Mount Rushmore (MORU) Fireworks &

Pyrotechnics Code & Best Practices Evaluation

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Author's Note

This report was prepared on behalf of, and for the National Park Service (NPS).

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Author's Note: This report is not a Formal Interpretation issued pursuant to National Fire Protection Association (NFPA) Regulations. Any opinion expressed is the personal opinion of the author and does not necessarily represent the official position of the NFPA or its Technical Committees.

Photo 1 A 2003 photo from below with 6" and larger color shells bursting above the carvings. [Photo credit: Cleveland.com]

Abstract

This Report is a professional evaluation of the proposed discharge sites for a fireworks display and/or proximate pyrotechnics Show at Mount Rushmore (MORU) National Memorial. These discharge sites have been evaluated for compliance with the relevant National Fire Protection Association (NFPA) codes and standards as well as best practices. The Report will be used to as part of the National Environmental Protection Act (NEPA) evaluation and decision process and inform the NPS and other authorities having jurisdiction (AHJs) in to approve and issue permits for a Show at MORU.

Photo 2 A still photo of multicolor comets fired from angle cakes from the Tops of Carvings. Regular comets do not burst while splitting comets (Crossettes) burst. [Photo credit: South Dakota Tourism]

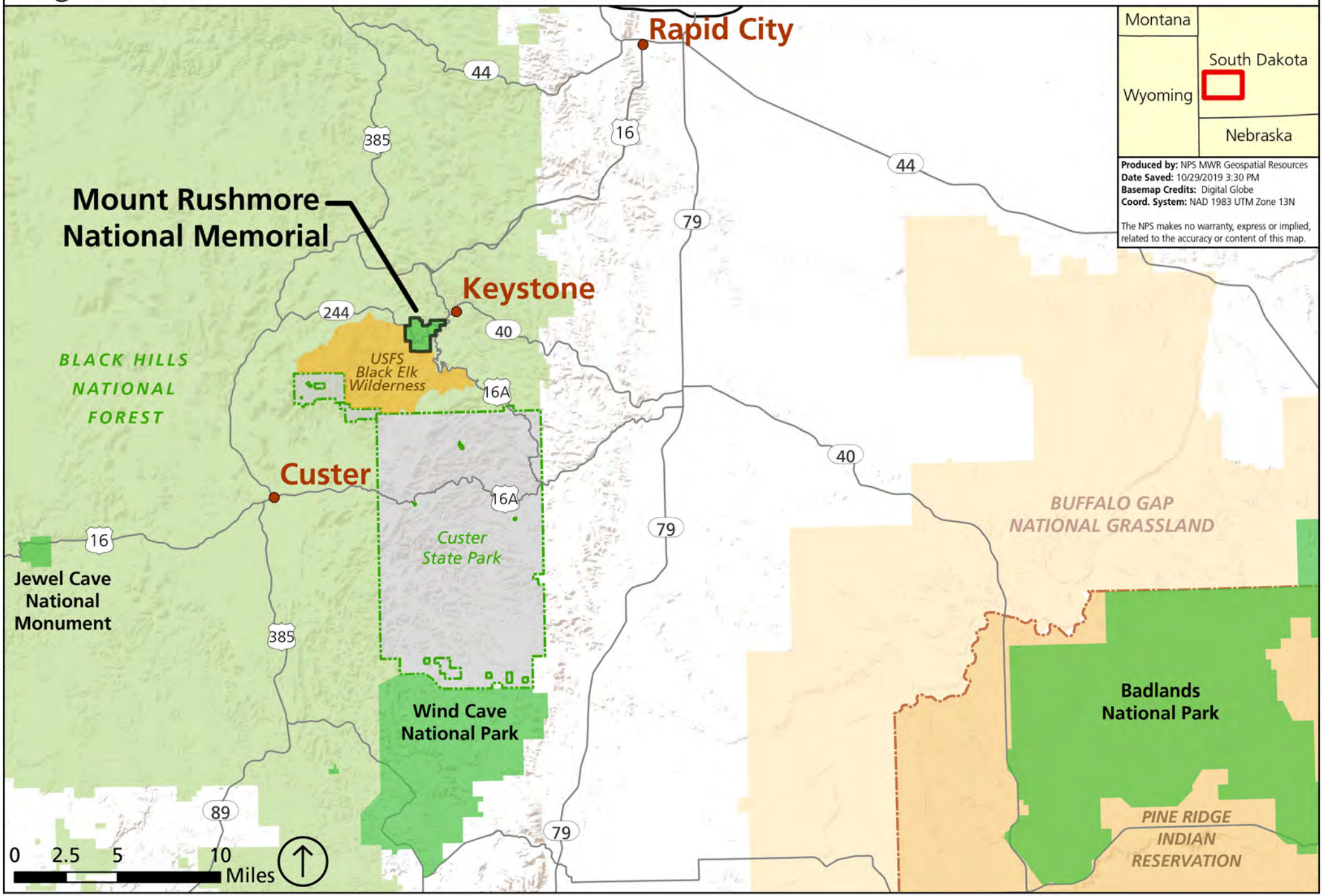
This Report is NOT an evaluation of the entertainment value, the logistical feasibility, the public service availability, or the economic viability of a Show at MORU. It will be up to the Sponsor(s) and the Operator[1] to determine the viewshed of the spectators in the Amphitheater to the MORU carvings together with the performance heights and dimensions of the fireworks and/or pyrotechnics in the sky from the proposed discharge sites, along with the mortar/tube angles in combination with the sizes, types and styles of fireworks and/or pyrotechnics to be fired from those discharge sites.

[1] NFPA 1123 3.3.39 **Operator**: The person with overall responsibility for the operation and safety of a fireworks display.

Mount Rushmore National Memorial
South Dakota

National Park Service
U.S. Department of the Interior

Regional Context



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Introduction

The Mount Rushmore (MORU) National Memorial in the Black Hills of South Dakota is one of the most iconic national memorials administered by the National Park Service (NPS). It is the state's most popular attraction with about 3,000,000 annual visitors from around the world.

The carvings of MORU (Presidents Washington, Jefferson, Lincoln and T. Roosevelt) were blasted out of the smooth, fine grain granite by some 400 workers between 1927 and 1941. Each carving is about 60 feet tall on southeast side of the mountain, which is 5,725 feet above sea level and some 500 feet above the Amphitheater.

MORU consists of 1,278.45 acres of rocky hills covered with ponderosa pine forest and was designated a National Memorial in 1933. It is surrounded by the Black Hills National Forest, which consists of over 1.25 million acres and is managed by the U.S. Forest Service.

The original Visitor Center Complex completed in 1957 consisted of the Amphitheater, Grandview Terrace, and Avenue of Flags together with a gift shop, restaurant, information center and surface parking lot. There have been numerous improvements over the years with additional amenities such as a parking ramp, the Presidential Trail and the Lincoln Borglum Museum.

The Avenue of Flags and Grandview Terrace are currently being renovated and should be completed later in 2020. The Avenue of Flags, Grandview Terrace and Amphitheater are closed to the public during these renovations.

A new Administrative Building replaced the old building in the late 1990s and the original Maintenance Facilities have been updated over the years. There is also a Water Treatment Facility and Employee Dormitory.

Executive Summary

- From 1998 to 2001 and 2003 to 2009 a non-profit organization (NPO) that partners with the NPS at MORU sponsored a fireworks display on July 3rd.
- The fireworks displays were fired by a professional fireworks display company and consisted of thousands of aerial fireworks up to 12"[2] fired electrically from high density polyethylene (HDPE) mortars in above ground wood frame racks, as well as multiple tube devices (cakes) from the Hall of Records.
- In February 2009, NPS staff completed an internal report that addressed concerns with the feasibility of the location of the discharge site, to the manner in which fireworks display was set up and conducted, to the challenges with a fireworks display in a forest on steep slopes, to the safety and security of the spectators, to the compliance with national fire codes, as well as Federal and state laws.
- The 2010 fireworks display was cancelled based on the concerns raised in the 2009 NPS report and recent forest conditions that increased the fuel load
- On May 6, 2019, the Department of the Interior and the State of South Dakota signed a Memorandum of Agreement (MOA) "to work to return fireworks to Mount Rushmore National Memorial in a safe and responsible manner on July 3, July 4, or July 5, beginning in the year 2020".
- In July 2019, staff from MORU and Regional NPS offices as well as from the South Dakota State Fire Marshal (SD SFM) and the Rapid City Fire Department

[2] 1123 4.1.1 Aerial shells, comets and mines are classified and described in terms of the inside diameter (ID) of the mortar from which they are fired (not their circumference)

(RC FD) surveyed potential discharge sites at MORU for a fireworks display in early July 2020. The group determined there were six potential discharge sites.

- On September 6, 2019 the NPS retained the Author to conduct a survey and evaluation of the potential discharge sites to comply with national fire codes and best practices, as well as Federal and state laws.
- The NPS provided the Author with the information available to date and the Author researched additional public information.
- The Author surveyed MORU and met with NPS staff as well as the SD SFM the week of October 7, 2019.
- The Author identified five additional potential discharge sites and divided one potential discharge site (Hall of Records) into five distinct portions
- The Author also consulted with NPS staff over the month of October and early November 2019, and researched additional information (See **References**)
- Based on the information available at this time, the Author has concluded that a fireworks display and/or pyrotechnic Show can be safely conducted at MORU and in compliance with national fire codes and best practices, as well as Federal and state laws, subject to the limitations and recommendations in this Report.
- Any such Show will be different from the previous fireworks displays, which were not in compliance with national fire codes and best practices, as well as Federal and state laws.
- It will be up to the Operator and Sponsor(s) to determine the entertainment value, the logistical feasibility, the public service availability, and the economic viability of a show at MORU.

Photo 3 Green grass and vegetation will burn easily if it receives sufficient heat or direct flame, especially if conditions are hot and dry. This is an example of a small grass fire that occurred during a battlefield reenactment using pyrotechnic and flammable gas special effects.

The fuel load was low, and winds were light, so the grass fire was slow moving. Firefighters with brush trucks and a ready source of water were on station, so it was not deemed a hazardous situation.

The reenactment continued for about an hour and after it concluded, the grass fire was extinguished.

Fireworks Displays at MORU 1998 - 2009

In 1998, a non-profit organization (NPO) that partners with the NPS at MORU sponsored a fireworks display from the Hall of Records canyon and on top of and behind the carvings. The NPO contracted with a professional fireworks company to perform the display on July 3rd.

The proposed display was deemed manageable by the NPS and other officials. Comprehensive operational and law enforcement plans to address issues with traffic control, fire protection, security and other issues were developed by the various Federal, state and local agencies in anticipation of the fireworks display.

The 1998 fireworks display was deemed a success by the NPO and tourism officials, so it was decided to continue it as an annual event. The July 3rd fireworks display continued until 2002 when it was cancelled due to drought conditions.

The July 3rd fireworks display picked up again in 2003 and the Federal, state and local officials continued to improve on their plans. At some point, NPS staff began to insist on changes to the display, such as reducing the sizes of the aerial shells from a maximum of 12" to 6" due to falling debris starting small fires in the forest below.

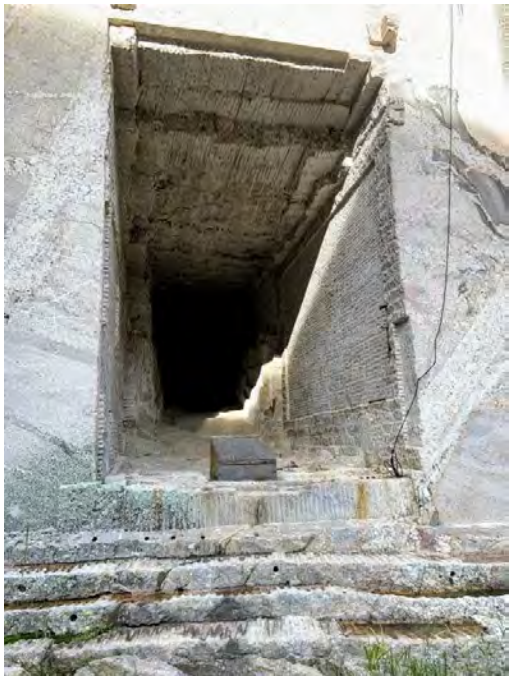

Photo 4 The actual Hall or Records was used by the crew to operate the firing control panel. Note there is no Means of Egress, Exit or Means of Escape. [Photo credit: NPS]

The last fireworks display was performed in the fog in 2009. The 2010 fireworks display was cancelled based on the concerns raised in the 2009 NPS Reconsideration of the Independence Day in Light of Updated Research and a recent pine beetle infestation that killed many ponderosa pines that increased the fuel load.

2009 NPS Reconsideration of the Independence Day in Light of Updated Research

In February of 2009, NPS staff at MORU issued an internal report that reviewed past experience with the fireworks displays and national fire codes and standards, Federal and state laws, as well as NPS policies. The NPS report concluded that many of the past practices were not in compliance national fire codes and standards, Federal and state laws, as well as NPS policies.

