personnel (Army, 2017). As shown in the figure, both fragmentation and blast impacts must be considered.

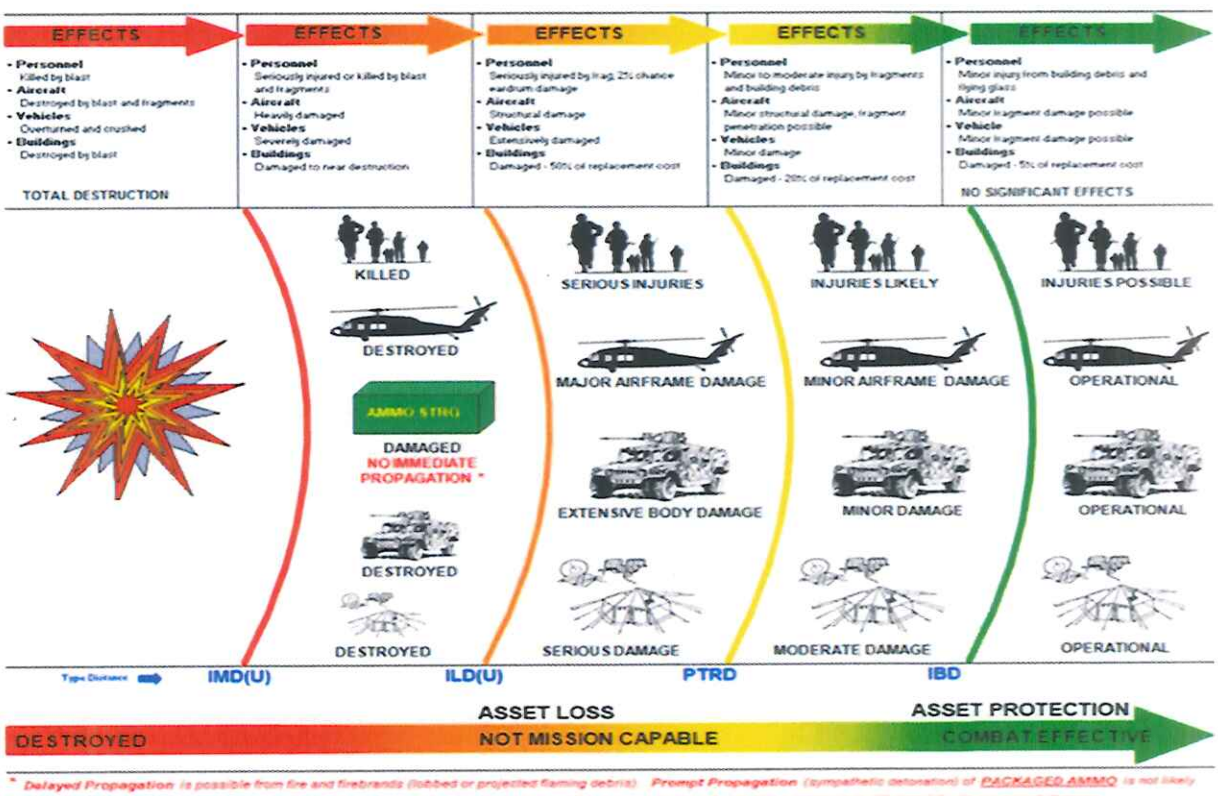

Figure 1: Siting Safety Terminology Graphic (Source: Department of Defense)

It is important to note, however, that this preliminary assessment does not replace a formal process hazards analysis (PHA) or Army Risk Assessment. Prior to the implementation of a system to treat the HSAAP explosive wastes, a formal and detailed PHA will be conducted to determine the relative risk and remedial actions required to reduce risks from the operation of a new treatment facility. Ultimately, the goal of the PHA will be to proactively identify potential risks associated with any proposed systems and then "design out" the highest potential risks to workers' health and the environment. In addition, the DDESB will need to review and ultimately approve the safety site plan for any solution.

2.1.1.3 Environmental Impacts and Permitting Requirements

OB of contaminated materials at HSAAP is permitted by the State of Tennessee and current operations comply with the site's permits. Potential technologies were evaluated against the ability to meet current and anticipated permit limits for both RCRA and the CAA.

Any changes to the treatment of explosive waste at HSAAP should offer a clear environmental advantage over current OB practices. Environmental impacts were considered in terms of the environmental media that will be impacted and any newly generated waste streams that will need to be managed. Any technology implemented at HSAAP will need to address environmental impacts and meet regulatory requirements. Factors used to assess environmental impacts include:

- New waste streams that will be generated by the technology.
- Emissions and discharge streams that will be created and how they will be managed.
- The potential for impacts to fauna, flora, air quality, soils, and water quality.

The feasibility of permitting the technologies under identified applicable environmental regulations is also an evaluation criterion. The specific regulations and resulting system requirements will be somewhat dependent upon the technology that is selected and volumes of waste to be treated. In addition, regulations may change and the most current requirements at the time of permitting will need to be met. As part of this study, the IPT evaluated each potentially viable technology in terms of its likely environmental impacts and its ability to be permitted for use under current environmental regulations (both federal and state).

Any technology that is ultimately selected for implementation will be subject to environmental permitting requirements under both federal and state programs. TDEC is the regulating authority who issues the permits in accordance with federal and state regulations. Additional Army requirements will also apply to any new technology. The following are regulations that may apply to the selected technologies.

- *Resource Conservation and Recovery Act (RCRA)*
- *Hazardous Waste Combustor (HWC) National Emission Standards for Hazardous Air Pollutants (NESHAP)*

- *National Environmental Policy Act (NEPA)*
- *Title V Operating Permit Modifications*
- *National Pollutant Discharge Elimination System (NPDES)*
- *State Regulatory Compliance*

2.1.2 Modifying Criteria

The IPT developed modifying criteria to determine engineering feasibility and provide additional distinguishing characteristics to the various technologies assessed as part of this effort. Criteria included in this portion of the study centered on utility requirements, siting, operational feasibility (e.g., throughput rate, staging, functionality, maintenance, ability to safely withstand a detonation, etc.), and waste to energy potential. Once a technology was determined to meet or exceed the threshold criteria, a preliminary assessment of the technology was conducted against the following modifying criteria. The results of the analysis are included in Section 4.0.

2.1.2.1 Location Assessment

As part of this study, BAE OSI completed a preliminary analysis of potential HSAAP sites that may be suitable for the possible deployment of new explosive treatment technologies. As no specific technology has been chosen at this point, several siting and equipment configuration assumptions were made. These assumptions will need to be refined and verified in subsequent phases of the overall project. This desktop study utilized the existing facility Geographic Information System (GIS) data mapping and estimated footprints based on configurations witnessed during technology site inspections.

BAE OSI eliminated areas within HSAAP already used/designated for other operations or that have restrictions due to environmental constraints (for example, production areas, the 100-Year Floodway and 100-Year Floodplain, etc.). For this analysis, the IPT assessed the estimated footprint, access, and utility requirements of each potentially viable technology against this designated land area.

2.1.2.2 Utility Accessibility

BAE OSI Engineering assessed the conceptual utility needs for those technologies deemed potentially viable for HSAAP to the extent practicable at this level of review. Existing utilities, including location, size, and capacity, were evaluated using the HSAAP GIS data set. The following critical utilities and infrastructure were assessed:

- Natural Gas
- Electricity (both high and low voltage lines)
- Road access (ingress/egress)

- Water (cooling, filtered, and potable)
- Steam
- Plant air
- Industrial sewer
- Sanitary sewer
- Stormwater management including storm drains and industrial stormwater collection
- Grading and topography
- Security systems (cameras, fencing, and gates)

2.1.2.3 Operational Feasibility

The BAE OSI Engineering, Safety, and Environmental representatives, along with the U.S. Army IPT members, assessed each technology based on its ability to be operated in an efficient and safe manner. Each technology was evaluated to determine the amount and types of resources needed to safely and efficiently operate the system. The following types of questions were considered:

- What types of pre-processing of the waste stream is required to effectively feed the system?
- What is the potential processing (throughput) rate and is it sufficient to meet HSAAP's quantities of the related waste stream(s)?
- What types of feed systems will be required for the alternative technology?
- Can the technology withstand a detonation of HSAAP material being treated within it with as little impact to continued operations as possible?
- How will the waste stream inputs and outputs be staged and stored both, before and after treatment?
- How much waste material can be staged and what are the staging requirements in terms of temporary storage, safety, stacking, and movement?
- What are the access requirements both in terms of ingress/egress and what is required for emergency access?
- What are the utility needs for the technology and what will be required in terms of utility expansions and upgrades?
- Is the technology approved by DDESB to achieve MDAS after treatment of the relevant waste stream or will a 2x100% inspection be required?

Operational inputs, including capacity and yearly maintenance and repair downtime, were estimated using a yearly operational period of 4,200 hours. This was calculated using a 12-hour per day shift, operating 7 days a week for 50 weeks per year (assuming 2 weeks per year of downtime for repair/maintenance). Actual operating periods may be adjusted to accommodate throughput needs and to optimize efficiencies.

2.1.2.4 Commercial Availability

The Commercial Availability criterion was established to ensure that potentially viable technologies are able to be implemented in a timely manner. A technology was considered to be commercially available if either the military itself provided a site specific technology or a vendor was identified that is a valid operating entity and able to provide services in the present timeframe.

2.1.2.5 Waste to Energy Considerations

The technologies were evaluated, to the extent practicable, for energy reduction and recovery potential. These efforts were not effective at this level of study as the determination is a design specific function and should be evaluated using lifecycle analysis. Waste to energy recovery options may include items such as preheating of combustion air to reduce fuel consumption, recovery of process heat for ambient heating, or incorporation of technologies such as a waste heat boiler to provide steam for use at the site. However, each of these solutions can create additional challenges that must be evaluated before they are incorporated into any design solution.