The 2009 NPS report concerns included:

- separation distances to spectator viewing areas from an elevated discharge site, especially with wind
- risks of aerial shells firing at steep angles, especially from an elevated discharge site
- potential for wildland fires and the limited fire prevention and fire protection resources
- difficulties with locating duds in a rocky forest fallout area
- hazards of aerial shells bouncing off of overhanging canyon walls
- safety of the crew firing from within the actual Hall of Records
- risks with chain fusing and rapid firing
- inability of mortar racks to withstand a catastrophic aerial shell malfunction in a mortar
- damage to the Memorial from burning cakes and fireworks malfunctions

The NPS Reconsideration concerns regarding the NPS policies, included:

- endangerment to property and critical utility infrastructure
- possible chemical hazards
- safe capacity and egress of the Visitor Center Complex for spectators
- perils to archaeological and natural resources

Photo 5 An example of a catastrophic aerial shell malfunction in a mortar. An 8" aerial shell functioned prematurely in an American made fiberglass mortar with a wood plug screwed into the bottom. The mortars were mounted in above ground wood frame racks.

The display site was in a park by a lake and fairly level. The mortar racks were located on a paved parking lot and nailed to each other for mutual support with 2" x 4"x 8' stringers. The show was computer fired and after the catastrophic aerial shell malfunction in the mortar, other 8" aerial shells continued to fire for many seconds before the show was stopped. Some shells flew down range well over 800 feet away into a grove of trees by some houses.

Note the remnant of mortar in the disintegrated rack in the center and the rack to the right that is missing all five of its mortars. The stringers supporting the group of mortars have been knocked off the racks. Not pictured is how this malfunction telegraphed down the line of mortar racks to the right, knocking other mortars loose and racks over as the computer continued to fire 8" shells.

Author Identified Concerns

In addition to the concerns identified in the 2009 NPS Reconsideration, the Author identified other issues, including:

- no record of any permit applications to the NPS or local fire officials by either the NPO or the professional fireworks company with diagrams of the discharge site, the fallout area and the spectator viewing areas for any years of the fireworks displays[3]
- no record of any permits issued by any Authority Having Jurisdiction (AHJ) to either the NPO or the professional fireworks company for any years of the fireworks displays[4]
- no information regarding the storage of the display fireworks in an approved Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) magazine for the days and weeks prior to the loading of the fireworks at the discharge site[5]
- no information regarding the storage or attendance by the Operator or any Assistants of the display fireworks loaded into the mortars and placed at the discharge site for the days prior to firing the display[6]
- the use of above ground wood frame mortar racks for 8" and larger aerial shells[7]
- no indication there were any Spotters around the Display Site watching the Fallout Area for normal or hazardous debris, duds, and blind stars or effects[8]

[3] 1123 10.3
[4] 1123 10.3
[5] 1124 Chapter 5 and 27 CFR, Part 555, Subpart K Storage
[6] 27 CFR, Part 555, Subpart K Storage
[7] 1123 4.5.1* and 4.5.3
[8] 1123 8.1.4.3

- no indication the Operator and/or Shooter was able to communicate with any of the Spotters or the AHJs, or vice versa[9]
- nothing to address the use of the Hall of Records as a limited egress discharge site and how the crew would be protected[10]

U. S. Geological Survey (USGS) Soil & Water Survey

In 2016, the U. S. Geological Survey (USGS) published the results of their soil and water survey conducted between 2011 and 2015 at MORU. These surveys began two years after the last fireworks display in 2009 and found fireworks debris on the ground.

The USGS determined that the past fireworks displays were the probable cause of elevated concentrations of perchlorate in groundwater and surface water. The concentrations are such that any further monitoring is advisable if there are fireworks displays in the future.

Fireworks compositions generally consist of a fuel, an oxidizer and a binder. Fireworks compositions create the bright colors and loud sounds due to the high heat and energy output of the fuel burning rapidly because of the higher levels of oxygen provided by the oxidizer (as opposed to combustible or flammable fuels that rely on the oxygen in the atmosphere to burn)

Potassium perchlorate (KClO4) is the most common oxidizer used in display fireworks. It is more stable than potassium chlorate (KClO3), which increases the sensitivity of fireworks compositions to ignition from impact or friction.

When fireworks stars and effects burn in the sky, the majority of the fuels and the oxidizers are consumed when heat and light are released, however any minute particles of

[9] 1123 8.1.4.3.2
[10] 1123 Chapter 7

compositions that are not burned will fall back down to the ground. The cardboard casings of aerial shells that burst apart in the sky and was in contact with the fireworks compositions will also fall back down to the ground with residual composition. Any duds or blind stars that failed to ignite in the sky will also fall down to the ground.

Over time, the remaining fuels and oxidizers that have come down to the ground in whatever form will eventually breakdown, thus resulting in potential contamination.

The level of contamination is based on the volume of unburned fireworks compositions that may come down over time, the type of soil and the volume of precipitation, and other factors.

Department of the Interior and South Dakota Memorandum of Agreement (MOA)

On May 6, 2019, the Department of the Interior and the State of South Dakota signed a Memorandum of Agreement (MOA). The MOA among other things called for the parties "to exercise their full authorities under State and Federal law to work to return fireworks to Mount Rushmore National Memorial in a safe and responsible manner on July 3[11], July 4, or July 5, beginning in the year 2020".

This Evaluation is a part of this process.

[11] NPS Staff advised the Author that July 3rd was the only date supporting law enforcement, fire protection and other critical resources were available for a show at MORU

Photo 6 An example of an ideal display site. This display site is in an open, grassy field with no overhead obstructions. It is accessible by motor vehicles so the equipment and fireworks can be delivered to the discharge site.

The discharge site within the display site is 400 feet wide and 100 feet deep and it is in an area closed to the public and under 24-hour video surveillance with security patrols. The main spectator viewing area is in the grandstand another 150 feet behind the photographer.

The fireworks display consists of limited sizes, types and styles of aerial fireworks to minimize normal and hazardous debris, concussive effects, etc. All mortar racks are individually staked to the ground or supported by heavy duty steel frames.

There are fire hydrants as well as sprinklers near the discharge site for ready access to water if needed.

Display Sites, Discharge Sites, Fallot Areas and Spectator Viewing and Parking Areas

In order to understand this evaluation, it is helpful to first discuss the basic terms, code standards and best practices for Display Sites, Discharge Sites, Fallot Areas and Spectator Viewing and Parking Areas.[12]

Typically, a fireworks display has a single display site, discharge site and fallout area but many spectator viewing and parking areas. Some fireworks displays may have more than one display site, discharge site and fallout area as well.

A perfect display site for absolute safety would be fired remotely in a desert by robots with nobody and nothing around it that could be harmed or damaged in the event of a failure or

[12] See the definitions in Appendix A -Definitions and Standards

malfunction. Every other display site always has a number of compromises to absolute safety, starting with the fireworks crew that will handle, set up and operate the fireworks display to the supporting personnel and the spectators, to the property in and around the display site.

Display Sites

Ideally, a display site is a large open area that is relatively flat, and either in or near a public park, or some other facility such as a fairground, ball field, golf course, racetrack or the like where spectators can gather to watch the fireworks. Anything less than this ideal requires additional attention to detail by the Operator, Sponsor(s) and AHJ(s) to provide the safest fireworks display possible.

The design of the fireworks display will be based on the many variables of the display site, available resources, anticipated weather conditions and other factors. The design is critical to the safe conduct of the display because what is decided or not decided regarding the fireworks and the firing equipment before the fireworks display will determine the possible outcome in the event of a failure or malfunction during the fireworks display.

Essentially with a fireworks display, one is inviting thousands of people to attend an outdoor event, in the dark, which in and of itself presents many challenges. The spectators are as

close as permitted to see large projectiles fired into the sky, where they will explode with solid chemicals burning at 800-1,000° C while spreading out high in the sky.

Photo 7 One of the factors to both the operation and the cost of a fireworks display is the amount of transportation and labor that is required to deliver the firing equipment and the fireworks to the display site, and then remove it all after the fireworks display. Larger, more complex shows at challenging venues require more resources, especially when working outside around the weather.

This normal functioning of a fireworks display involves fireballs and firebrand near the ground where the fireworks are fired from, followed by burning pieces of paper and cardboard falling back to the ground over many thousands of square feet. And this is what happens when there are no equipment failures or fireworks malfunctions.

The entire area around the exploding projectiles in the sky must be kept clear of unauthorized personnel. All public paths and roads must be closed and any bulk storage areas of materials that have a flammable, explosive or toxic hazard, and occupied dwelling buildings and structures must be accounted for as well, both during and after the display until this area can be cleared of any duds, and blind stars or effects.

This entire area also must have any potential combustible fuels, such as grass, trees and shrubs either be in a stage and condition that a wildland fire is not likely, or mitigation measures have been taken to reduce the chances of a wildland fire, or if possible, removed.

Discharge Sites

Selecting the appropriate discharge site is one of the most important facets to a safe fireworks display. Ideally it is reasonably flat and readily accessible with no or limited combustible vegetation and overhead objects. Also, of importance is a clear line of site of the portion of the sky the fireworks will burst above the discharge site to the main spectator viewing area (otherwise there is no point to shoot the fireworks display).

The location of the discharge site in relationship to the main spectator viewing area will determine in part what fireworks can and should be used. Ideally the designer will choose the sizes, types and styles of fireworks that provide for the safest fireworks display possible, followed by what fireworks are most visible and entertaining to the spectators using the well understood design principles of scale, proportion, rhythm and pace.

Fallout Areas

The fallout areas are where the normal debris from a fireworks display is expected to land. It is also where any hazardous debris, duds, blind stars and effects are expected to land, provided the designer selected the right sizes, types and styles of fireworks for the display site and the anticipated weather conditions.

The fallout area is also where any aerial shells, comets or mines are likely to fire in the event of an equipment failure or fireworks malfunction, however this will depend in large part on sizes, types and styles of fireworks selected as well as the types of mortars and mortar racks, placement and securement methods, and fusing and firing methods.

It is possible that an errant fireworks can be fired at such an angle, especially from an elevated discharge site, that it can travel well outside the display site and then explode.

Spectator Viewing and Parking Areas

Essentially any place that spectators can view a fireworks display and park their cars while there to watch the show are spectator viewing and parking areas. However, from the perspective of the fire codes, the concern is primarily on spectator viewing and parking areas that are immediately adjacent to the display site. It is not uncommon that a fireworks display held for the benefit of a private audience at an outdoor venue may have an even larger audience outside of that venue.

Ideally, spectator viewing and parking areas are located in public parks, or some other facility such as a fairground, ball field, golf course, racetrack or the like that has the basic infrastructure to serve a large crowd at an outdoor event. Grandstand seating and/or open grassy areas are preferred for warm weather shows. A park or facility with permanent or temporary restrooms, food and beverage services and other amenities are often desired.

Separation Distances

In evaluating a potential display site, it is common that the first and sometimes the only consideration is the required minimum separation distances[13] between the aerial shells to be fired in a proposed discharge site, and the proposed main spectator viewing and parking area. If noted,

[13] 1123 5.1.3.1

but sometimes overlooked when evaluating a potential display site are bulk storage areas of materials that have a flammable, explosive or toxic hazard, and dwelling buildings and structures. The distance will be measured and a determination often made that it will be "safe" to fire the largest aerial shells possible that meet the prescribed minimum separation distance.

Photo 8 An example of a computer firing control panel. These panels can fire thousands of cues in increments as fast a 1/10th of a second. They are proprietary and together with the design software, testers, junctions, firing modules and cables needed to make the entire system work, can cost tens of thousands of dollars

The reality is there are a host of other critical variables that can and should be taken into account before deciding on what sizes, much less what types and styles of fireworks can safely be fired at a particular display site. Many of these other critical variables are conditional and evaluating each in relationship to the others requires a thorough and thoughtful process.

Other Critical Variables

The Operator, Sponsor(s) and AHJ(s) must also evaluate and assess a number of other critical variables above and beyond just the separation distances. All of these variables must be considered along with the separation distances in order to develop a comprehensive show plan that provides for the safest possible fireworks display. These variables include:

- Aerial shell types and styles (Single break, multiple break, salutes, reports, inserts, comets, mines, splitting effects, bursting effects, falling or trailing effects, Roman candles, cakes, etc.)

- Display fireworks vs articles pyrotechnic
- Quality, reliability and consistency of the display fireworks and/or article pyrotechnic
- Quality, reliability and consistency of the mortars and mortar racks[14]
- Quality, reliability and consistency of the methods to secure mortars and mortar racks and securement (Steel or lightweight mortar materials[15], buried in the ground, troughs or drums[16], methods of bracing and securing above ground mortar racks[17],
- Method(s) of ignition (manual, electrical or computer)
- Fusing type (Single shot vs. chain fused[18])
- Pace of the show (slow, moderate or rapid fire)
- Combustible fuel types and loads (Grass, weeds, deciduous vs non- deciduous shrubs and trees, quantity of leaves and needles on the ground, etc.)
- Weather conditions prior to as well as potentially during the fireworks display (hot, dry, windy vs. cold, wet and calm) [19]
- Fire prevention (What needs to be done *beforehand* to mitigate potential for wildland fires vs. what can be done with the resources and time available)[20]

[14] 1123 4.5.4, 4.5.7* and 4.61*
[15] 1123 4.3.8* and 4.3.10*
[16] 1123 4.4
[17] 1123 4.5
[18] 1123 4.6.2 and 5.1.3.3.2
[19] 1123 8.1.4.1 and 8.1.4.2*
[20] 1123 8.1.1*

- Fire protection (What needs to be done *during and after* to mitigate potential for wildland fires vs. what can be done with the resources and time available)[21]
- Ability of the Spotters to watch for normal or hazardous debris, duds, and blind stars or effects[22]
- Ability of the Monitors to secure the display site[23]
- Ability of the Spotters to communicate directly with the Shooter[24]
- Ability to police the display site for duds, and blind stars or effects immediately after the fireworks display, and again at first light.[25]
- Access and logistics to the discharge site (Haul the firing equipment and fireworks in and the firing equipment out)
- Ability to manage the spectator viewing and parking areas safely [26]
- Ability to secure the discharge site(s) and fallout area(s) prior to[27], during[28] and after[29] the fireworks display
- Ability to mitigate the risks to the crew for a fireworks display from floating vessels and floating platforms[30] or a rooftop, other structure or other limited egress discharge site[31]

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[21] 1123 8.1.1*
[22] 1123 7.6.4
[23] 1123 8.1.2.1 and 8.1.4.1
[24] 1123 8.1.4.3.2
[25] 1123 8.2.12*
[26] 1123 8.1.2*
[27] 1123 8.1.2.4
[28] 1123 8.1.2.1 and 8.1.4.1
[29] 1123 8.2.12*
[30] 1123 Chapter 6
[31] 1123 Chapter 7

- Ability of the fire protection and emergency response personnel to respond to a situation[32]
- Potential for hazardous condition given the variables of the fireworks display, the display site and the weather[33]

Operator, Sponsor(s) and AHJ(s) Duties

Ultimately the decisions on how a fireworks display is planned, set up and operated and how the display site(s), discharge site(s), fallout area(s) will be decided by the Operator (there is only one) with the Sponsor(s) and the AHJ(s). The decisions that are made or not made will determine the likely outcome of any equipment failure or fireworks malfunction.

What happens in the event of an equipment failure or fireworks malfunction is likely to be almost instantaneous and unfold very rapidly and result in a series of hazardous situations that are potentially deadly to people and dangerous to property. The typical failures and malfunctions at a fireworks display occur so rapidly they are almost impossible for any human to react to, much less respond to, with any response too little, and too late to mitigate the hazardous situation. At that point, luck is the only potential mitigating factor.

This is why it is so important to design and plan a fireworks display anticipating the worst-case scenarios so the risks can be mitigated to an acceptable level of safety. The primary goal is to eliminate as many risks to life and property as possible, and mitigate the risks that cannot be eliminated.

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[32] 1123 8.1.4.4 and 8.1.5
[33] 1123 8.1.4

Photo 9 An example of a catastrophic aerial shell malfunction in a mortar. A 6" single break color shell has just burst inside a 6" HDPE mortar with a wood plug in an above ground wood frame rack. This photo was taken from over 100 feet away. Note an HDPE mortar from the mortar rack and pieces of the mortar rack flying up and out from the explosion with the fireball of the burst charge and burning stars, some of which landed still burning over 200 feet away.

Fireworks Failures and Malfunctions

There are a number of fireworks failures and malfunctions[34] that are wort-case scenarios that the Operator as well as the Sponsor(s) and AHJ(s) must consider. Here are a few:

- A catastrophic aerial shell malfunction of an aerial fireworks shell in a mortar is always a possibility. Such an event in a mortar made of lightweight mortar materials in an above ground wood frame rack, particularly of a larger, more powerful aerial shell can lead to devastating results. This type of malfunction can

[34] See Author's Terms for Malfunctions

be compounded by the methods that mortar racks are grouped or not, the materials and methods to secure the mortar racks and the elevation of the discharge site in relationship to the fallout areas and spectator viewing areas.

- A catastrophic aerial shell malfunction of an aerial fireworks shell in a mortar in a mortar rack containing chain fused aerial shells (or a blowout of a tube in a cake or finale box). Once ignited, the chained aerial shells or devices will continue to fire until it blows itself out, or it is spent.
- Failing to secure mortar racks properly or grouping them together so the mortar racks rely on each other for mutual support can result in mortars or mortar racks being realigned and firing aerial shells well outside the display site.
- Aerial shells that break low, especially over a fallout area with a substantial amount of fuel load, such as an area with lots of dry vegetation.
- Firing aerial shells at steep angles without adding additional fallout area to compensate.
- Failing to angle mortars and mortar racks away from the spectators and increasing separation distances in anticipation of winds blowing towards the spectators or over a sensitive part of the fallout zone.
- The Operator and AHJs being unable to communicate effectively with each other, as well as the Shooter and Spotters during the fireworks display
- Failing to recognize the difference between normal debris and hazardous debris.
- Selecting fireworks that are inappropriate for the display site and the conditions
- Failing to modify plans when things do not go as expected (they never do)

There are many others from possible incursions into the fallout area by a few spectators to the Shooter being unable to hear a call on the radio from a Spotter to a fire fighter overreacting to a few small pieces of glowing paper debris that helicopter outside the display site.

Applicable National Fire Protection Association (NFPA) Codes & Standards

The Author has identified the following National Fire Protection Association (NFPA) codes and standards that are applicable to a fireworks display/proximate pyrotechnic Show at MORU. These are:

- NFPA 1123, *Code for Fireworks Display* (2018)
- NFPA 1124, *Code for the Manufacture, Transportation, and Storage of Fireworks and Pyrotechnic Articles* (2017)
- NFPA 1126, *Standard for the Use of Pyrotechnics Before a Proximate Audience* (2016).
- NFPA 101, *Life Safety Code*® (2018) [Egress and other safety to life issues in an Assembly Occupancy]

Also applicable for a fireworks display/proximate pyrotechnic Show at MORU is:

- NFPA 1141, *Standard for Fire Protection Infrastructure for Land Development in Wildland, Rural, and Suburban Areas* (2017)
- NFPA 1143, *Standard for Wildland Fire Management* (2018)

Key NFPA 1123 Standards

The Operator

The most important standards in NFPA 1123 and NFPA 1126 are the definitions and requirements of the Operator/Pyrotechnic Operator. This one person is ultimately responsible for ensuring that all of the standards are followed and for the safe operation of the show. NFPA 1123 8.1.3 says it best: "**The Operator shall have primary responsibility for safety**".

Minimum Required Radius of the Display Site

The minimum required radius of the Display Site is established in 1123 5.1.3.1. The formula is 70 feet per ID inch of mortar for the largest shell to be fired (in that discharge site). Other provisions, such as 5.1.4 and 5.2 modify this formula based on other factors, such as for using mines and comets, the bulk storage of hazardous materials, and elevations above the spectator viewing areas, etc.[35]

[35] The *Display Fireworks Manual* (2010) and from Natural Resources Canada and the *Study Guide for Display Operator Training Program* (2017) from the Pyrotechnics Guild International, Inc. (PGI) address shell types and sizes, mortar placement and angle, elevated discharge site, wind speed and direction, and other factor in greater detail. Both documents provide for increased separation distances to spectator viewing areas based on these variables.

Photo 10 Flammable liquid and gas storage at different locations at MORU must be considered when establishing separation distances from discharge sites, in particular from any that are elevated.

However, the base formula in 5.1.3.1 is predicated on buried mortars that are vertical (90°) and firing single break color shells one at a time with a wind speed of zero. It does not take into account the use of lightweight mortar materials in above ground wood frame racks that cannot withstand a catastrophic malfunction. It does not take into account a group of these racks in close proximity to one another, relying on each other for mutual support, or angled to as much as 45°, or the potential for equipment failures or fireworks malfunctions.

It also does not take into account aerial shells that are chain fused[36] or the rapid pace a computer firing system can fire aerial shells, or wind speed and direction, and how these factor into separation distances in the event of equipment failures or fireworks malfunctions.

These factors are all up to the Operator to assess and determine using the applicable national fire codes and best practices[37] in consultation with the Sponsor(s) and the AHJ(s).

An experienced and prudent Operator understands these are the minimum separation distances[38], but will also know the worst case scenarios where mortars are knocked over from a catastrophic malfunction in a mortar or the failure of a mortar rack support, which can result in aerial shells firing at steep angles well beyond the designated fallout area.

An experienced and prudent Operator also understands that scale and proportion principles yield the optimum viewing of a show for the spectators. Generally, these are at distances greater than the minimums in the standards, especially for elaborate and complex pyromusicals.

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[36] 1123 5.1.3.3.2 The minimum separation distances are doubled for "mortars, racks or other holders that are not sufficiently strong enough to prevent their being repositioned in the event of an explosive malfunction"

[37] Best practices in the fireworks trade are developed within each professional fireworks display company and vary significantly. Some companies have comprehensive professional development and safety programs, while others simply do what they've always done in the past and trust to luck. The trade tends to be secretive and very little is shared, much less published. What is published are such things as the *Display Fireworks Manual* (2010) and *Special Effects Manual* (2014) from Natural Resources Canada, the *Celebrate Safely* (DVD), American Pyrotechnics Association (APA), (2014), and the *Study Guide for Display Operator Training Program* (2017) from the Pyrotechnics Guild International, Inc. (PGI).

[38] The Canadian minimum separation distances are significantly greater than NFPA 1123 (Table 3-1), with formulas for increasing the distances to compensate for wind speeds and directions, as well as mortar angles (Table 3-2). These minimum distances are tripled "When mortars are not properly buried, placed in non-destructible racks or barricaded"

Overhead Projections and 25 Foot Clearance from Aerial Shell Trajectory

The issues of what constitutes an "overhead projection"[39] and the requirement for a 25-foot clearance from aerial shell trajectory is an essential standard when evaluating discharge sites at MORU. Every proposed discharge site at MORU has something that might be a potential "overhead projection", depending on where mortars ore tubes are placed. There are trees with branches, rock walls or stage walls that must be considered.

Photo 11 If a human can get to or stand on a location, some type of holder and fireworks or pyrotechnic device can be placed there. Whether it is safe and prudent for a human to get to that location, or place and use any particular type of fireworks or pyrotechnic device requires a serious evaluation of the various risks involved. [Photo credit: Seattle Space Needle]

This standard has been in NFPA 1123 since it was first adopted by in 1978. It has remained with the same exact wording ever since.

The purpose of the standard is twofold. First, protect property from potential damage from being struck by an aerial shell, and: second, protect the aerial shell from damage from an overhead object.

[39] 1123 5.1.4.7 The area selected for the discharge of aerial shells shall be located so that the trajectory of the shells shall not come within 25 ft. (7.6 m) of any overhead object.

At that time, fireworks displays were much smaller and typically fired from steel mortars buried in rows in the ground or troughs with the finale fired from cardboard mortars in above ground wood frame racks or finale boxes. The aerial shells were fired manually with fusees, portfires or other open flame sources, reloaded and fired multiple times.

The largest aerial shell size standard in the first two editions of NFPA 1123[40] was for 6" aerial shells (the separation distance and the fallout to the spectators was same at 150 feet, but 500 feet from hazardous materials, hospitals and penal facilities).

The buried mortars were angled slightly away from the Shooter and as the mortar was fired and reloaded over the course of the show, the recoil would often drive the mortar into the ground and/or change the angle of the mortar. Thus, the trajectory of the last shot could be very different than the first shot.

The vast majority of shows were then, and still are fired by volunteer groups in small communities across the country. They are often conducted in parks and ballfields and other public spaces with overhead wires, streetlamps, flagpoles, as well as trees and shrubs.

The standard is limited to only aerial shells. It does not include any other aerial fireworks such as comets, mines, Roman candles and cakes.

It is arbitrary because there is a single standard for all aerial shells no matter the size or type of the shell, or the mortar placement or angle. It is also the same for all overhead objects, no matter how tall or potentially sensitive to being damaged by an aerial shell, or causing damage to an aerial shell.

[40] NFPA 1123, Code for the Public Display of Fireworks (1978 and 1982)

A strict interpretation of the standard would treat any object that is within 25 feet of a mortar and taller by any measurement than that mortar as an overhead object. Thus, any mortar that is both taller than another mortar and within 25 feet would be considered and "overhead object" and one or the other mortar would be required to be moved further than 25 feet away.