2.2 Request for Information (RFI)

After the IPT developed the Initial Requirements and Evaluation Criteria described above, the criteria were used to develop an RFI to send to vendors that provide potential thermal and non-thermal technologies potentially appropriate to treat one or more of the HSAAP waste streams. The IPT used SME knowledge to identify vendors of technologies deemed potentially suitable for application at HSAAP. A total of 24 potential vendors were identified and contacted in December 2017. As part of the RFI process, each vendor was requested to sign a Non-Disclosure Agreement (NDA) with BAE OSI to allow for a more detailed exchange of information regarding waste streams and technology capabilities. Technologies represented by vendors who did not sign an NDA were not excluded from evaluation; however, the ability of the IPT to adequately assess their specific capabilities was compromised by a lack of adequate information exchange. A total of 18 vendors returned acceptable signed NDAs and were provided an RFI to respond to and 10 vendors submitted valid responses. The remaining either declined to submit NDAs or did not respond to follow-up contact efforts.

The IPT reviewed vendor responses and discussed them during briefings to determine the respective technology's potential feasibility for application to one or more of the HSAAP waste streams. A few of the respondents proposed to engineer solutions for HSAAP but were not providers of COTS technologies. Some respondents were determined to be third-party vendors and not the actual providers of the technology. In several cases, it was necessary to visit their technologies to witness demonstrations and operational capacity. The combination of vendor information, meetings with the vendors, and site visits were used to assess the feasibility of each potentially viable technology.

2.3 Vendor / Technology Site Inspection

The IPT reviewed the vendor submissions and selected the most promising technologies for a site visit. This selection was also based on the availability of the technology for evaluation and its direct applicability to the HSAAP waste streams. The purpose of the site inspections was for the IPT to more thoroughly evaluate the specific technologies and witness their deployment in the field. Travel included site visits to both commercial vendor and other DoD facilities. The site visits also presented the opportunity to interview personnel (both vendor and Government) and gain insight into both the technologies used at their facilities and energetic treatment technologies in general.

The following technologies were observed during site visits:

- Contained Burn Static Firing Chamber, (similar to a Contained Burn Chamber [CBC])
- RKI, including both hardened and brick-lined systems (4 locations)
- Hydrolysis
- Industrial Supercritical Water Oxidation (iSCWO) system
- Contained Detonation Chamber (CDC)
- Plasma Arc
- Fluidized Bed Incinerator (FBI)
- Moving Bed Reactor (MBR)
- Metal Parts Furnace (MPF)
- Static Detonation Chamber (SDC)
- Temporary Car-Bottom Furnace

The following technologies were discussed during site visit interviews:

- CBC
- Rotary Kiln Incinerators (hardened and brick-lined)
- Decineration™
- Supercritical Water Oxidation
- Car-Bottom Furnace

2.4 Technology Review

Based on the collective knowledge and experience of the IPT, a total of 25 technologies were selected for review as part of this effort. The IPT assessed each technology against the threshold criteria using the information received from the vendors in response to the RFI (and additional inquiries, when conducted), as well as observations made and data gathered during site visits, literature searches, and SME knowledge. Technologies which failed to meet threshold criteria were considered non-viable. Technologies which met or exceeded threshold criteria were considered potentially viable and subject to further evaluation against modifying criteria and a comparative analysis.

3.0 SUMMARY OF TECHNOLOGY ALTERNATIVES

Based on the initial analysis against the threshold criteria, 20 technologies were determined not to be viable alternatives for implementation at HSAAP. The remaining five technologies have potential viability. This section contains a brief description of each technology and a summary of the IPT's assessment against the threshold criteria in table format. Section 3.1 presents the non-viable technologies in alphabetical order. Section 3.2 presents the potentially viable technologies, also in alphabetical order. The non-viable and potentially viable technology alternatives are listed below:

Non-Viable

- Biodegradation
- Chemical Treatment
- Composting
- CDC
- Decineration™
- Detonation of Ammunition in a Vacuum Integrated Chamber (DAVINCH)
- Electrochemical Destruction
- Electromagnetic Destruction
- Explosives Destruction
- FBI
- Gas Phase Chemical Reduction (GPCR)
- Humic-Acid Catalyzed Hydrolysis
- Hydrolysis
- iSCWO
- Microwave Incineration-Oxidation
- Plasma Arc Pyrolysis
- Static Fire
- Thermal Oxidizer
- Tunnel Furnace
- Wet Air Oxidation

Potentially Viable

- CBC
- Flashing Furnace
- MBR
- RKI
- SDC

3.1 Non-Viable Technologies

The non-viable technologies discussed in this section failed to meet the threshold criteria defined in Section 2.1.1. In some cases, where technologies failed to meet site-specific TRL requirements, a full safety and/or environmental evaluation were not conducted.

3.1.1 Biodegradation

Biodegradation is a non-thermal technology that uses microbes to degrade organic materials in a controlled industrial process. Byproducts include carbon dioxide and/or short-chain organics, water and minimal off-gases. The process typically uses water and waste-specific microbes and controls for pressure and temperature within a vessel to induce/enhance and accelerate the biodegradation process. No specific vendors were identified, and capacity has not been demonstrated. The primary limiting factor for adoption of this technology at HSAAP is the low overall and project-specific TRL rating and lack of commercial availability. Table 3 summarizes the overall assessment for this technology.

TABLE 3: BIODEGRADATION ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9 for general waste treatment
Project Level TRL for HEW (e.g., Bulk Product)	TRL 5. Limited data on energetics destruction at anything other than pilot-scale.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	Technology not applicable to NHCW.
Project Level TRL for NHNCW (e.g., Demo waste)	Technology not applicable to NHNCW. TRL 6 for soil only.
Safety	Not demonstrated with possible exception of soil.
Environmental Impacts	Wastewater streams will need evaluation. Nature of sludge and volumes of waste will also require evaluation. Sludge management could be problematic.

3.1.2 Chemical Treatment

Chemical treatment of explosive waste is a non-thermal technology that uses a chemical decontamination spray or bath. The process results in an approximate 80% reduction of organics and releases short-chain organic acids, CO_2, and water. Byproducts include a liquid waste stream that would be required to be discharged to the HSAAP Industrial Wastewater Treatment Facility (IWWTF) or be shipped off-site for disposal. HSAAP currently uses a form of chemical treatment for risk reduction measures on production process equipment that is being disposed. The current on-site method is to treat the explosives process equipment internally with caustic in order to remove any gross contamination of explosives. This reduces the risk associated with the equipment being handled and sent to the burning ground but does not negate the need to further treat the equipment since achievement of MDAS is not expected nor is this a DDESB approved method. Because most equipment has areas that cannot be visually inspected, thermal decontamination is still required after caustic treatment.

Outside of HSAAP, one commercial vendor was identified that offered a different form of chemical treatment. This vendor's product has been used at other military installations for explosives decontamination with reportedly acceptable results (vendor communications 3, 2018). However, application at an industrial scale needs to be demonstrated. This commercial technology has not received DDESB approval for achievement of MDAS for contaminated items treated by this method. In order to successfully implement this application at an industrial scale, the chemical could only be applied to items that could be 100% visually inspected and then those items would have to pass the site specific 2x100% inspection process. BAE OSI identified a potential use as a "one-off" type treatment of large containers/vessels if it can be determined that the treatment method is successful. If used, additional inspection requirements (2x100%) would likely be required. Additional evaluation of this method will be required prior to adoption. Any items that cannot be treated via this method or do not pass the 2x100% inspection process would still require thermal treatment to achieve MDAS. These challenges and applications have not been demonstrated on an industrial scale. Table 4 summarizes the overall assessment of this technology.

TABLE 4: CHEMICAL TREATMENT ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Has been demonstrated for treatment at small and moderate scale. For large-scale operations the TRL is reduced to a 7 as additional verification is required.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 7 for small batches of bulk product from known material content. These have been demonstrated in small scale. However, scale-up performance has been difficult and remains unproven. Large scale treatment was awarded a TRL of 6.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL 6. Limited data on energetics destruction at anything other than pilot-scale or small scale. Will require subsequent inspection. DDESB approval not received.
Project Level TRL for NHNCW (e.g., Demo waste)	TRL 6. Additional data has been requested from the vendor. May be appropriate for this waste stream under specific conditions/applications. Will require subsequent inspection. DDESB approval not received.
Safety	No adverse safety issues related to the chemical application have been noted at small scale applications. Safety is not demonstrated at scale.
Environmental Impact and Permitting	Wastewater streams need evaluation to determine their treatment requirements and volumes. Off-site treatment, if required, is problematic from a logistics standpoint.

3.1.3 Composting

Composting of explosive contaminated waste streams is a non-thermal technology that uses microbes to degrade organic materials in a natural environment. Byproducts include CO_2 and/or short-chain organics, water, and minimal off-gases. The process typically uses soil and waste-specific microbes to degrade the organics. It is a very slow process. No specific vendors were identified for energetic applications. The non-viable determination was made based on the project-level TRL score and lack of COTS vendor availability. Table 5 is a summary of the overall assessment of this technology.

TABLE 5: COMPOSTING ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Composting has been used in pilot- and full-scale operations for non-energetic organic materials and is a well proven biological treatment process for these types of materials.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 5. Limited data on energetics destruction at anything other than laboratory-scale. Additional study is required.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	Technology not applicable to NHCW.
Project Level TRL for NHNCW (e.g., Demo waste)	TRL 5 (for soil only). Limited data on energetics destruction at anything other than laboratory-scale was found. For non-soil applications a lower TRL is appropriate.
Safety	Safety has not been assessed.
Environmental Impacts	The hazard status of solid sludge is uncertain. Concerns for transferring waste constituents through the soil have been identified.