Given that most fireworks displays now use lightweight mortars in above ground wood frame racks that are fired once and not reloaded, the concern over a mortar changing angles over the course of a show is no longer a concern; *provided that the mortar rack is securely placed*.

The intent of this standard is to prevent an aerial shell from striking and damaging an overhead object and/or being damaged by that overhead object. The distance needed to prevent this from happening is dependent on the size and type of the aerial fireworks, the type of mortar or tube and the method of placement, the angle of the mortar or tube in relationship to the overhead object, the height and type of overhead object, and the size and type of overhead object in combination with the potential for this event creating a hazardous situation.[41]

An example where 25 feet is more than is needed: A 3" aerial shell (round) is loaded into an HDPE mortar in an above ground wood frame rack that is at 85°. It is placed 5 feet away from a retaining wall in a park that is 50 feet tall and slopes away at 88°. The trajectory of a 3" aerial shell (round) will not be an issue with the retaining wall unless there is an incredibly strong wind towards the retaining wall at ground level.

An example where more than 25 feet is needed: A 12" aerial shell (round) is loaded into an HDPE mortar in an above ground drum filled with sand at 90°. It is placed 25 feet away from a cell phone tower that is 180 feet tall also at 90°. The trajectory of the 12" aerial shell (round)

[41] Aerial shells can be fired through plywood sheets mounted a few feet above the mortar with little to no effect on their performance.

could possible strike the cell phone tower, even if there is a slight breeze away from the cell phone tower. [50 feet would be a more prudent distance].

An Operator will need to determine exactly where in any of the proposed MORU discharge sites mortars and tubes can be placed in relationship to overhead objects, whether it is rock walls or tree branches, and exactly what size and type of fireworks or pyrotechnics can be safely fired from those locations.

An Operator will need to substantiate the location and angle choices according to 1123-1.3 Equivalency.

Photo 12 An example of troughs full of sand for 8", 10" and 12" mortars. Troughs and drums are often used where ground water levels are high and the soil is too soft to handle the recoil from large diameter mortars, or where the ground is too hard to bury the mortars.

AHJ Discretion

MORU is one of the more challenging venues one could pick for a fireworks display. The fact that it is a rocky mountain in a forest alone is enough of a challenge, but the many other variables, from the potential discharge sites at multiple elevations, to the angles needed to shoot bursting fireworks above the carvings, makes it incredibly complex.[42][43]

Photo 13 A 3" blowmolded HDPE mortar after a 3" single break salute shell was intentionally burst in the mortar. Note how the HDPE has stretched before failing in the classic banana peel deformation.

The applicable fire codes for a show at MORU as adopted by the NPS and the South Dakota State Fire Marshal are NFPA 1123, 1124 and 1126. Each is applicable to specific portions of a show depending on the timing and location of the show.

The NPS and other AHJs both can and should give consideration to establishing specific minimum standards for a fireworks show at MORU based on their collective knowledge and experience to ensure public safety and protect the national treasure of MORU.

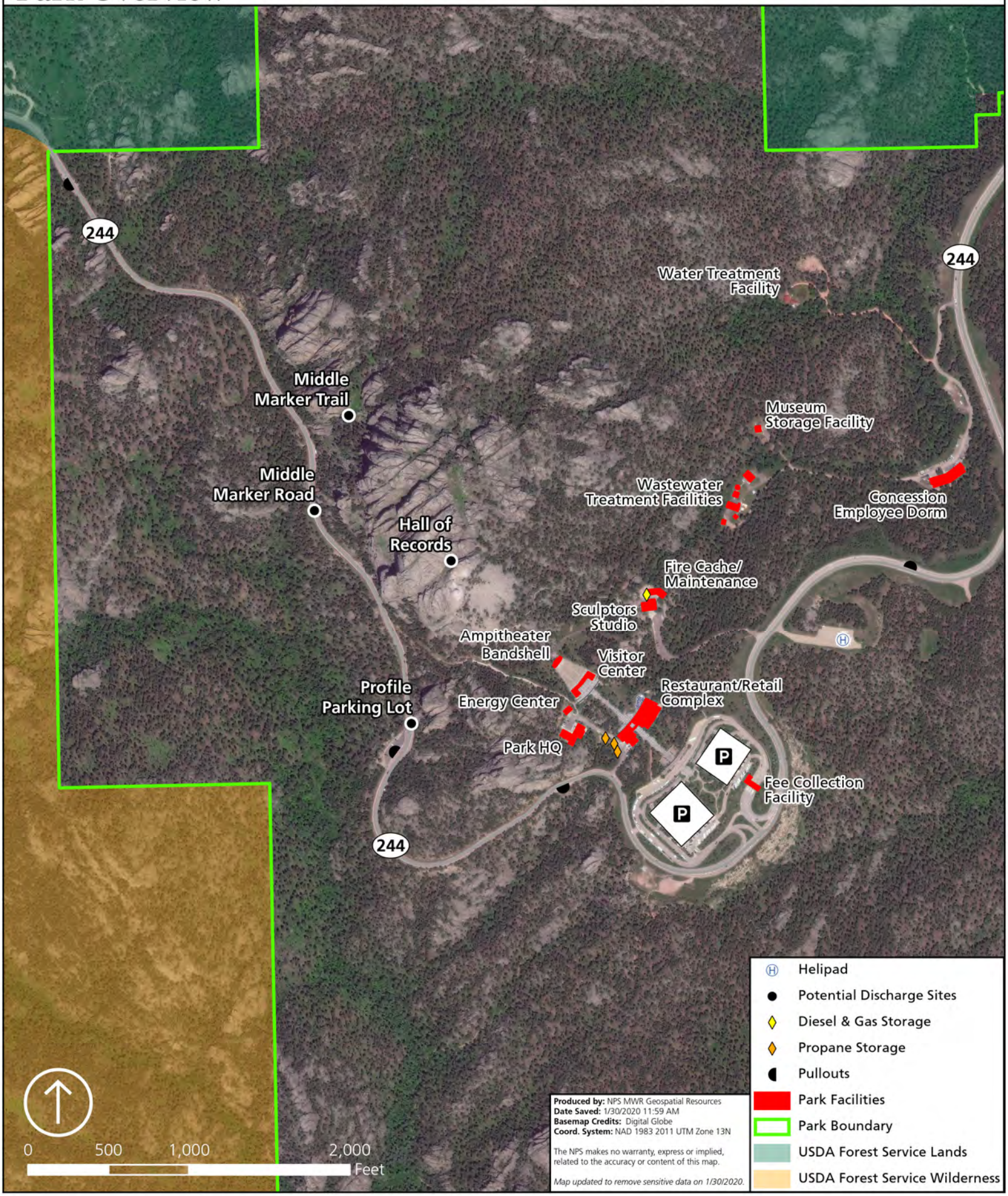
[42] 1123 5.1.1 establishes additional criteria for the AHJ above and beyond the very broad definition of "Approved" for venues and situations just like MORU.

[43] 1123 5.2.2.1 in particular is applicable because MORU certainly has "unusual' and "safety-threatening conditions" no matter the weather or wildland fire conditions

Mount Rushmore National Memorial
South Dakota

National Park Service
U.S. Department of the Interior

Park Overview



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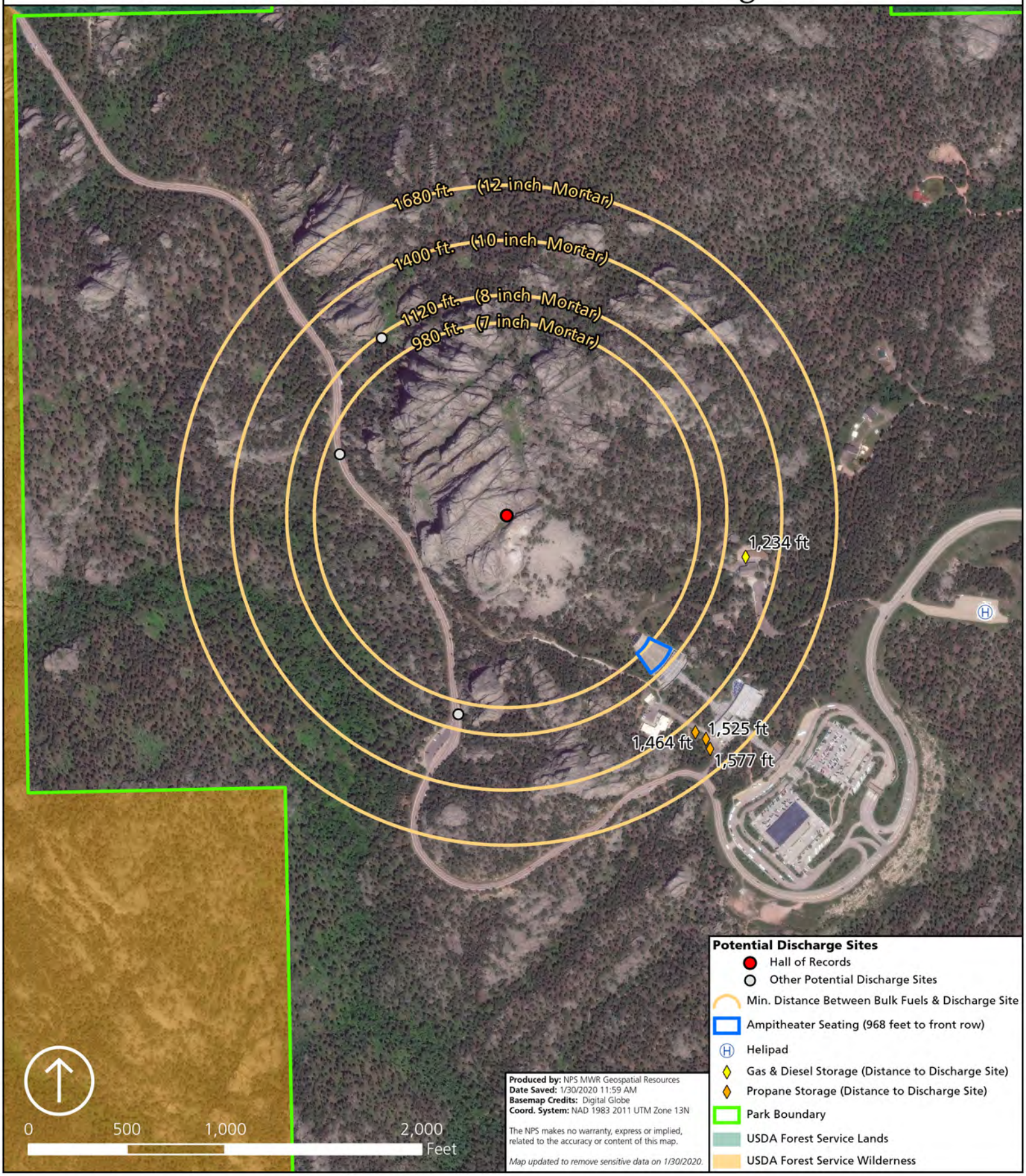
Mount Rushmore National Memorial
South Dakota

National Park Service
U.S. Department of the Interior

Hall of Records Discharge Site
Minimum Distance Between Bulk Fuels & Discharge Site



Potential Discharge Sites
- Hall of Records
- Other Potential Discharge Sites
- Min. Distance Between Bulk Fuels & Discharge Site
- Ampitheater Seating (968 feet to front row)
- Helipad
- Gas & Diesel Storage (Distance to Discharge Site)
- Propane Storage (Distance to Discharge Site)
- Park Boundary
- USDA Forest Service Lands
- USDA Forest Service Wilderness

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Mount Rushmore National Memorial
South Dakota

National Park Service
U.S. Department of the Interior

Hall of Records Discharge Site
Minimum Distance Between Spectators & Discharge Site

Potential Discharge Sites
- Hall of Records
- Other Potential Discharge Sites
- Min. Distance Between Spectators & Discharge Site
- Ampitheater Seating
- Helipad
- Gas & Diesel Storage (Distance to Discharge Site)
- Propane Storage (Distance to Discharge Site)
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Photo 14 The Hall of Records Canyon, Entry and Ridge from the top of the steps of the Guard Shack. The actual Hall of Records is to the left of the Canyon and the Entry is to the right. The Ridge is to the top left (Note the wiring crew up in the rocks of the Ridge)

NPS Proposed Discharge Sites

In July 2019, staff from MORU and Regional NPS offices as well as from the South Dakota State Fire Marshal (SD SFM) and the Rapid City Fire Department (RC FD) met with at MORU and surveyed potential discharge sites for a July 3, 2020 fireworks display. The survey included taking photographs and geographic information system (GIS) measurements at the various potential discharge sites.

The group determined there were six potential discharge sites, which are as follows:

Hall of Records Discharge Site

The Hall of Records Discharge Site is the location used for the previous fireworks displays from 1998 to 2001 and 2003 to 2009. It is the logical first choice for a discharge site at MORU because it is directly behind the carvings and only about 1,000 feet from the spectators in the Amphitheater. Most aerial fireworks fired from this location will burst above the carvings and be readily visible[44] to the spectators in the Amphitheater.