3.1.4 Contained Detonation Chamber

A CDC is a specially designed chamber that thermally treats high explosive materials. Also referred to as a Donovan Blast Chamber, the CDC, was originally designed available from a commercial vendor but is no longer offered for commercial sale. The CDC consisted of a large, double-walled steel chamber that was provided with a series of air inputs and recirculation systems to enhance combustion. The materials designated for treatment in the chamber were loaded and equipped with donor charges that would initiate the items. The net explosive weight (NEW) of the items being destroyed determined both the size of the chamber and the amount of donor charge needed in the detonation. Several design items were included in the system to absorb the energy of the resulting blast. The primary method of blast absorption was large bags of water that were filled and hung from the chamber walls. These bags of water both absorbed portions of the blast forces and resulted in steam generation that helped enhance the destruction process. The floor of the chamber was also covered in a layer of pea gravel. After the bags of water, munitions, and donor charges were loaded into the chamber, the chamber was sealed and the munitions were detonated. The off-gases from the detonation were released to an expansion tank and then to a downstream air pollution control system. No current vendors were identified for this technology. The primary non-viable determination was made by the lack of COTS vendor capacity and operational challenges during the demonstration and validation of these systems at other DoD sites. Table 6 is a summary of the overall assessment of this technology.

TABLE 6: CONTAINED DETONATION CHAMBER ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 8. Mobile units exist for small scale munitions destruction only.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 7. System was deployed for demonstration but did not function at a satisfactorily level with bulk energetics.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	Technology not applicable to NHCW.
Project Level TRL for NHNCW (e.g., Demo waste)	Technology not applicable to NHNCW.
Safety	Safety has not been demonstrated for bulk energetics. Concerns for worker exposure have been identified for bulk energetics.
Environmental Impacts	Solid ash residuals similar to existing OB ground pan residuals.

3.1.5 Decineration™

Decineration™ is a thermal technology that uses electrical heating to decompose complex, long-chain, solid nitrogenated energetics into short-chain hydrocarbon gases. The decineration™ tube is divided into three temperature-controlled chambers and is a customized, continuous process system. Only one vendor was identified for this technology. During discussions held with the vendor and previous system users, the IPT determined this technology was not mature to the level required for application at HSAAP. Capacity was estimated based on data obtained from a separate military installation where the system was tested or evaluated as a solution for ammunition demilitarization. However, it has not been proven in production-scale operations. Table 7 is a summary of the overall assessment of the Decineration™ technology.

TABLE 7: DECINERATION™ ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 6. Not demonstrated successful at an operational level.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 6. Not demonstrated successful at an operational level.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL 6. Not demonstrated successful at an operational level.
Project Level TRL for NHNCW (e.g., Demo waste)	TRL 6. Not an acceptable method for this waste stream (demonstrated unsuccessful at metals decontamination).
Safety	Safety not demonstrated at scale. Substantial pre-processing of NHNCW would be required to achieve input size requirements.
Environmental Impacts	Waste requires additional treatment for complete Propellant, Energetic, and Pyrotechnic Materials (PEP) destruction. Air Pollution Control (APC) equipment is required.

3.1.6 Detonation of Ammunition in a Vacuum Integrated Chamber (DAVINCH)

The DAVINCH is a horizontally-mounted, double-walled, steel, thermal treatment chamber that uses donor charges to destroy chemical munitions inside the unit. The off-gases are then treated by an APC system prior to release to the atmosphere and any remaining solids, ash or metal components may require further treatment before disposal. One commercial vendor was identified for this technology. However, they were unresponsive to multiple contact attempts for additional information. Therefore, the IPT completed the assessment based on information available through other sources. Based on identified information, the technology would only be applicable to bulk explosives. However, further design work would be required to determine actual feasibility, and multiple units would likely be required to address waste quantities generated at HSAAP. The IPT determined this technology was not mature to the TRL required for application at HSAAP. Table 8 is a summary of the DAVINCH technology assessment.

TABLE 8: DAVINCH ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Systems have been deployed to scale for chemical weapon treatment but to a much lesser extent for PEP.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 7. No specific data available for this waste stream. However, bulk explosives are similar to donor charges and should process acceptably.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL undetermined. Not attempted with this waste stream.
Project Level TRL for NHNCW (e.g., Demo waste)	TRL undetermined. Not attempted with this waste stream.
Safety	The system has been used safely for similar applications. It is designed to handle exothermic reactions.
Environmental Impacts	Wastewater and APC treatment will be required. Wastewater, ash and emissions will require management.

3.1.7 Electrochemical Destruction

Electrochemical Destruction is a non-thermal technology that oxidizes organic compounds via electron transfer to alkaline fuel cells. The fuel cell uses positive and negative electrodes to cycle organics within a pH-controlled aqueous solution. Since no commercial vendors were identified for this technology and its TRL rating is low, the IPT determined this technology was not viable for utilization at HSAAP. Table 9 summarizes the overall assessment of Electrochemical Destruction technology.

TABLE 9: ELECTROCHEMICAL DESTRUCTION ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 5. Not demonstrated successful at an operational level.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 4. Bench and pilot-scale testing of single energetics only. Would require substantial pre-treatment to solubilize the explosives.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL undetermined. No evidence was identified to demonstrate the application of this technology for this waste stream. Similar materials have been treated using this technology, but not enough data was identified to infer suitability for HSAAP.
Project Level TRL for NHNCW (e.g., Demo waste)	Technology not applicable to NHNCW.
Safety	Safety has not been demonstrated.
Environmental Impacts	Wastewater treatment will be required. No APC is required. Spent fuel cells will need to be properly managed.

3.1.8 Electromagnetic Destruction

Electromagnetic Destruction is a non-thermal technology that uses a granite dust emulsion to initiate and breakup ammunition items and provides cleaned, metal parts for recycling. The IPT identified one commercial vendor. Only test-level demonstrations on capacity were identified. The primary limiting factor for this technology is its low TRL ratings at the waste stream specific (project-level) assessment. Table 10 summarizes the overall assessment of Electromagnetic Destruction technology.

TABLE 10: ELECTROMAGNETIC DESTRUCTION ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 8. Three units are known to have been put into production.
Project Level TRL for HEW (e.g., Bulk Product)	Technology not applicable to HEW.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	Technology not applicable to NHCW.
Project Level TRL for NHNCW (e.g., Demo waste)	TRL 4. Possible solution for small metal parts. Not suitable for large metal parts due to chamber size restrictions.
Safety	Demonstrated safe for small arms ammunition. Significant strong initiations noted with 30-mm and larger items.
Environmental Impacts	Metal parts should be acceptable for scrap once approved for disposal. Spent emulsion either needs regeneration or disposal as a hazardous waste with possible pre-disposal treatment.

3.1.9 Explosives Destruction System

Explosives Destruction System is a thermal treatment technology that neutralizes and destroys assembled chemical weapons. It includes a thermal treatment chamber, heating source, reagent injection/neutralization and chemical storage tanks. It is designed for small-scale batch processing and donor charges of up to 9 lbs. NEW (TNT equivalent). It is unlikely this technology could be sized-up to handle the waste quantities generated at HSAAP due to the small batch size and slow batch cycle. It was developed by the U.S. military and is not available through any commercial vendors. Explosives destruction is not considered a viable technology for the HSAAP waste streams due to a lack of commercial availability and low project-level TRL rating. Table 11 summarizes the overall assessment of Explosive Destruction technology.

TABLE 11: EXPLOSIVES DESTRUCTION ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Demonstrated successful at an operational level for chemical weapons.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 7. Treatment of chemical weapons qualifies as a prototype for bulk explosives. Applications with only explosives would have to be demonstrated to achieve a higher TRL.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	Technology not applicable to NHCW.
Project Level TRL for NHNCW (e.g., Demo waste)	Technology not applicable to NHNCW.
Safety	Has been demonstrated safe for current applications. It has not been determined if a system deployed to scale could be safely operated for energetic waste streams.
Environmental Impacts	Liquid and solid waste disposal and APC treatment will be required.

3.1.10 Fluidized Bed Incinerator (FBI)

FBIs are a thermal technology that contains the destruction process within a reactor vessel and works by suspending solids in upward flowing air currents to achieve organic breakdown. The systems are sensitive to feed rate variability and consistent feed material characteristics (size, consistency in thermal mass, etc.). The vendor suggested a laboratory mock-up of a system to test feasibility with various components. The systems may include downstream heat recovery. Substantial pre-processing of HSAAP waste streams would be required for implementation of this technology. The IPT characterized the FBI as a non-viable technology due to the difficulty of pre-processing and material handling, the variability of the HSAAP waste streams, and the technology's lack of demonstrated ability for explosive waste treatment. Table 12 is an overall summary of the FBI technology.

TABLE 12: FLUIDIZED BED INCINERATOR ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Systems have been deployed to scale for chemical and hazardous waste treatment but to a much lesser extent for PEP.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 7. Vendor suggested a laboratory mock-up of a system to test feasibility with various components.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL undetermined. Vendor did not recommend treatment of this waste via this technology.
Project Level TRL for NHNCW (e.g., Demo waste)	TRL undetermined. Vendor did not recommend treatment of this waste via this technology.
Safety	Safety has been demonstrated for current applications. It has not been determined if a system deployed to scale could be safely operated for energetic waste streams. Concerns exist with the thermodynamic transition of bulk materials from burning to explosion.
Environmental Impacts	Wastewater and APC treatment required.

3.1.11 Gas Phase Chemical Reduction (GPCR)

GPCR is a non-thermal treatment technology that uses hydrogen gas to reduce the components of organic waste streams through a reactor at 1,560° Fahrenheit (F). Waste streams including methane, nitrogen gas, ammonia, and hydrogen sulfide are produced. Materials must be vaporized before treatment can occur. Two commercial vendors were identified for this technology. Capacity data, and the technology's ability to handle HSAAP's waste volumes, was not determined. Concerns for the pre-processing requirements of this technology and the overall current level of development resulted in the non-viability determination for this technology. Table 13 is a summary of the overall assessment of this technology.

TABLE 13: GAS PHASE CHEMICAL REDUCTION ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 8 for PCB and pesticide contaminated oil and sediments.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 4. Only completed at lab-scale with explosives and significant work required to address solubility concerns.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	Technology not applicable to NHCW
Project Level TRL for NHNCW (e.g., Demo waste)	Technology not applicable to NHNCW.
Safety	It has not been determined if a system deployed to scale could be safely operated. Concerns with vaporizing explosives and managing hydrogen gas.
Environmental Impacts	Wastewater and APC treatment will be required.

3.1.12 Humic-Acid Catalyzed Hydrolysis

Humic-Acid Catalyzed Hydrolysis is a non-thermal treatment technology designed for treating nitrogenated organic chemicals including nitroaromatics, nitroamines, and nitrate esters using an alkaline hydrolysis reactor. Waste streams include air emissions and commercial grade fertilizer (in some applications). Materials must be free of metals prior to treatment. Only one commercial vendor was identified for this technology. Capacity data, and the technology's ability to handle HSAAP's waste volumes, was not determined. The IPT determined Humic-Acid Catalyzed Hydrolysis to be a non-viable technology due to a low TRL rating for bulk product (pan waste material) and its non-applicability for the other waste streams. Table 14 is summary of the assessment of Humic-Acid Catalyzed Hydrolysis technology.

TABLE 14: HUMIC-ACID CATALYZED HYDROLYSIS ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 6. System has been successfully tested in relevant environment.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 4. Completed at lab-scale to date. Bulk explosives could be suitable with more testing. Catch basin waste not suitable due to potential for metal contamination in that specific waste stream.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	Technology not applicable to NHCW.
Project Level TRL for NHNCW (e.g., Demo waste)	Technology not applicable to NHNCW.
Safety	It has been safely demonstrated on energetic waste but with limited scale testing on PEP. Additional process-related safety concerns will need to be addressed.
Environmental Impacts	Wastewater and APC treatment will be required. Any byproduct created will most likely be a secondary waste stream requiring disposal.

3.1.13 Hydrolysis

Hydrolysis is a non-thermal treatment technology that uses aqueous chemical reactions for the conversion of PEP, chemical weapons, hazardous waste, etc., to non-hazardous, short-chain organics. Alkaline solutions are used to chemically break down the hazardous components. Waste streams typically include salts, simple acids, air emissions and sludge. Several commercial vendors were identified for this technology. Capacity data, and the technology's ability to handle HSAAP's waste volumes, was not determined. Preliminary data suggests, however, that multiple units would likely be required. Given the HSAAP specific TRL rating and the concerns for management of the waste streams generated by the technology, it was determined that Hydrolysis is not viable for HEW and is not applicable for the remaining waste streams. Table 15 is a summary of the overall assessment for the Hydrolysis technology.

TABLE 15: HYDROLYSIS ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Systems have been deployed to scale for chemical weapon treatment but to a much lesser extent for PEP.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 6. Additional demonstration is required for this waste stream.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	Technology not applicable to NHCW.
Project Level TRL for NHNCW (e.g., Demo waste)	Technology not applicable to NHNCW.
Safety	Safety has been demonstrated for the designed waste stream. It has not been determined if a system deployed to scale could be safely operated for the site specific waste stream. Concerns regarding required size reduction were also noted.
Environmental Impacts	Hydrolysate and possibly sludge and APC treatment will be required. Byproduct will likely be a secondary waste stream requiring disposal.

3.1.14 Industrial Super-Critical Water Oxidation (iSCWO)

ISCWO is a non-thermal treatment technology that improves upon the hydrolysis and wet air oxidation technologies, conducting the hydrolysis reaction above the critical point for water (i.e., in the supercritical range). Secondary waste streams from this technology typically include wastewater discharge and air emissions. One commercial vendor was identified for this technology, but limited data was available on energetics application as no signed NDA was returned. A standard unit, as proposed by the vendor, could manage the potentially applicable portions of HSAAP's HEW volume, assuming the recommended solids concentration and particle size is acceptable for operation. Recommended solid particle size is < 0.5 millimeters (mm) (0.02 inches) prior to slurrying (vendor communications 2, 2018) which could present a challenge for some waste streams. Considering this, the most likely candidate stream for treatment via iSCWO is the bulk explosives wastes that do not contain foreign object debris (FOD). Without adequate demonstration of this system, and in consideration of the pilot recommended by the vendor at their facility, the IPT does not consider this a viable OB alternative technology. Table 16 is a summary of the overall assessment for the iSCWO technology.

TABLE 16: INDUSTRIAL SUPER-CRITICAL WATER OXIDATION ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Systems have been deployed to scale for a variety of wastes.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 6. Vendor recommends pilot testing of any specific waste stream for which a design is proposed
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL Undetermined. Some demonstration of treatment of contaminated wastes but further research needed
Project Level TRL for NHNCW (e.g., Demo waste)	TRL Undetermined.
Safety	Safety has been demonstrated on various chemical wastes. It has not been determined if a system deployed to scale could be safely operated. Primary concerns are size reduction, slurrying system, and high-pressure compressor.
Environmental Impacts	Wastewater and APC treatment will be required.

3.1.15 Microwave Incineration-Oxidation

Microwave Incineration-Oxidation is a thermal treatment technology that uses concentrated microwaves for denaturing organics by vibrating individual atoms to induce molecular decomposition. The process occurs within an unheated rotary tube. No data on the use of this system for energetics, or capacity, was discovered. Waste streams typically include solids and air emissions. One commercial vendor was identified for this technology. It was determined to be non-viable based on the overall low level of development for the HSAAP wastes streams. Table 17 is a summary of the Microwave Incineration-Oxidation technology assessment.

TABLE 17: MICROWAVE INCINERATION-OXIDATION ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 6. Pilot-scale operations for organic-laden waste streams
Project Level TRL for HEW (e.g., Bulk Product)	TRL 2. A prototype was evaluated with mixed results.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL Undetermined. Not attempted with this waste stream.
Project Level TRL for NHNCW (e.g., Demo waste)	TRL Undetermined.
Safety	More research needed on the impacts of microwave radiation on HSAAP bulk explosives.
Environmental Impacts	Solids disposal and APC treatment will be required.

3.1.16 Plasma Arc Pyrolysis

Plasma arc pyrolysis is a thermal treatment technology that oxidizes organic compounds and converts inorganic compounds into a non-leachable slag within a stationary pyrolysis chamber using an electric current passed through a torch. The torch operates at extremely high temperature (>20,000°F) with an energy intensive electric current. One commercial vendor was identified for energetic waste with this technology. Capacity data, and the technology's ability to handle HSAAP's waste volumes, was not determined. It was determined to be non-viable for the HSAAP waste streams due to a lack of direct application. Table 18 is a summary of the Plasma Arc Pyrolysis technology IPT assessment.

TABLE 18: PLASMA ARC PYROLYSIS ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 8 for designed waste stream.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 6. No applications treating bulk explosives were identified. A prototype was evaluated with mixed results.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL Undetermined. Not attempted with this waste stream but is potentially viable due to use of the technology for similar wastes contaminated with non-energetic contaminants.
Project Level TRL for NHNCW (e.g., Demo waste)	TRL Undetermined. TRL 8 (for contaminated soil only). A lower TRL for contaminated soils with higher concentrations of explosives and other non-combustible waste is appropriate. Scaled applications for contaminated soil have been demonstrated.
Safety	Safety has been demonstrated for lightly contaminated soil and other non-HSAAP waste streams. It has not been determined if a system deployed to scale could be safely operated for energetic waste. Exothermic reactions are possible.
Environmental Impacts	APC treatment will be required. Slag will be non-hazardous.

3.1.17 Static Fire

Static Fire is a batch-process thermal treatment technology for assembled rocket motors that involves an electrical charge used to "fire" the rocket in a secured position. The process has historically occurred outside at OB grounds with no APC. No data on the use of this system for explosives was discovered. Waste streams typically include solids and air emissions. No commercial vendors were identified as these systems are typically field fabricated. Table 19 is a summary of the Static Fire technology assessment.

TABLE 19: STATIC FIRE ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Systems have been deployed to scale for rocket motor destruction.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 1. Technology has not been attempted for treatment of HEW.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	Technology not applicable to NHCW.
Project Level TRL for NHNCW (e.g., Demo waste)	Technology not applicable to NHNCW.
Safety	Safety has not been assessed for this study.
Environmental Impacts	Environmental Impacts the same as OB, as emission are released directly to the atmosphere.

3.1.18 Thermal Oxidizer

Thermal Oxidizers are a thermal treatment technology that uses controlled flame combustion to destroy liquid organic wastes in a continuous feed system. The systems have not been deployed for solid energetic waste such as that produced at HSAAP, but one system used to treat liquid energetic waste was identified. It is possible to liquefy the bulk product waste, but additional efforts would be required to develop and prove-out a system. Capacity data, and the technology's ability to handle HSAAP's waste volumes, was not determined. Numerous commercial vendors for this technology were identified. However, due to the lack of applications with explosives, the IPT determined this technology to be non-viable for the HSAAP waste streams (see Table 20).

TABLE 20: THERMAL OXIDIZER ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9 Thermal oxidizers have been well demonstrated as thermal treatment devices for liquid and gaseous chemical waste streams.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 5. Systems have not been deployed for dry-bulk explosive waste material. A prototype will be required.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	Technology not applicable to NHCW.
Project Level TRL for NHNCW (e.g., Demo waste)	Technology not applicable to NHNCW.
Safety	Safety has been demonstrated for the designed waste streams. It has not been determined if a system deployed to scale could be safely operated for HSAAP wastes. Size reduction and physical state modifications could present a significant hazard.
Environmental Impacts	APC treatment will be required.