This discharge site can only be reached by climbing the mountain or by helicopter.[45] Transporting the equipment and the fireworks here is extremely difficult. The area is mostly rocky but there are nearby forests, in particular below the mountain.

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[44] What fireworks effects are readily visible from any discharge site or portion of a discharge site to the Spectators in the Amphitheater, especially those in the front rows with the backstage blocking the view of the carvings and in the Grand View Terrace to the sides with tree branches blocking the view of the carvings will be for the Operator to determine. This will require a viewshed analysis in combination with a detailed evaluation of the performance heights and widths of the various aerial shells, comets and mines.

[45] A Special Permit from the U. S. Department of Transportation (DOT), Pipeline and Hazardous Materials Safety Administration (PHMSA) for aircraft to carry Class 1 Explosives. See 49 *CFR*, Part 107, Subpart B - Special Permits

The Hall of Records Discharge Site is the most complex of the six NPS proposed discharge sites. It has multiple portions on different levels that must be considered when evaluating the potential for use as a discharge site. In order to better understand these differences, the Author divided the Hall of Records Discharge Site into five distinct portions in order to address the different issues presented in each portion.

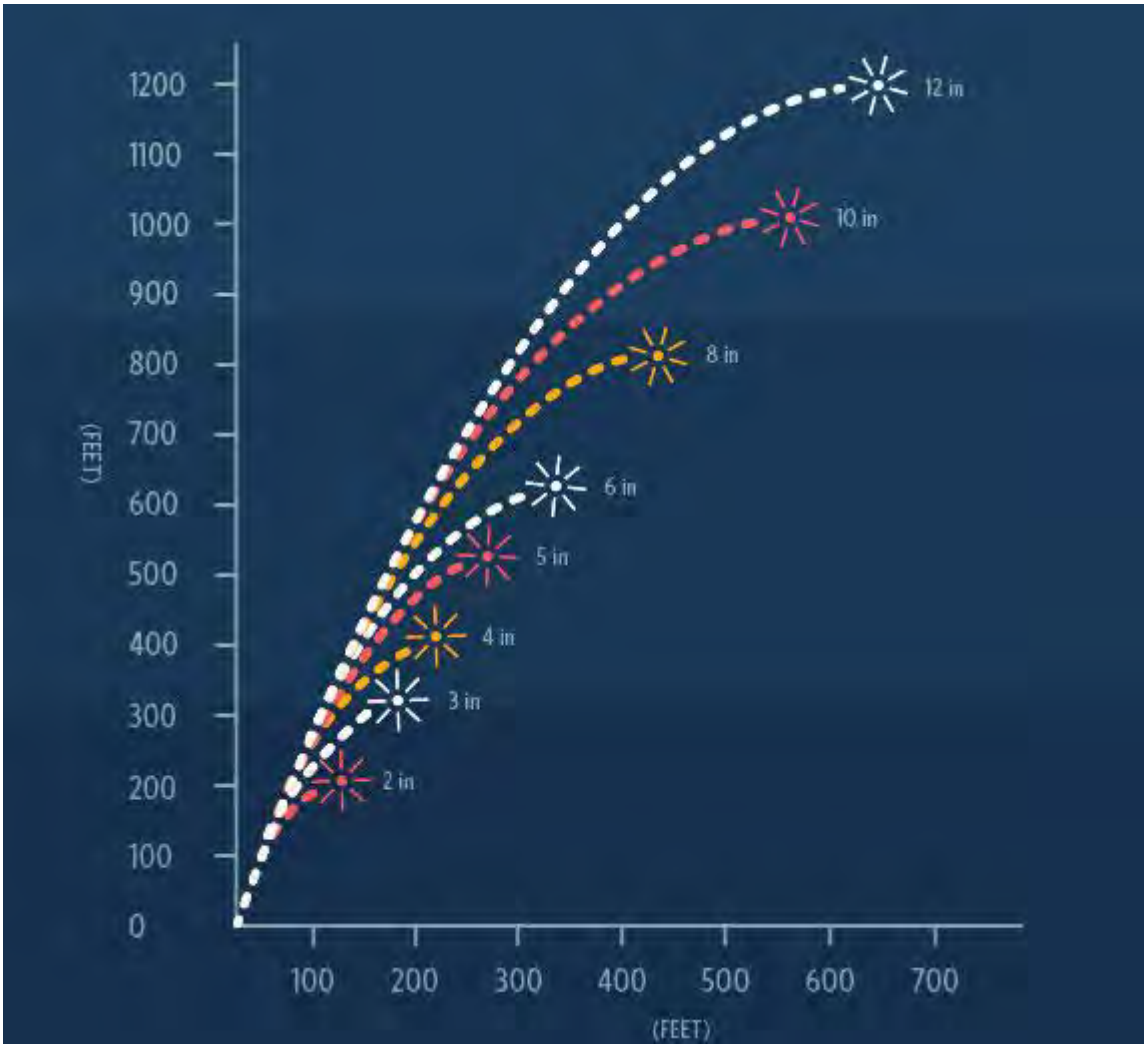

Photo 15 The rough rule of thumb for performance heights of most aerial shells. The actual performance heights can vary significantly depending on the type, style, manufacturer as well as the mortars and their placement. The performance heights for articles pyrotechnic are much more precise due to the higher quality of the various propellants and compositions combined with the tighter tolerances between the device and the mortar or tubes. [Chart credit: pyroinnovations.com]

Portions of the Hall of Records Discharge Site

The five distinct portions of the Hall of Records Discharge Site are as follows:

- Hall of Records - Canyon (The wide portion of the canyon immediately in front of the Hall of Records)
- Hall of Records - Entry (The narrow entry into the Canyon at the top of the metal staircase. It has a chain link fence and gate with concertina wire)
- Hall of Records - Top of Carvings (The platform and rock shelf behind and on top of the carvings)
- Hall of Records - Guard Shack Steps (The steps and landing to the Guard Shack)
- Hall of Records - Ridge (The top of the ridge behind the Hall of Records)

Description of the Hall of Records Discharge Site

At the base of the steel steps up to the Hall of Records is a chain link fence and gate with concertina wire. Within the Entry at the top of the steps is another fence and gate with concertina wire.[46]

The Canyon and Entry vary in depth from about 80 to 120 feet. The Canyon walls tend to slope outward while the Entry walls tend to slope inward.

There is very little level ground in the Canyon or Entry. There are rocks of various sizes that jut out of the ground, as well as some sandy areas and vegetation. The remnant steel pipe used to power the air drills when MORU was carved from the rock remains in the Entry.

[46] The fences, gates and concertina wire are to keep people from climbing into the Hall of Records to reach the carvings

Photo 16 The Tops of Carvings. Note the burn marks on the granite rock from the cakes that were placed here 10 years earlier and the Visitor Center Complex in the background.

The Hall of Records was blasted out of the wall of the Canyon. It was never finished and considered a significant cultural and historic resource.

Another set of steel steps rises up from the Canyon floor to the Guard Shack. It has a steel deck landing.

The Top of Carvings is accessible only by climbing some of the rocks above the Guard Shack. There is a short deck behind Washington's head behind the carvings and a few level areas, but otherwise it is uneven fine grain granite.

The Ridge is behind the Hall of Records and is slightly above the carvings. It is solid granite and accessible only by climbing the rocks. It has limited locations for placing mortars or

mortar racks for display fireworks with heavier recoil, especially given the challenge to properly secure the mortars or mortar racks. It has more locations suitable for placing articles pyrotechnic that are 2" or smaller.

Means of Egress, an Exit or a Means of Escape

It should be noted that NO portion of the Hall of Records, other than the small area outside the fence in the Entry by the top of the steps, has anything that could be considered a Means of Egress, an Exit or a Means of Escape[47] during a fireworks display. Only the small area outside the fence in the Entry by the top of the steps could be considered a Means of Escape during a fireworks display; and then only for a limited number of authorized and ambulatory personnel behind a sturdy shield, and if the only way out (the steps) were illuminated.

Photo 17 Some of the plastic debris recovered in the Hall of Records during the survey of October 2019, ten years after the last fireworks display. These are a plastic time fuse tube from a large diameter aerial shell, plastic time fuse holders from medium diameter aerial shells, a spacer with a plastic time fuse holder from a Roman candle, and the remnant of a quickmatch leader fuse in a plastic casing with a plastic T connector for an electric match (Note the strands of still viable blackmatch fuse)

[47] See Other NFPA Key Definitions

Photo 18 The fence and gate with concertina wire in the Entry of the Hall of Records. The Shooter and Shooter's Assistant should be located outside of this gate, near the stairs behind a shield or barricade and with no mortars in the entry or within 75 feet of their position. 1123 – 7.3.3.1. [Photo credit: NPS]

Hall of Records Discharge Site – Limited Egress Discharge Site

The Hall of Records is the perfect example of a limited egress discharge site and the reason for the standards in NFPA 1123, Chapter 7. There is only one viable way into and out of the Hall of Records. It is challenging enough in the daylight for an ambulatory individual to climb up to or down from, let alone one that is wearing the personal protective equipment (Hard hat, safety glasses, and long sleeved natural fiber clothing) that may be attempting to escape the discharge site, in the dark, and in the event of equipment failures or fireworks malfunctions.

Each of the portions of the Hall or Records Discharge Site identified by the Author present their own unique possibilities and challenges for the placement of different types of fireworks or pyrotechnics. They vary in both footprint available for the placement of mortars and holders, the absence or presence of rock walls, and elevations.

Any 2” or larger aerial fireworks shells, mines or comets fired from the Canyon should be visible to spectators in the Amphitheater, but the smaller aerial fireworks that burst 200 feet above ground level (AGL) or less may just barely be visible, especially for those seated in the front rows of the Amphitheater.

Any articles pyrotechnic 2” or less fired from the Tops of Carvings and most aerial fireworks 2” or less fired from the Ridge would be visible to spectators in the Amphitheater, including those in the front rows of the Amphitheater.

Ground level fireworks fired from the Tops of Carvings would likely not be visible to spectators in the Amphitheater.

Past Fireworks Displays from the Hall of Records Discharge Site

The Author only has limited information on the past fireworks displays, but what is known is useful in evaluating the potential for a future fireworks display at MORU.

The first three portions of the Hall of Records Discharge Site were used in the previous displays. The entire Hall of Records Canyon and Entry were filled with mortar racks, while the Top of Carvings was used for cakes.

The crew used the actual Hall of Records to place the firing control panel and fire the display. It provided exceptional protection from any normal or hazardous debris, duds, and blind stars or effects, but would trap the crew in the event of a catastrophic malfunction of an aerial

shell in a mortar just a few feet away. Any muzzle breaks, low breaks or tipovers could also prove to be disastrous for the crew that was confined inside a hole in the rocky wall.

Past displays used a qualified rope line team[48] to transport the fireworks, mortar racks and firing equipment up and back down the mountain. It took about two weeks to get everything up for the show and well over a week to get everything back down after the show.

The fireworks crew had to climb up and down the mountain each day to set up the equipment, load the fireworks and then strike the equipment. The fireworks crew also had to climb down the mountain in the dark after the display.

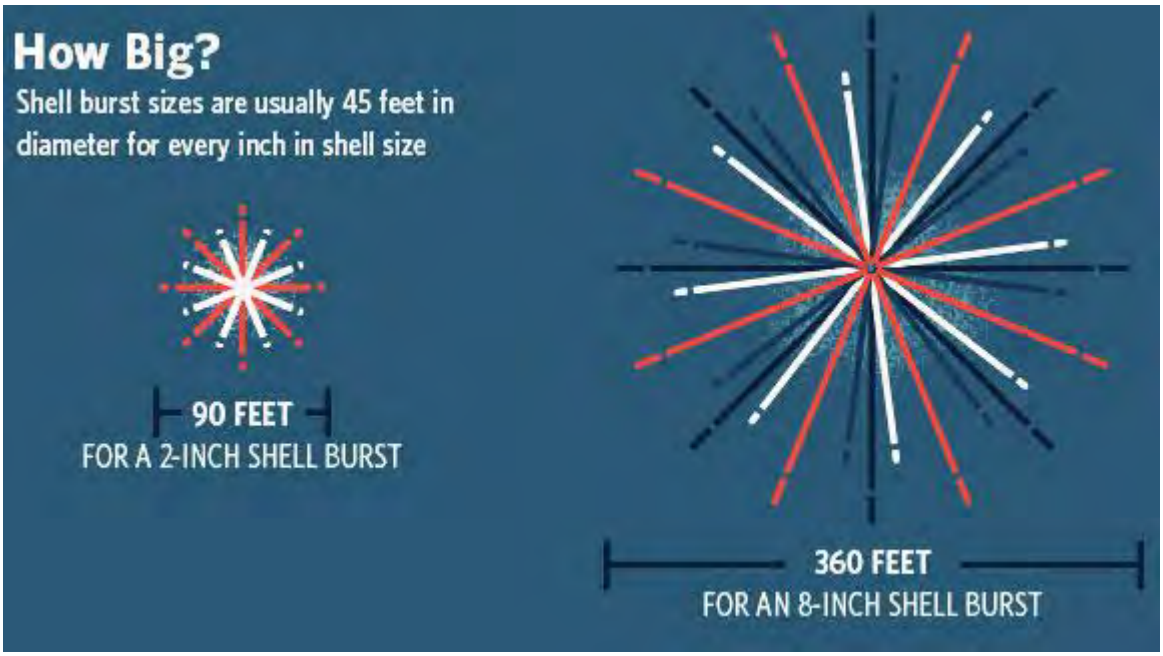

Photo 19 The burst size of aerial shells varies just like the performance height. Generally, the larger the aerial shell, the larger the burst pattern. This is a factor in both the design of a show for entertainment purposes as well as safety considerations.

[48] A qualified rope line team has the training and experience to setup and operate rope lines with trusses, hoists, pulleys, blocks and tackles, and other specialized equipment and technique to transport loads up and down steep hills, mountains, buildings and structures.

Issues: Hall of Records Discharge Site

The Hall of Records Discharge Site presents a number of significant issues, including:

- Requires climbing the mountain to access and a qualified rope line team or helicopters to bring equipment and fireworks up and back down.
- The entire discharge site is a limited egress discharge site subject to the requirements of NFPA 1123 Chapter 7.
- Nearby forest on steep, rocky ground, but with some open areas where Spotters could watch for duds, low breaks or hazardous debris.
- Nearby forest on steep, rocky ground, presents exceptional challenges for fire prevention and fire protection, especially at night.
- The only ready source of water for wetting down dry vegetation or to fight wildland fires is limited in capacity, and is only at the base on one side of the mountain, plus it is a great distance to the canyon and the top.

Photo 20 The Hall of Records Entry is narrow with walls that tend to slope inwards.

Photo 21 A dramatic segment from a show utilizing articles pyrotechnic mines and comets at multiple angles and 2" aerial shells fired vertically. These high-quality fireworks that are smaller allow for creative pyrotechnists to design and perform shows in venues that would be too small or otherwise too risky for larger aerial shells. Note the precise performance heights and effects diameters of the three different types of devices along with the uniformity of colors of each device. [Photo credit: Pirotecnia Ricardo Caballer S.A.]

- Most articles pyrotechnic 2" or less from the Top of Carvings and Ridge would be readily visible to spectators in all of the Amphitheater. Most aerial fireworks 2" to 5" would also readily visible to spectators in all of the Amphitheater.

Conclusion: Hall of Records Discharge Site

The Author's conclusion is that using the Hall of Records Discharge Site to shoot aerial fireworks 2" to 5" can be done safely if in strict compliance with NFPA 1123 and best practices,

but only if wildland fire conditions[49] in July are low to moderate, with favorable wind speeds and directions, as well as dew points, and subject to the other recommendations in this Report. Although the minimum separation distances may provide for larger aerial shells, the other factors at this display site, such as the elevated discharge site, the mountainous forest with a heavy fuel load, the likely conditions in early July, the challenges with spotting hazardous debris, the limitations on fire prevention and fire protection measures, and the potential for equipment failures and fireworks malfunctions, firing larger aerial shells pose a significant and unacceptable risk.

More specifically the Author concludes the following for the Hall of Records Discharge Site:

- The Canyon may be used for the types and styles of aerial fireworks 2" to 5" as recommended in this Report[50] that are fired straight up or angled to the sides, but not angled so that the trajectory of any aerial fireworks will hit or bounce off the canyon walls
- The Canyon may be used for placing mortars in racks that are perpendicular to the spectator viewing area and secured individually with ¾" plywood equilateral triangle screwed into the sides with at least six 2" deck screws or in groups

[49] Wildland fire conditions are described in Appendix B.

[50] These types and sizes of fireworks using the placement methods described here will meet the minimum separation distances in 1123 - 5.1.3.1 and 1123 - 5.1.4.3 as well as the best practices in The *Display Fireworks Manual* (2010) and from Natural Resources Canada, *Celebrate Safely* (DVD), American Pyrotechnics Association (APA), (2014, and the *Study Guide for Display Operator Training Program* (2017) from the Pyrotechnics Guild International, Inc. (PGI), subject to wind speeds and directions

secured by heavy duty steel frames, with all racks flat on the ground (loose sand or shims may be needed underneath given the uneven ground).

- The Entry may not be used for the placement of any mortars, tubes or other fireworks.[51]
- The Tops of Carvings may only be used for ground level fireworks and aerial fireworks or articles pyrotechnic that are 2" or less, and placed in metal holders with metal or wood bases, and on those areas that are reasonably flat and level, including the deck, but only on those areas approved by the NPS.

Photo 22 Articles pyrotechnic in metal holders and mounted on a truss. Article pyrotechnic are typically light enough and have low recoil so they can be placed in metal holders that can be mounted to almost any sturdy structure. [Photo credit: Pirotecnia Ricardo Caballer S.A.]

- The Guard Shack Steps may only be used for aerial fireworks or articles pyrotechnic 2" or less in custom metal holders that are securely attached to the sides of the steps, subject to approval by the NPS.

[51] 1123 7.3.4.1

- The Ridge may only be used for aerial fireworks or articles pyrotechnic 2" or less in metal holders with metal or wood bases on those areas that are reasonably flat and level, but only on those areas approved by the NPS.[52]

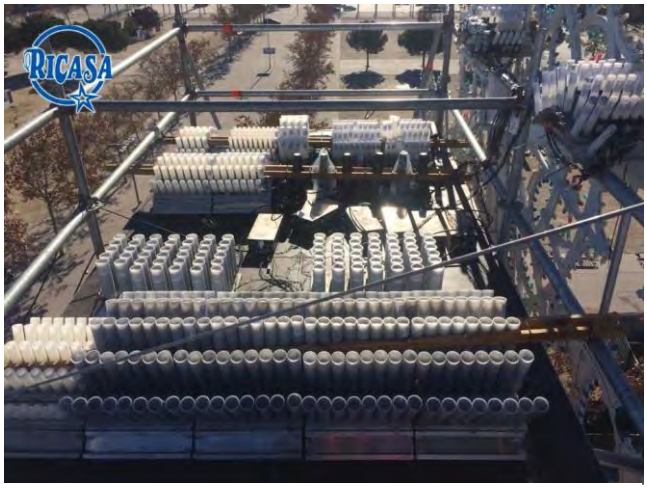

Photo 23 Article pyrotechnic in metal holders placed on top of a truss. These smaller mine and comets effects can be as dramatic or even more dramatic than aerial shells, yet they can be placed in many locations not suitable for mortars and much closer to the spectators. They also have almost no fallout and thus present less hazard to any nearby combustible materials. [Photo credit: Pirotecnia Ricardo Caballer S.A.]

- The firing control panel should be set up outside of the fence at the Entry.[53] The Shooter and the Shooter's Assistant, the only two people that need to be there during the show[54], may operate the firing control panel provided they are protected by a 4' x 8' x ¾" plywood and/or ¼" Lexan[55]™ shield mounted on two equilateral triangle frames made of 2" x 4", or equivalent.

[52] The Ridge is about 100 feet above the Hall of Records canyon, necessitating additional separation distances to the spectators. It is solid granite with very few, level surfaces suitable for mortars or mortar racks with heavy recoil, especially given the difficulty in securing mortar or mortar racks properly at this location.

[53] 1123 7.3.3.1

[54] 1123 9.3.3

[55] 1123 – 6.2.3 (3) and 7.3.4.1 (3) ¾" plywood and ¼" Lexan™ have proven to be useful materials for protection from most, but not all, burning stars and fireworks debris. A combination of ¾" plywood with and ¼" Lexan™ window provides protection while allowing personnel to see through the shield. Shields that are angled deflect burning stars and debris better than shields that are vertical. Shields in limited egress discharge sites need to be placed away from the nearest mortars or effects according to 1123 – 7.3.3.1.

- The Entry steps should be illuminated during the display using solar lights or equivalent to provide for a Means of Escape.
- Fire prevention and protection for a show from this discharge site should address a show on the top of a steep, rocky mountain with the nearby forest. It would be essential to determine where to place Spotters to be able to watch for duds, blind stars, low breaks or hazardous debris. Planning where fire fighters should stage equipment and personnel in safe locations to respond to any potential wildland fires in the dark, would also a critical factor.
- Removal of the quickmatch leader fuses, a prohibition on chain fusing and cakes, together with the other recommendations in this report will reduce, but not entirely eliminate, the potential negative impact of any catastrophic aerial shell malfunction in a mortar or other malfunctions.

In order to protect against direct hits by aerial shells or large, powerful bursts in close proximity require heavier and sturdier barricades, such as sandbags, railroad ties, steel plate, etc.

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Indian Camp Discharge Site

The Indian Camp Discharge Site is located [redacted]

Photo 24 The Indian Camp Discharge Site is open but rocky and uneven with vegetation. It is surrounded by a fence and the [redacted].

The Indian Camp Discharge Site is surrounded by a chain link fence with gates with concertina wire. The ground is relatively flat, but very rocky with some low vegetation. There are only a few nearby trees, but there are piles of fence material and other items left over from past efforts to secure the area.

The Indian Camp Discharge Site is another example of a limited egress location, depending on the number, type and placement of any mortars. The fence alone limits egress combined with the steepness and rough terrain just outside of the fence.

This discharge site can only be reached by [redacted] or by helicopter. Transporting the equipment and the fireworks here is extremely difficult (Moving the fence and other materials up here required a qualified rope line team that took [redacted].

The Indian Camp Discharge Site would support mortars buried in troughs or drums and mortars in above ground racks, but only in the open areas and only on the ground that was relatively flat.

Fireworks fired from this location can be angled slightly to burst [redacted], so it is likely the smallest aerial shells that would be visible to the spectators in the Amphitheater would be 6" aerial shells; however 6" aerial shells from this distance to the Amphitheater would look about the same size or smaller as 4" or 5" aerial shells fired from the Hall of Records.

Issues: Indian Camp Discharge Site

The Indian Camp Discharge Site presents a number of significant issues, including:

- Requires [redacted] to access and a [redacted] or helicopters to bring equipment and fireworks up and back down.
- Nearby forest on steep, rocky ground, but with some open areas where Spotters could watch for normal or hazardous debris, duds, and blind stars or effects
- Nearby forest on steep, rocky ground, presents exceptional challenges for fire prevention and fire protection, especially at night.
- The only ready source of water for wetting down dry vegetation or to fight wildland fires is limited in capacity, and is only at the base on one side of the mountain plus it is a great distance to the canyon and the top.
- The [redacted] would necessitate using aerial fireworks at least 6" and larger as anything smaller would likely be visible to spectators in the Amphitheater.

- The location [redacted] would necessitate compensating by moderate angling the mortars to have bursts above the carvings.
- The discharge site may need to meet the requirements of NFPA 1123, Chapter 7 and best practices for a limited egress location, which would limit the number, type and placement of any mortars.

Conclusion: Indian Camp Discharge Site

The Author's conclusion is that using the Indian Camp Discharge Site to shoot aerial fireworks up to 6" can be done safely if in strict compliance with NFPA 1123 and best practices, but only if wildland fire conditions in July are low to moderate, with favorable wind speeds and directions, as well as dew points, and subject to the other recommendations in this Report. Although the minimum separation distances may provide for larger aerial shells, the other factors at this display site, such as the elevated discharge site, the mountainous forest with a heavy fuel load, the likely conditions in early July, the challenges with spotting hazardous debris, the limitations on fire prevention and fire protection measures, and the potential for equipment failures and fireworks malfunctions, firing larger aerial shells pose a significant and unacceptable risk.