3.1.19 Tunnel Furnace

Tunnel furnaces are a thermal treatment technology that use controlled flame combustion to oxidize organic components of a waste stream into carbon dioxide and water. Working much like a pizza oven, the tunnel furnace utilizes a rotating conveyor system to process trays of energetic waste through a heated chamber, ignite the materials, and burn off the reactive components. Non-combustible components of the waste remain in the tray and are manually removed by operators after the tray cools. Off-gases from the process, such as acid gases, volatilized metals, and partially cracked hydrocarbons are sent downstream to an afterburner and APC system. Capacity data, and the technology's ability to handle HSAAP's waste volumes, was not determined. Only one commercial vendor was identified for this technology and, based on discussions with them, it was not determined if the system could handle a detonation of material (it can manage deflagrations). Considerably more work will be required to determine the system's capacity for the HSAAP bulk waste material. For this reason, the IPT determined this technology to be non-viable for near-term implementation. Table 21 is a summary of the Tunnel Furnace technology assessment.

TABLE 21: TUNNEL FURNACE ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Some types of propellants have been treated successfully. However, there are a limited number of systems in the operational environment (2 total, 1 of which is shut down).
Project Level TRL for HEW (e.g., Bulk Product)	TRL 6. Demonstrated for use with double-base propellants. More evaluation of the thermal transition of HSAAP explosives is required.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	Technology not applicable to NHCW.
Project Level TRL for NHNCW (e.g., Demo waste)	Technology not applicable to NHNCW.
Safety	Safety has been demonstrated for non-HSAAP wastes. It has not been determined if a system deployed to scale could be safely operated. Current systems designed for small-scale, continuous processing of bulk propellants and are not necessarily amenable to treatment of explosives. Concerns related to material detonation and the inability of the system to withstand detonations.
Environmental Impacts	Solid residual (like OBG ash) for disposal and APC treatment required.

3.1.20 Wet Air Oxidation

Wet Air Oxidation is a non-thermal treatment technology that uses elevated temperature and pressure to oxidize dissolved, slurried, or pulverized organics in a waste stream. The process results in an approximate 80% reduction of organics and releases short-chain organic acids, CO_2, and water. This technology has largely been replaced with supercritical water oxidation. No commercial vendor was identified for this technology. The IPT does not consider this technology viable due to a lack of commercial vendors and low TRL ratings. Table 22 is a summary of the Wet Air Oxidation technology assessment.

TABLE 22: WET AIR OXIDATION ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9 for traditional wastewater treatment.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 3. Systems have not been deployed beyond laboratory-scale for PEP.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	Technology not applicable to NHCW.
Project Level TRL for NHNCW (e.g., Demo waste)	Technology not applicable to NHNCW.
Safety	Safety has not been demonstrated beyond laboratory scale testing. It has not been determined if a system deployed to scale could be safely operated. Concerns for exothermic reactions, corrosiveness and high pressure have been raised.
Environmental Impacts	Sludge management, wastewater and APC treatment will be required.

3.2 Potentially Viable Technologies

The five potentially viable technologies included in this section initially met or exceeded threshold criteria defined in Section 2.1.1. As such, these technologies were reviewed in great detail to determine if they could be implemented for HSAAP specific waste streams. A description of each of these technologies, as well as a summary of the IPT's assessment is provided in alphabetical order below.

3.2.1 Contained Burn Chamber

A CBC is a thermal treatment technology that encloses a traditional open burn tray in a pressure-rated vessel, ignites it with either a spark or burner, holds the gases, and then slowly releases them to the downstream APC after treatment. The chamber is designed to sustain the pressure generated from the burning of energetic wastes but is not designed to sustain detonations. Review of this technology indicated the primary type of energetic material treated in a CBC to date is propellant. Propellant oxidizes under differing conditions than explosives and thus equipment that is appropriate for one may or may not be appropriate for the other. The energetic force and rate of release of that force from propellants differs substantially from that released from primary or secondary explosives. Thermal treatment of propellant is likely to result, at the most, in a deflagration as propellant releases a subsonic reaction wave. Conversely, the thermal treatment of explosives can result in detonations due to their release of a supersonic reaction wave when they decompose. While secondary explosives, such as those at HSAAP, are generally more stable than primary explosives, under the right temperature and pressure conditions, material detonations are quite possible and therefore must be expected. As a result of these differences, equipment that is suitable for treatment of propellant may not be suitable for the treatment of primary or secondary explosives. Thorough communication with the vendor and other research on the CBC did not reveal significant information about processing of secondary explosives with this technology. Because of this lack of information, the quantity of HSAAP waste treatable in any given batch is still undetermined. Batch sizing will determine if any material being processed for treatment will require quantity/size reduction to ensure safe treatment in the chamber. Currently, the technology is only offered by one vendor. CBCs have had DDESB safety site plan approvals for operations at other facilities. CBCs have not obtained DDESB approval to achieve MDAS.

The processing capacity of a CBC is generally a function of the unit's size and ability to withstand the pressure wave generated from material initiation. As CBCs are designed to process energetic material, the chamber's shell is engineered to withstand pressures typically associated with energetic burning. However, the chamber is not capable of withstanding a detonation (vendor communications 1, 2018). According to the vendor, ultimately the size of the chamber is adjusted as necessary to meet facility throughput demands, with the chamber being sized based upon the expected off-gas volume and oxygen demands for the combustion process (vendor communications 1, 2018).

The CBC is most suitable for treating the HEW streams however concerns have been raised regarding the system's ability to withstand a detonation should it occur. The vendor has described that by adjusting the operating atmospheric pressure, their design will avoid a detonation. However, due to the lack of more detailed information on the types and quantities of secondary explosives demonstrated within operational units, the project team was not able to validate this statement. Demonstration of capacity with bulk explosives sufficient to treat HSAAP's waste quantities was not provided, but the vendor verbally stated that necessary throughput could likely be met. The largest demonstrated Class 1.1 system identified by the vendor handled material which may not be directly applicable to HSAAP, and supporting data was not provided due to proprietary data issues. In order to determine potential throughput of the CBC, the IPT assumed that the 1.1 material was comparable to HSAAP waste. At this rate, the batch volume is an insufficient capacity for HSAAP's quantities and will require multiple units to meet throughput requirements. Although it may be possible to also treat contaminated combustibles in the CBC, the vendor suggested other technologies are more suitable. The CBC is also not designed or suitable for treating the contaminated non-combustible wastes. Table 23 is a summary of the CBC technology assessment.

TABLE 23: CONTAINED BURN CHAMBER ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Various systems proven in operational environment
Project Level TRL for HEW (e.g., Bulk Product)	TRL 8. The TRL was reduced from a 9 to an 8 until further demonstration from the vendor on 1.1 explosives can be provided.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL 8. Requires a burner system to initiate and maintain combustion. Although it may be possible to treat contaminated combustibles in the CBC, the vendor suggested other technologies are more suitable.
Project Level TRL for NHNCW (e.g., Demo waste)	Not designed for NHNCW treatment
Safety	Safety assessed as "undesirable" for HEW and "tolerable" for NHCW. Cannot withstand detonation. The system is not recommended by the vendor for NHNCW.
Environmental Impacts	Solid residue will require disposal and APC treatment for off-gas stream will be required.

3.2.2 Flashing Furnace

Flashing furnaces are a thermal treatment technology that uses controlled flame combustion or electric heating to oxidize waste into CO_2 and water. Other products of combustion will vary depending on waste constituents and this will dictate regulatory requirements and the types of APC equipment needed for the system. Alternate names for these systems include: contaminated waste processors (CWP), Car Bottom Furnace (CBF) and metal parts furnaces (MPF). The terminology used often varies depending on what is being treated in the unit. These furnaces can either operate with a stationary loading system (manual loading into the chamber) or with a car bottom loading system. Absent the loading system, the furnaces function the same. Multiple vendors provide this technology. Multiple units may be required to meet throughput demands due to longer treatment times for items such as concrete. Flashing Furnaces have been approved by DDESB for thermal decontamination but they are not typically designed or used for the bulk treatment of PEP. In general, bulk explosives are not amenable to treatment in a Flashing Furnace due to its inability to withstand an explosive force. However, those bulk explosives not prone to detonation (non-Division 1.1 materials) could potentially be treated in the oven, but additional testing will be required to determine the safety and limits. Table 24 is a summary of the Flashing Furnace technology assessment.

TABLE 24: FLASHING FURNACE ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Systems have been deployed at scale and operational for many years for a variety of waste streams.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 7. Ovens are not designed for detonation of PEP although they have been used at an experimental level; however, any bulk products that are not classified as 1.1 are expected to be able to be thermally treated in this system and would have a higher TRL.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL 9. Systems have been deployed at scale for a variety of waste streams including items that are minimally contaminated with PEP.
Project Level TRL for NHNCW (e.g., Demo waste)	TRL 9. Systems have been deployed at scale and operational for many years for a variety of waste streams, including items that are minimally contaminated with PEP.
Safety	Safety assessed as "undesirable" for HEW and "tolerable" for NHCW and NHNCW. Not designed for treatment of bulk explosives. Incidents have occurred where levels of PEP contamination were not properly determined, leading to unplanned detonations during decontamination.
Environmental Impacts	APC treatment will be required to manage off-gas stream. Ash residuals will require proper disposal.