Mount Rushmore National Memorial
South Dakota

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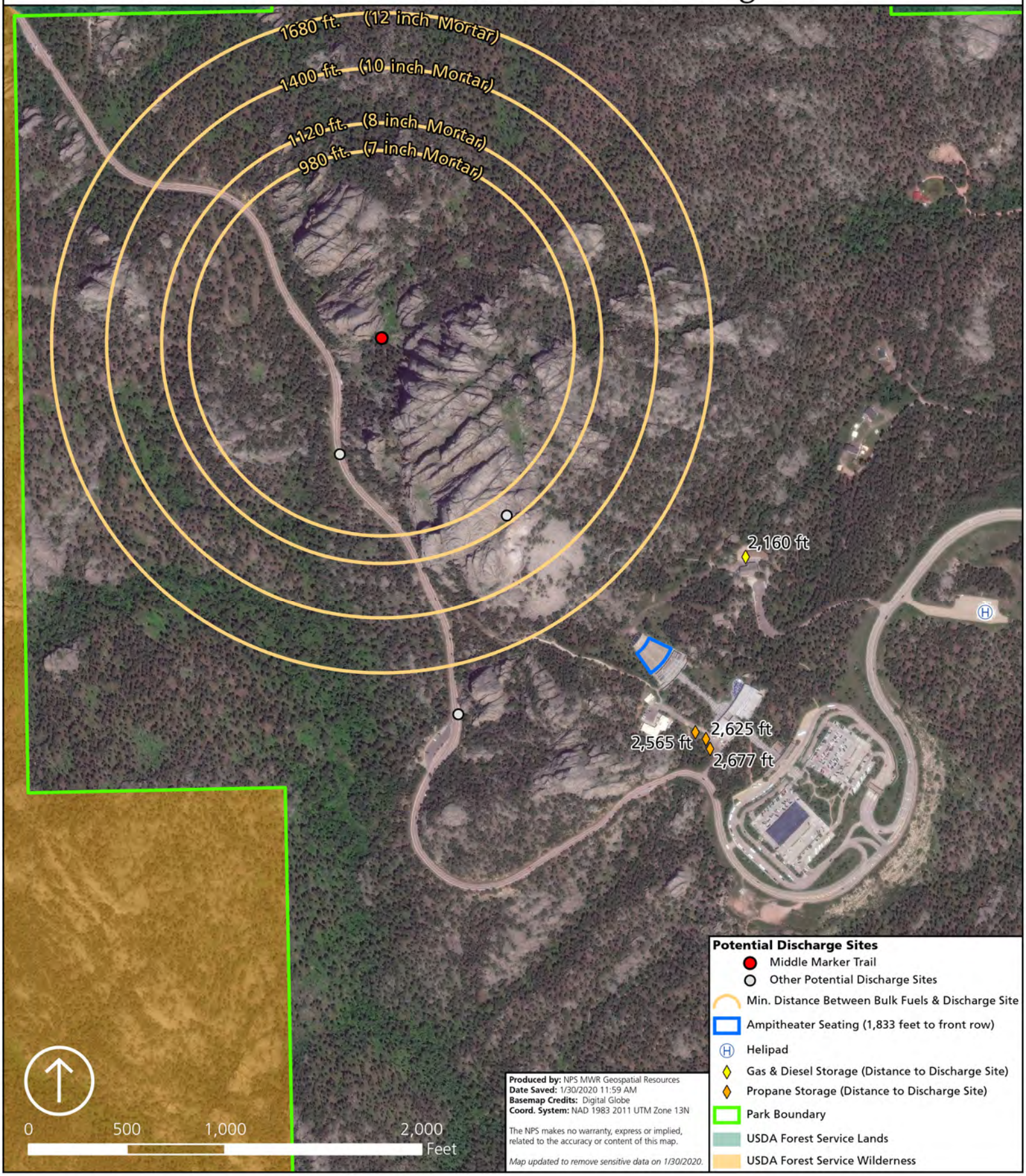
Middle Marker Trail Discharge Site
Minimum Distance Between Bulk Fuels & Discharge Site



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South Dakota

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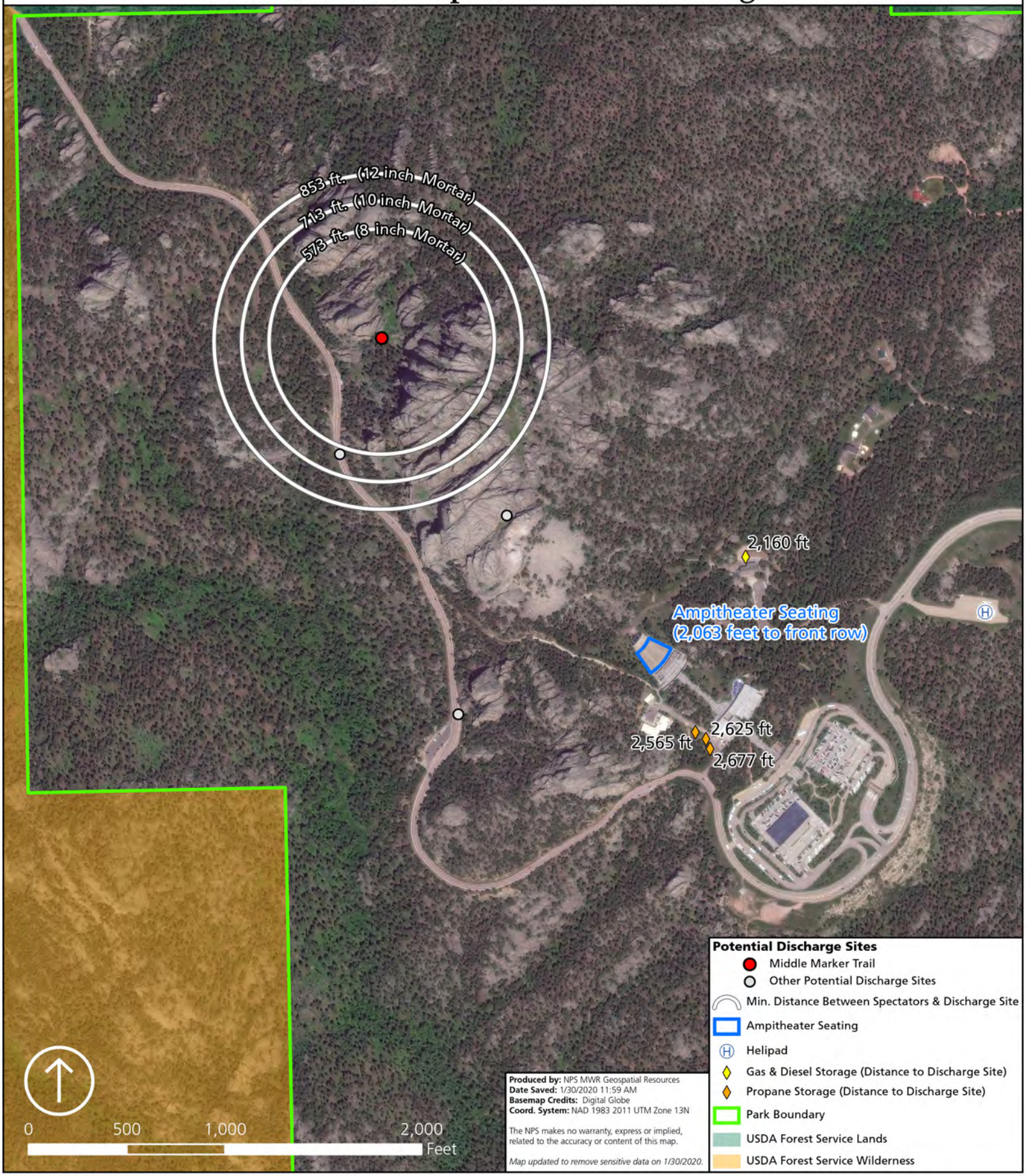
Middle Marker Trail Discharge Site
Minimum Distance Between Spectators & Discharge Site



Potential Discharge Sites
- Middle Marker Trail
- Other Potential Discharge Sites
- Min. Distance Between Spectators & Discharge Site
- Ampitheater Seating
- Helipad
- Gas & Diesel Storage (Distance to Discharge Site)
- Propane Storage (Distance to Discharge Site)
- Park Boundary
- USDA Forest Service Lands
- USDA Forest Service Wilderness

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Middle Marker Trail Discharge Site

The Middle Marker Trail Discharge Site is located about 1,100 feet behind the carvings and about 2,000 feet from the Amphitheater.

This discharge site is close to South Dakota Highway 244. It is on the backside of the mountain with the carvings. It would require substantial manual effort to haul the equipment and fireworks up to the open area. The ground is sloped and rocky, with many large ponderosa pine trees all about and up the slopes.

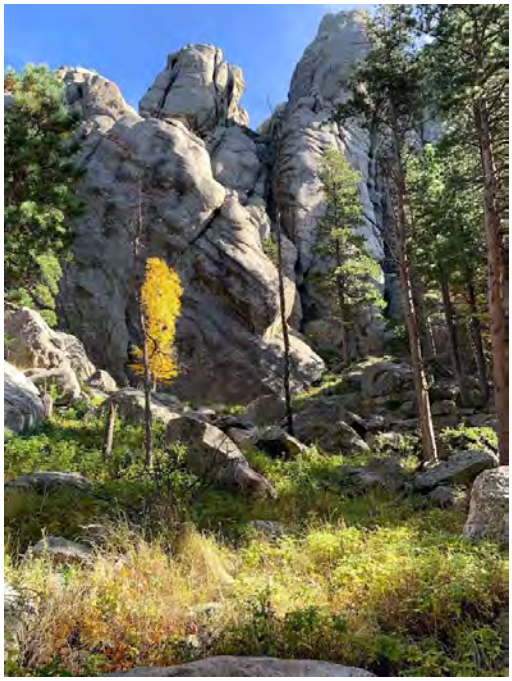

Photo 25 The Middle Marker Trail Discharge Site is an open area in the rocky forest on the backside of the mountain. The distance and differences in elevation would require large diameter shells to possibly be visible to the spectators in the Amphitheater.

The Middle Marker Trail Discharge Site would support mortars buried in troughs or drums, but not large dumpsters. It would support mortars in above ground racks, but only in the open areas and only on the ground that was relatively flat.

Issues: Middle Marker Trail Discharge Site

The Middle Marker Trail Discharge Site presents a number of significant issues, including:

- Surrounded by forest on steep, rocky ground making it difficult if not impossible for Spotters to watch for normal or hazardous debris, duds, and blind stars or effects.

- Surrounded by forest on steep, rocky ground making it difficult if not impossible for fire fighters to stage equipment and personnel in safe locations to respond to any potential wildland fires in the dark.
- No ready source of water for wetting down dry vegetation or to fight wildland fires.
- The carvings between it and the Amphitheater would necessitate using aerial fireworks 8” or larger (probably only 10” and 12” would be visible at this distance) as aerial fireworks smaller than 8” would likely not be visible to spectators in the Amphitheater.
- The location and moderate slope to one side of the carvings would necessitate compensating by moderate angling the mortars in an attempt to have bursts above the carvings.
- Moderate angling of mortars may place tree branches unacceptably close to the trajectory of the aerial shells.

Photo 26 An example of wetting down combustible vegetation such as tall grass, even when it is green. This is a time-honored method to preventing potential grass fires from the normal or hazardous debris that come back down to the ground in a discharge site and fallout area. Doing so at MORU is a challenge given the limited water capacity and ability to pump water up a mountain, the type and volume of vegetation, and the size of the fallout areas from elevated discharge site(s).

Conclusion: Middle Marker Trail Discharge Site

The Author's conclusion is that using the Middle Marker Trail Discharge Site to shoot some of the smallest of the articles pyrotechnic 2" or less might be done safely if in strict compliance with NFPA 1126 and best practices, but only if wildland fire conditions in July are ideal, and subject to the other recommendations in this Report; however there is no practical place for spectators to view such a show.

The to shoot aerial fireworks 2" or larger at the Middle Marker Trail Discharge Site cannot be done safely or in compliance with NFPA 1123 and best practices, and even if conditions in July are ideal.

Although the minimum separation distances may provide for larger aerial shells, the other factors at this display site, the differences in elevations between this discharge site and the Amphitheater necessitating using larger diameter aerial shells, the mountainous forest with a heavy fuel load, the likely conditions in early July, the challenges with spotting hazardous debris, the limitations on fire prevention and fire protection measures, and the potential for equipment failures and fireworks malfunctions, firing larger aerial shells pose a significant and unacceptable risk.

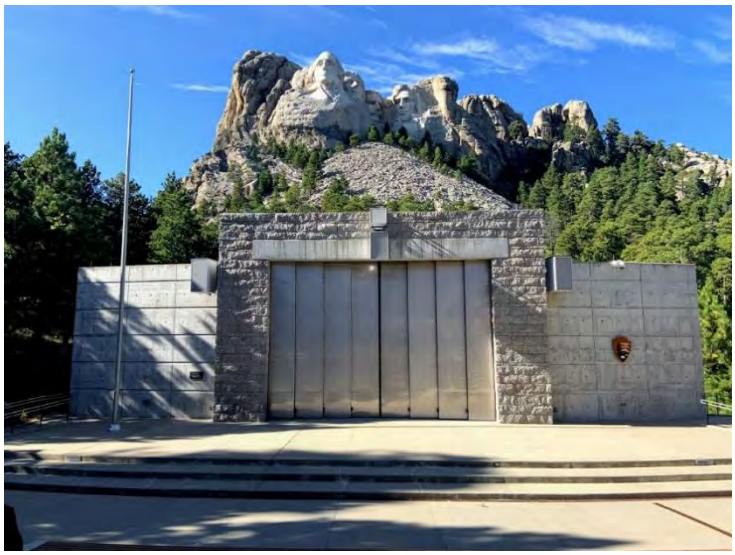

Photo 27 The Amphitheater stage and backstage with the MORU carvings above could serve as a discharge site for some articles pyrotechnic. Any proximate pyrotechnics here would need to be designed around whatever other programs and entertainment are conducted here on the day of the Show. Note: The view of the carvings from venter of the first three rows is blocked by the backstage. Other locations have the view blocked by tree branches.