3.2.3 Moving Bed Reactor

MBRs are a hardened vessel in which steel balls and air are used to conduct heat throughout the MBR chamber and the steel balls absorb the impact of detonating items within the chamber. The unit uses the heat from controlled flame combustion to oxidize organic compounds into CO_2 and water and provides a safe means for detonation and deflagration of waste explosives and explosive-containing ammunition items. Ordnance items, bulk explosives, and other energetic materials are loaded into uniform waste containers and relayed via a conveyor and lift system to the top of the MBR, which is filled with a bed of steel balls. The waste containers are the primary waste delivery mechanism into the system. In addition to the bulk explosives, additional combustible materials will be required to fill the remaining space within the containers. There is the possibility that small NHCW items can be used to fill this space. However, any materials added to the container are still ultimately limited in size. The steel balls cycle through the chamber creating a moving bed that helps transport the waste containers through the chamber. As the waste flows downward through the chamber, it is slowly heated to avoid premature detonation. When the temperature reaches the critical point, the waste either burns or detonates. The steel balls provide dampening if a detonation occurs. The inside of the chamber and the steel balls are heated by a continuous stream of hot air flowing from an adjacent burner system into the reactor. Waste containers move through the chamber with the steel balls via gravity feed. The speed of this movement is controlled by a valve at the bottom of the reactor, which also controls the rate at which the steel balls exit the reactor. Any metal parts, non-combustible materials or other ash-like materials generated when the item is treated exits the MBR at the bottom along with the heated steel balls. This discharge stream passes through a cooler and then a sifter that separates the metal parts or other non-combustible materials and ash from the steel balls. The balls are transferred to a storage tank and ultimately back to the top of the MBR via a bucket conveyor system. The sorted ash, metal parts, and other non-combustible materials are collected and disposed. Further testing or evaluation of this material may be required prior to disposal. Off-gases from the reaction flow to a downstream afterburner for further organics destruction before passing to an APC system.

The IPT identified one vendor of this technology. There are two units in operation. Operating units have treated class 1.1 explosives, including RDX. To achieve the currently demonstrated throughput of the largest unit in operation, the HSAAP HEW will need to be packaged into containers with up to a 15-times size reduction from our current packaging size and material NEW. This increased handling presents a safety concern for HSAAP. In addition, the capacity of the larger unit will only meet approximately one third of HSAAP's desired throughput. While this is less than the required capacity, the vendor indicates that the reactor can be sized to accommodate larger charges and greater throughput. If this is not possible then multiple units will be required to meet the projected throughput requirements. The MBR has not been DDESB site safety plan approved because this technology has not been implemented in the U.S. to date. Regulatory agencies are unlikely to be familiar with this technology. As a result, additional review by multiple agencies may be necessary before this technology could be implemented at HSAAP. Table 25 is a summary of the MBR technology assessment.

TABLE 25: MOVING BED REACTOR ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Systems have been deployed at scale for PEP and other waste streams for many years.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 9. Systems have been designed and operated for bulk explosives and other forms of munitions.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL 8. Technology is capable of treating waste streams such as small combustibles.
Project Level TRL for NHNCW (e.g., Demo waste)	Not designed for decontamination of metal parts and other NHNCW waste streams.
Safety	Safety assessed as "tolerable" for HEW and "acceptable" for NHCW. Operational systems have been operated safely.
Environmental Impacts	APC treatment will be required to manage off-gas stream. Ash residuals will require proper disposal.

3.2.4 Rotary Kiln Incinerator

RKIs are a thermal treatment technology that uses controlled flame combustion to oxidize organic components into CO_2 and water. Material is moved through the system by rotation of the kiln. The rotation rate and temperature of the kiln determine when and where the material is burned or initiated. The solids waste (ash) stream varies by feed item. Materials pass through an RKI system in a generally linear manner. Wastes, fuel, and combustion air are fed to the kiln and heated. From there, the off-gases go to a downstream afterburner for further organics destruction before passing into the downstream APC equipment. The processing capacity of RKIs is a function of the unit's size and rotational speed. For RKI's processing munitions, the shell's ability to withstand the potential energetic force of the treated material is also a factor. Vendors surveyed for this study were capable of supporting feed rates in excess of 70 pounds per hour (lbs./hr.) of bulk explosives (RDX). The feed rate of contaminated combustible wastes would only be limited by the geometry of the kiln. For RKI systems, the explosive wastes will need to be repackaged. Feed variation can also be a concern with this waste stream. Numerous vendors were identified for this technology. RKI units have received DDESB safety site plan approval for similar applications however DDESB has not approved the treatment for MDAS qualification.

3.2.4.1 Hardened Steel Rotary Kiln Incinerators

RKIs can be divided into two categories – hardened steel and brick-lined. Conceptually these types operate identically; differences include unit dimensions and the means of heat shielding within the kiln. Hardened steel RKIs are traditionally employed for the destruction of highly energetic or explosive wastes, as the hardened steel walls (shells) are meant to sustain the impact from material initiation. Only the hardened steel kilns can withstand an explosive force. Since no scale-up is possible, the wastes will need to be packaged into boxes with up to a 35-times reduction from our current packaging size and material NEW. This increased handling presents a safety concern for HSAAP. In addition, the hardened steel kilns rely on different "recipes" to ensure that the wastes being treated initiate in the center of the kiln, where the retort sections are thickest. This prevents damage to the system and helps prevent fugitive emissions. Each recipe sets an operating temperature and kiln rotational speed that helps to ensure this mid-unit initiation. Mixed or inconsistent feeds that do not initiate at the same temperature can present challenges when fed to one of the hardened steel systems. The HSAAP catch basin explosive waste stream is not only mixed, it is highly variable due to the manufacturing of process intermediates and over 80 different explosives products. The off-specification explosives can also be problematic for recipes as they are also inconsistent. As such, establishing a set recipe to run HSAAP waste through a RKI could be challenging. Multiple recipes, either on pre-feed adjustments to the waste materials or operational adjustments to the kiln temperatures and rotational speed may be required. In order to determine if the existing RKI designs have adequate adjustability to safely accommodate the level of mixed and inconsistent materials generated at HSAAP, further piloting for HSAAP specific waste would be required.

3.2.4.2 Brick-Lined Rotary Kiln Incinerators

Brick-lined RKIs are not as resilient to material initiations and are typically used in situations where the wastes employ less of an explosive force. An advantage of these systems is the ability to enlarge the opening and shell diameter, thus allowing for larger items to be fed into the system. The larger opening and shell diameter are more amenable to treating wastes such as the NHCW. However, the brick-lined kilns cannot tolerate any sort of unexpected detonation. Therefore, this type of kiln will have to be operated with only materials that can be proven to not detonate, which is estimated to be a very small percentage of NHCW. Altering the feed system to be inert or other modifications will be required. Table 26A and 26B provide summaries of hardened steel and brick-lined RKIs.

TABLE 26A: HARDENED STEEL ROTARY KILN INCINERATOR ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Systems have been deployed at scale for PEP and other waste streams for many years.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 8. Hardened RKI can handle bulk explosives, but considerable recipe development may be required.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL 8. Substantial material resizing will be needed with a customized design to load the unit. Hardened steel units are not scalable to the same level as brick-lined.
Project Level TRL for NHNCW (e.g., Demo waste)	TRL 7. Large items will not fit into the system without considerable size reduction. Smaller items will require subsequent inspection (DDESB has not approved RKI furnace for NHNCW decontamination). Items failing inspection will require additional treatment.
Safety	Safety assessed as "undesirable" for HEW and "tolerable" for NHCW. It has not been determined if a system deployed to scale could be safely operated. Concerns over the level of pre-processing and volume reduction of HEW were noted along with potential for pre-detonation of mixed material and feed-end clogging.
Environmental Impacts	Wastewater and APC treatment will be required.

TABLE 26B: BRICK-LINED ROTARY KILN INCINERATOR ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Systems have been deployed at scale for non-PEP waste streams for many years.
Project Level TRL for HEW (e.g., Bulk Product)	TRL 7. Brick lined kilns processing HEW have lower TRL than do hardened steel kilns processing HEW. Substantial size reduction is required and unplanned detonations will damage the unit requiring repair and downtime.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL 8. Size reduction of NHCW will be required. Brick-lined kilns can be upsized to treat larger items but substantial resizing of materials will still likely be required. Unplanned detonations will damage the unit requiring repair and downtime.
Project Level TRL for NHNCW (e.g., Demo waste)	TRL 7. Will require subsequent inspection. DDESB has not approved RKI furnace for NHNCW decontamination. Items failing inspection will require additional treatment.
Safety	Safety assessed as "undesirable" for HEW and NHCW. It has not been determined if a system deployed to scale could be safely operated. Concerns over the level of pre-processing and volume reduction of HEW were noted along with potential for pre-detonation of mixed material and feed-end clogging.
Environmental Impacts	Wastewater and APC treatment will be required.

3.2.5 Static Detonation Chamber

An SDC is a thermal treatment technology that uses electrically generated indirect heat to initiate explosive items in a sealed chamber. An SDC operates as a semi-continuous process. Closely-packed energetics are loaded into boxes and transferred, either manually or via robotic arm, to a conveyor belt. From there, they are automatically pushed into the chamber by a mechanized ram through an airlock system. Off-gases are treated in a downstream afterburner and APC system. Any non-combustible fraction of the waste feed, like shell casings, is contained within the chamber and used to absorb the energy from detonations. The SDC system relies on these non-combustible pieces to operate effectively. The processing capacity of SDCs is generally a function of the unit's size and ability to withstand explosive force. As SDCs are designed to process energetic material, the chamber's shell is engineered to withstand a certain amount of explosive force. As such, the potential feed rate of waste to the chamber depends upon the detonation and/or deflagration rates of the waste materials to be treated. One commercial vendor was identified. The units are available in multiple sizes and can be scaled to some level to meet customer needs, however, a preliminary analysis of throughput capabilities indicate that multiple systems will likely be needed to meet anticipated demand. Operating units have treated class 1.1 explosives, including RDX. To achieve the currently demonstrated throughput of the largest unit in operation, the HSAAP HEW will need to be packaged into containers with up to a 31-times size reduction from our current packaging size and material NEW. This increased handling presents a safety concern for HSAAP. Additionally, a considerable amount of size reduction will be required to feed the system for NHCW and NHNCW to the unit geometry. To the best of the IPT's knowledge, at least one SDC has received DDESB site safety plan approval for treatment of PEP waste; however, none were identified as approved by DDESB to achieve MDAS. Table 27 is a summary of the SDC technology assessment.

TABLE 27: STATIC DETONATION CHAMBER ASSESSMENT SUMMARY

ASSESSMENT CRITERIA	DISCUSSION
Overall TRL for typical technology application	TRL 9. Multiple systems in operation throughout the world
Project Level TRL for HEW (e.g., Bulk Product)	TRL 9. The system is capable of handling the HEW waste stream including the potential for detonation. Repackaging of bulk waste into smaller charges will be required.
Project Level TRL for NHCW (e.g., PPE, Wood, etc.)	TRL 9. Multiple systems in operation throughout the world processing combustible items with explosives. Considerable size reduction will be required or only small items may be treated.
Project Level TRL for NHNCW (e.g., Demo waste)	TRL 9. Multiple systems in operation throughout the world processing non-combustible items with explosives. However, treatment of these items is limited to small items. Any non-combustible items will be required to go through the 2x100 inspection process to achieve MDAS. Items failing inspection will require additional treatment. Note: small metal items are required for system operability.
Safety	Assessed as "tolerable" for HEW and NHNCW. NHCW is assessed as "acceptable". Demonstrated safe for containing detonations. Concerns were identified regarding the level of material handling required to reduce charge or material size.
Environmental Impacts	Solid residual stream for disposal and APC treatment will be required.

4.0 COMPARATIVE ANALYSIS OF POTENTIALLY VIABLE TECHNOLOGIES

To assess the most appropriate technologies available for the HSAAP waste streams, the IPT developed evaluation criteria, both threshold and modifying, as defined in detail in Section 2.1 of this report. The following subsections present a comparative analysis of the potentially viable technologies against the evaluation criteria and each other. The comparative analysis included an evaluation against the following criteria:

- Waste specific TRL
- Safety
- Environmental Impacts and Permitting
- Siting Locations
- Utilities
- Operational Feasibility
- Commercial Availability

4.1 HSAAP Waste Specific TRL

Many of the technologies evaluated for this project have been deployed commercially and/or at military institutions for a variety of applications. However, these applications, in many cases, are not representative of the waste streams specific to HSAAP. As a result, the TRL levels allocated to the technology from a general industry perspective are not necessarily applicable to the specific HSAAP waste stream for which it is being considered. Therefore, the IPT, using the DoD TRL application approach, applied a waste stream-specific TRL for each technology. These are summarized below in Table 28.

TABLE 28: SUMMARY OF WASTE SPECIFIC TRLS

SUMMARY OF WASTE SPECIFIC TRLS FOR POTENTIALLY VIABLE TECHNOLOGIES			
Technology	**HEW**	**NHCW**	**NHNCW**
Contained Burn Chamber	8	8	Not Applicable[1]
Flashing Furnace	7	9	9
Moving Bed Reactor	9	8	Not Applicable[1]
Hardened Steel Rotary Kiln Incinerator	8	8	7†
Brick-lined Rotary Kiln Incinerator	7	8	7†
Static Detonation Chamber	9	9	9†
1. This technology is not designed to process this waste stream. † Only suitable for small items			

4.2 Safety

The IPT assessed the safety of each technology in terms of its safety history as determined by vendor-supplied information supplemented by SME knowledge of existing similar facilities and information gathered in this study of existing similar facilities. The safety assessment also included an evaluation of the processes' ability to handle a potential detonation at a specific NEW rating, the amount of repackaging/re-handling of waste material required to load or feed the systems, and other potential risks to personnel from associated operations (transport, handling, and disposal) for the types and volumes of waste generated at HSAAP. It is important to note that this assessment did not reach the level of a PHA. A PHA will be completed if a specific technology is selected and reached the appropriate design maturity. However, the preliminary assessment used these methods to assign a safety risk rating (for each of the technologies and the candidate waste streams. A summary of the safety ratings assigned to each technology is provided in Table 29.

TABLE 29: SAFETY RATING OF POTENTIALLY VIABLE TECHNOLOGIES

Technology	HEW	NHCW	NHNCW
Contained Burn Chamber	Undesirable	Tolerable	Not Applicable[1]
Flashing Furnace	N/A, TRL not met	Tolerable	Tolerable
Moving Bed Reactor	Tolerable	Acceptable	Not Applicable[1]
Rotary Kiln Incinerator	Undesirable	Tolerable (hardened RKI only) Undesirable (Brick-Lined RKI)	N/A, TRL not met
Static Detonation Chamber	Tolerable	Acceptable	Tolerable †

1. This technology is not designed to process this waste stream.
† Only for small non-combustible items

4.3 Environmental Impacts and Permitting

The IPT also assessed the technologies in terms of their ability to meet the anticipated environmental standards and permitting requirements based on the current regulatory framework for control of air emissions and hazardous waste treatment, storage, and disposal. Additional environmental standards include surface and groundwater protection, floodplain regulations, NEPA compliance, DoD-related environmental standards, and BAE OSI internal environmental compliance. These include the HSAAP Plant Protection Standards that are imposed on all new construction projects. This assessment is based on the IPT's understanding of the current regulatory framework and compliance requirements. No formal discussions or applications have been made to the regulatory agencies at this time. Furthermore, environmental standards may change as a result of regulatory or policy shifts. These will need to be re-assessed if a final technology selection is made. All technologies are expected to be able to meet the regulations listed in Section 2.

4.4 Potential Locations

The IPT identified three sites as potential locations for an alternative treatment facility. BAE OSI evaluated locations from a site safety standpoint using estimated QD arcs, as well as the requirements to provide utilities necessary to support the proposed technologies. Site location analysis included a determination of topography, road, security, basic storage, and logistic issues. Considerations also included the estimated amount of site work required to prepare the site for technology deployment such as, earthwork, runoff control, soil conditions, and stability. Issues related to permitting that may impact each location have been identified to the extent possible. No geotechnical or archeological investigations have been completed at these sites to date. These locations will be further evaluated against any selected technologies and their operational requirements.

4.5 Utilities

BAE OSI assessed the utility needs of each potentially viable technology based on data presented by the vendors and obtained during various site inspections. The data is preliminary and will require refinement and more detailed engineering if a technology is selected. Based on the information obtained to date, the following comparisons were made (see Table 30). Based on these preliminary estimates HSAAP maintains the ability to provide the utility needs for each of the potentially viable technologies.

TABLE 30: UTILITY NEEDS PER TECHNOLOGY

	HSAAP UTILITIES REQUIRED							
Technology	****Natural Gas (MMcf/yr)**	**Electricity (MW/yr)**	**Electricity (kW running)**	**Water (gpm)†**	**Steam (lb/hr)**	**Compressed Air (cfm)**	**Industrial Sewer**	**Sanitary Sewer**
Contained Burn Chamber	33-42	200 -325	50		*n/a			
Flashing Furnace	35-46	40 – 60	10		*n/a			
Moving Bed Reactor	47	3,500	850	< 300 gpm	*n/a	100	< 30 gpm	< 40 gpm
Rotary Kiln Incinerator	50.4	500 - 750	125		*n/a			
Static Detonation Chamber	33-42	225 - 250	60		*n/a			

*Steam is not required for the operation of any of the listed technologies but may be required for wash-downs.
** Natural gas usage will vary with final design. Supplied numbers include afterburner requirements necessary for sufficient organics destruction where required.
†Water and Sewer (Industrial and Sanitary) usage are not a major utility requirement for these technologies

4.6 Operational Feasibility

BAE OSI Engineering, Safety, Environmental, and Project Management representatives, in conjunction with U.S. Army IPT members, evaluated the operational feasibility of each potentially viable technology and considered capacity and material handling.

4.6.1 Capacity

Although final capacity determinations will not be possible until a complete design effort is undertaken and the final capacity requirements are established, the IPT made preliminary determinations in regards to the ability of each potentially viable technology to meet the throughput demands. The following determinations, based primarily on vendor supplied data, were made for each waste stream:

CBC:

- HEW: Throughput needed to meet demands is undemonstrated for Class 1.1 material in this unit. The vendor stated upsizing to meet capacity may be possible, but only if treated material will not detonate. No documentation to prove up-size potential was provided.
- NHCW: The vendor did not prefer to treat all of this waste in this type of unit for the HSAAP application. However, one unit could be used to satisfy a portion of the throughput demands for this waste.
- NHNCW: This waste stream is not applicable to this technology.

FF:

- HEW: Unit is not sufficiently rated to serve as a reliable treatment option for the typical NEW associated with this waste stream and is provided a TRL below minimum project objectives for this waste.
- NHCW: The vendor estimated that one unit will be sufficient.
- NHNCW: The vendor estimated that one or two co-located units will be sufficient.

MBR:

- HEW: Throughput needed to meet demands is borderline for Class 1.1 material (RDX) in the existing installations. The low-end of the throughput demand range is demonstrated, higher-end of range will require upsizing or multiple units. The vendor stated upsizing to meet the higher capacity is likely possible and provided preliminary documentation to demonstrate the up-size potential.
- NHCW: The vendor estimated one unit will be sufficient to treat the smaller-sized items in this waste category, as they can be used as cushioning to the HEW charges. This is not a solution for large NHCW items without size reduction.
- NHNCW: This waste stream is not applicable to this technology.

SDC:

- HEW: Demonstrated capacity for this unit will require multiple units. No up-size potential was provided by the vendor.

- NHCW: One unit will be sufficient to treat the smaller-sized items in this waste category. This is not a solution for large NHCW items without size reduction. Addition of these larger items, once size-reduced, may increase the number of units required.
- NHNCW: One unit will be sufficient to treat smaller sized items in this waste category. This is not a solution for large NHNCW items.

RKI (Hardened Steel):

- HEW: Demonstrated capacity for this unit will require multiple units to treat the volumes anticipated. No up-size potential is possible for this technology.
- NHCW: One or two units will be sufficient to treat the smaller-sized items in this waste category. This is not a solution for large NHCW items without size reduction. Addition of these larger items, once size-reduced, will likely increase the number of units required.
- NHNCW: This unit is not a reliable treatment option for these materials, as the TRL for these wastes in this technology is below minimum project objectives.

RKI (Brick-lined):

- HEW: This unit is not a reliable treatment option for these materials, as the TRL for these wastes in this technology is below minimum project objectives.
- NHCW: One or two units should be sufficient to treat the smaller-sized items in this waste category. This is not a solution for large NHCW items without size reduction. Addition of these larger items, once size-reduced, will likely increase the number of units required.
- NHNCW: This unit is not a reliable treatment option for these materials, as the TRL for these wastes in this technology is below the minimum project objectives.

4.6.2 Material Handling

BAE Engineering and Safety representatives completed a preliminary evaluation of the waste handling requirements of each technology. This evaluation was purposefully biased towards those technologies with a demonstrated history of material handling of explosives. Many of the potential vendors have the capability and experience to design material handling systems, however, the IPT determined that designing a new material handling system will introduce additional risks to facility operations and therefore those systems with a demonstrated history are preferred. As part of this evaluation, they evaluated how the COTS equipment feed systems can meet required capacities. Considerations included waste material size reduction requirements (if any), repackaging of the waste material, and the type of feed system for each technology. For most of the technologies, it was determined that some waste size reduction, repackaging, and/or handling will be required to accommodate the feed requirements of the system. In some cases, the required feed system design is manageable but may pose some operational or design challenges. The factors that would make a material handling system undesirable include those that require significant waste size reduction, repackaging, and/or handling. The feed system design in these systems will be complex and may pose significant design or operational challenges. Because the safety evaluation included material handling requirements for each technology as part of the assessment, a separate rating solely for material handling was not completed.

4.7 Commercial Availability

Out of the 24 potential vendors sent RFIs in late 2017, 13 responded, of which, 10 stated they are capable of supporting the request. A few of the respondents proposed to engineer solutions for HSAAP but were not providers of COTS technologies. Some respondents were determined to be third-party vendors and not the actual providers of the technology. Based on a consensus of the IPT, those vendors who responded were provided BAE NDAs to complete. The IPT reviewed each of the five potentially viable technologies against the commercial availability criteria and all five technologies were found to be commercially available.

5.0 SUMMARY AND CONCLUSIONS

After screening out 20 technologies that did not meet the threshold criteria developed for this effort, the IPT evaluated the remaining five potentially viable technologies as they could be applied to HSAAP's HEW, NHCW, and NHNCW. As Table 31-33 indicate, certain technologies are more viable than others for the various waste streams. It is important to note that the CBC, FF, RKI, and SDC technologies have previously been approved by the DDESB as part of a site-safety plan for the treatment of energetic wastes review (NASEM, 2018). The specifics of these approvals were not immediately available and the prior approval should not be used to infer subsequent acceptance as each location/application is evaluated independently and each location is unique. Only the MBR (which has not been previously deployed in the USA) has not been subjected to DDESB review.

TABLE 31: COMPARATIVE ANALYSIS FOR HEW

Technology	TRL	Safety*	Capacity
Contained Burn Chamber	8	Undesirable	One or more systems are required
Flashing Furnace	7	N/A, TRL not met	N/A, TRL not met
Moving Bed Reactor	9	Tolerable	One or more systems are required
Hardened Steel Rotary Kiln Incinerator	8	Undesirable	More than one system is required
Static Detonation Chamber	9	Tolerable	More than one system is required
*Safety criteria include an evaluation of the technology's ability to withstand a detonation, the increased handling of the material, and historical safety of the system.			

TABLE 32: COMPARATIVE ANALYSIS FOR NHCW

Technology	TRL	Safety	Capacity
Contained Burn Chamber	8	Tolerable	One unit is sufficient
Flashing Furnace	9	Tolerable	One unit is sufficient
Moving Bed Reactor	8	Acceptable	One unit is sufficient to cover small sized materials
Steel Hardened Rotary Kiln Incinerator	8	Tolerable	One unit is sufficient to cover small sized materials
Brick-lined Rotary Kiln Incinerator	8	Undesirable	Undetermined
Static Detonation Chamber	9	Acceptable	One unit is sufficient to cover small sized materials

TABLE 33: COMPARATIVE ANALYSIS FOR NHNCW

Technology	TRL	Safety	Capacity
Contained Burn Chamber	N/A[1]	N/A[1]	N/A[1]
Flashing Furnace	9	Tolerable	One or more systems are required
Moving Bed Reactor	N/A[1]	N/A[1]	N/A[1]
Rotary Kiln Incinerator	7	TRL Not Met	TRL Not Met
Static Detonation Chamber	9†	Acceptable Only for small non-combustible items	one unit will be sufficient to treat small items

1. Not applicable. This technology is not designed to process this waste stream.
† Size reduction of waste materials should be minimized to the extent practicable in an effort to reduce contact with and handling of contaminated materials. The preference from a safety and material handling perspective is for a final technology that minimizes size reduction requirements. Flashing Furnace has demonstrated suitable feed systems. An SDC feed system is feasible for small non-combustible items.

5.1 Considerations for HSAAP

Implementation of any of the potentially viable technologies at HSAAP will require a substantial change to the standard operating procedures currently in place. Section 1.0 of this report describes the current practice of open burning. This practice has been used for many decades and refined to incorporate additional safeguards. The technology(s) that require the least amount of additional handling of the waste stream(s) to sort, re-size, load, unload, transport, and dispose of the residual materials, will be more favorable. Any technology requiring an increase in the amount of pre-treatment and handling of the waste streams has the capacity to significantly increase risk (both safety and environmental). For this reason, the IPT gave this factor considerable weight in its review and assessment of the various technologies. An additional consideration is that of complexity. The further a technology deviates from the existing method of handling the current waste streams, particularly by imposing additional critical control points, mechanical and electrical systems, and the resultant safety and environmental protocols, the more likely the occurrence of system failures, shut-downs, and/or repairs. For this reason, the IPT sought systems that are relatively simple in design and operation when possible.

5.1.1 Environmental Controls

Any new explosive waste technology implemented at HSAAP will undergo rigorous environmental review and permitting, including RCRA permit evaluation. A likely outcome of the permitting requirements will be the implementation of various APC devices to reduce the level of emissions from the chosen technology. The required APC equipment will vary depending on the wastes treated in the chamber and the way in which that chamber is operated (controlled flame combustion vs. indirect heating). Overall, treatment of any hazardous waste in the chamber will dictate the APC equipment required.

5.1.2 Facility Locations

Three potential locations for the construction of new treatment systems have been identified for HSAAP as part of this study. Each location has its own particular merits and challenges and a final site determination will need to be made prior to design of the new systems. Each location will also require an extension of necessary utilities including water (filtered and potable), sewer (sanitary and industrial), at least one sewer pump station, electricity (assumed three-phase medium voltage with step down transformers), natural gas, fiber/cable, road development for ingress/egress, grading and barricades/retaining walls.

5.1.3 Operations and Capacities

As previously stated, operational procedures and capacities were major considerations during this study of potentially viable technologies. A combination of technologies will be required to replace most of the operational capabilities and throughput of the current open burning methods for HSAAP's three waste streams (HEW, NHCW, and NHNCW). For HEW, a review of the potentially viable technologies indicates that the CBC and possibly the MBR technologies will likely require the least amount of re-handling.

The CBC tray system utilized is most similar to that currently in operation. During vendor discussions, the vendor stated that the CBC tray system could be sized to accommodate the anticipated feed rates. However, the vendor's information on their largest system to date only calculated to meet approximately one third of HSAAP's needs. This also assumes that the material processed by that system is directly applicable to HSAAP wastes. The vendor could not provide additional details on the type of waste due to NDAs in place with their customers. Additionally, the TNT equivalence of the actual material processed in the system is unknown and could reduce that capacity by as much as 41% percent. At either rate, a single CBC system will not be able to process the throughput required by HSAAP; therefore, more than one unit would be required. While the tray system is the most similar to HSAAP's current process, the CBC does not have the ability to withstand a detonation. This factor is weighted heavily due to the potential significant safety and operational impacts. Without the additional details on the current material processed and the inability to withstand a detonation, this technology is not a strong candidate for HSAAP.

The MBR's current maximum charge size still presents a significant re-handling of HEW material. Based on preliminary information provided by the vendor, the charge size may be able to be increased and one MBR system may be capable of meeting the throughput requirements based on anticipated volumes.

For an SDC, at least two units will be required to meet the projected throughput. However, the re-handling required to achieve batch sizes is a safety concern for HSAAP.

The IPT determined that a RKI will likely require the most significant amount of re-handling in order to feed the system with more than two units needed to meet the projected throughput. This is further complicated by the issue of recipe development and piloting needed to determine the viability of developing recipes for the complex and variable HSAAP HEW waste stream.

Based on this review of alternative technologies, a large portion of the cage and pile materials (NHCW and NHNCW) could be placed into some form of Flashing Furnace. The Flashing Furnace technology will likely require the least amount of re-handling of these waste streams. For NHNCW, the amount of re-sizing of the material will be a function of the size of the furnace opening and its volumetric capacity. Items larger than the aperture will need to be resized, treated by another means, or open burned.

5.2 Conclusions

BAE OSI developed this report summarizing the assessment of the alternative treatment technologies inclusive of technical maturity, safety, environmental permit attainability, facility siting, operational feasibility, and commercial availability. Capital expenditures were also reviewed, but not used as evaluation criteria. Until a technology(s) is selected, designed, installed, and commissioned, OB practices to treat HEW, NHCW, and NHNCW must continue at HSAAP in compliance with all environmental regulations and permits.

6.0 REFERENCES

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