Mount Rushmore National Memorial
South Dakota

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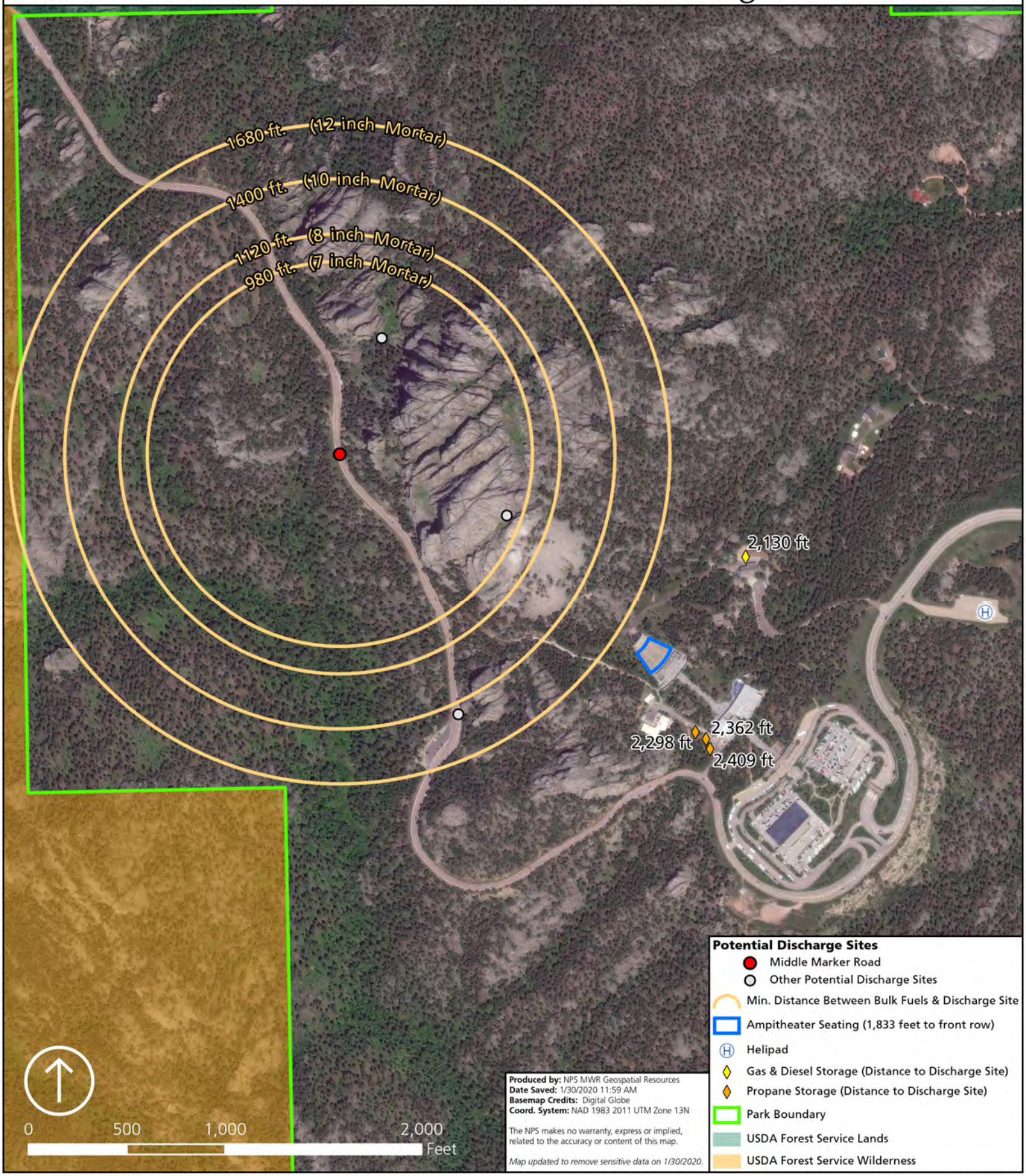
Middle Marker Road Discharge Site
Minimum Distance Between Bulk Fuels & Discharge Site



Potential Discharge Sites
- Middle Marker Road
- Other Potential Discharge Sites
- Min. Distance Between Bulk Fuels & Discharge Site
- Ampitheater Seating (1,833 feet to front row)
- Helipad
- Gas & Diesel Storage (Distance to Discharge Site)
- Propane Storage (Distance to Discharge Site)
- Park Boundary
- USDA Forest Service Lands
- USDA Forest Service Wilderness

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South Dakota

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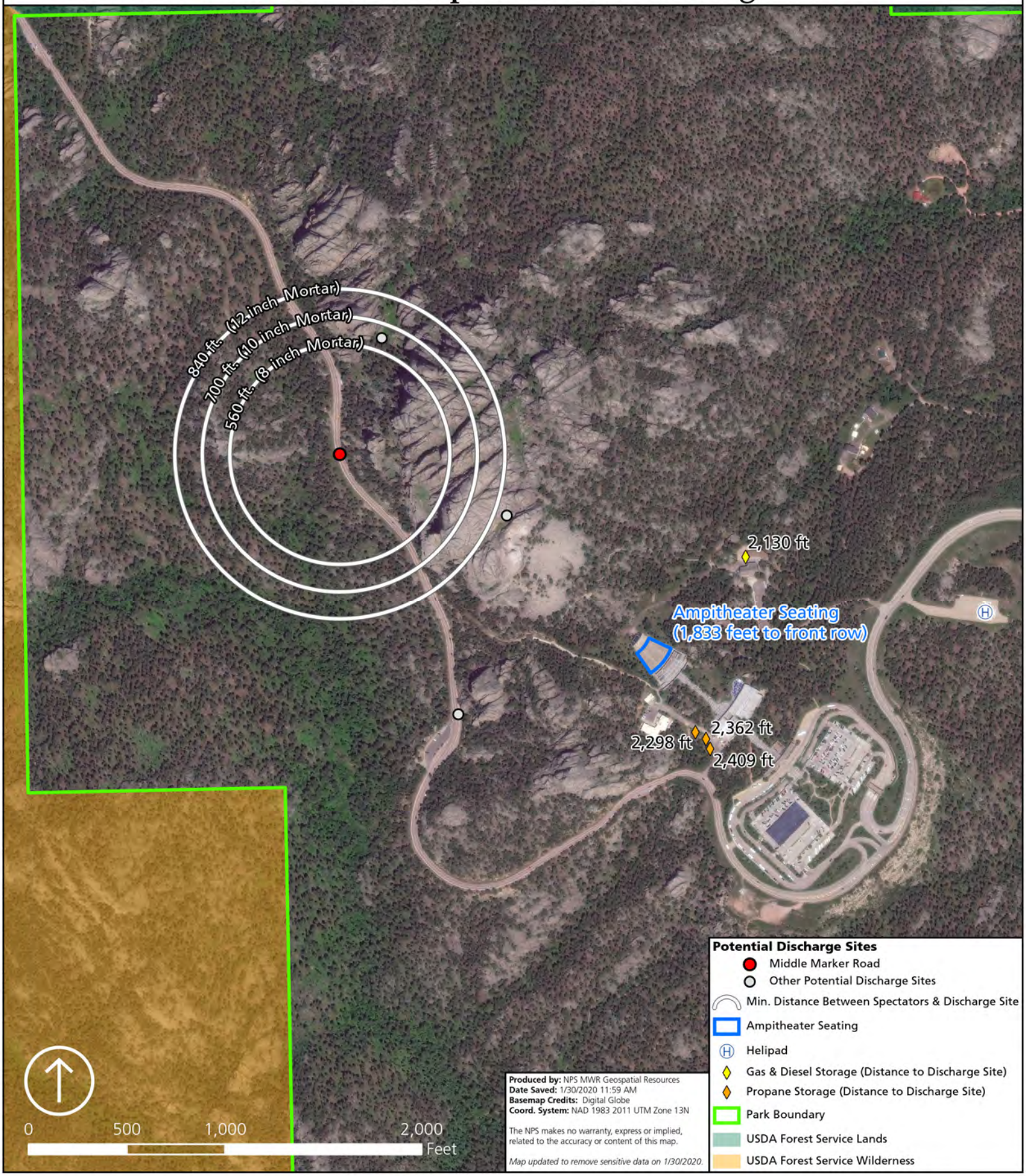
Middle Marker Road Discharge Site
Minimum Distance Between Spectators & Discharge Site



Potential Discharge Sites
- Middle Marker Road
- Other Potential Discharge Sites
- Min. Distance Between Spectators & Discharge Site
- Ampitheater Seating
- Helipad
- Gas & Diesel Storage (Distance to Discharge Site)
- Propane Storage (Distance to Discharge Site)
- Park Boundary
- USDA Forest Service Lands
- USDA Forest Service Wilderness

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Middle Marker Road Discharge Site

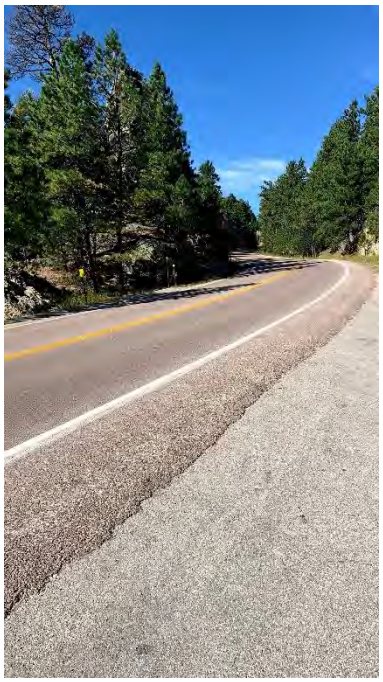

Photo 28 Middle Marker Road Discharge Site is a section of South Dakota Highway 244 behind the carvings

The Middle Marker Road Discharge Site is on South Dakota Highway 244 and located about 1,000 feet behind and slightly to one side of the carvings. It is over 1,700 feet from the Amphitheater.

This discharge site has road access and presents a good, hard. smooth surface, although the slope is both relatively steep and away from the carvings.

The Middle Marker Road Discharge Site would support mortars buried in troughs or drums, or in large dumpsters. It would support mortars in above ground racks, whether on the surface of the road or on trailers. Dumpsters or trailers could be set up at some other location and moved to this discharge site for loading and firing. It may also be feasible to load the mortars in the dumpsters and trailers at some nearby location, close the highway and move them to the discharge site the day of the show.

Issues: Middle Marker Road Discharge Site

The Middle Marker Road Discharge Site presents a number of significant issues, including:

- Requires road closure in order to set up the mortars and load the fireworks, or place the dumpsters or trailers with the mortars loaded with the fireworks.

- Surrounded by forest on steep, rocky ground making it difficult if not impossible for Spotters to watch for normal or hazardous debris, duds, and blind stars or effects.
- Surrounded by forest on steep, rocky ground making it difficult if not impossible for fire fighters to stage equipment and personnel in safe locations to respond to any potential wildland fires in the dark.
- No ready source of water for wetting down dry vegetation or to fight wildland fires.

Photo 29 Two flatbed trailers with drums filled with sand for large diameter mortars and heavy-duty metal frame racks for medium diameter mortars. A trailer or dumpster can be setup and the fireworks loaded at a secure location, and then the roads closed to the public for movement of the trailer or dumpster to the discharge site on the day of the show. [Photo credit: Fireworks FX, Inc]

- The carvings between it and the Amphitheater would necessitate using aerial fireworks 8" or larger as aerial fireworks smaller than 8" would likely not be visible to spectators in the Amphitheater.
- The moderate slope away from the carvings would necessitate compensating by moderate angling the mortars in an attempt to have bursts above the carvings.
- Moderate angling of mortars buried in dumpsters would require additional bracing with heavy material capable of withstanding the recoil.
- Moderate angling of mortars may place tree branches up the slope towards MORU unacceptably close to the trajectory of the aerial shells.

Conclusion: Middle Marker Road Discharge Site

The Author's conclusion is that using the Middle Marker Road Discharge Site to shoot some articles pyrotechnic 2" or less might be done safely if in strict compliance with NFPA 1126 and best practices, but only if wildland fire conditions in July are ideal, and subject to the other recommendations in this Report; however the only practical place spectators could view such a show would be from the road.

Although the minimum separation distances may provide for larger aerial shells, the other factors at this display site, the differences in elevations between this discharge site and the Amphitheater necessitating using larger diameter aerial shells, the mountainous forest with a heavy fuel load, the likely conditions in early July, the challenges with spotting hazardous debris, the limitations on fire prevention and fire protection measures, and the potential for equipment failures and fireworks malfunctions, firing larger aerial shells pose a significant and unacceptable risk.

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South Dakota

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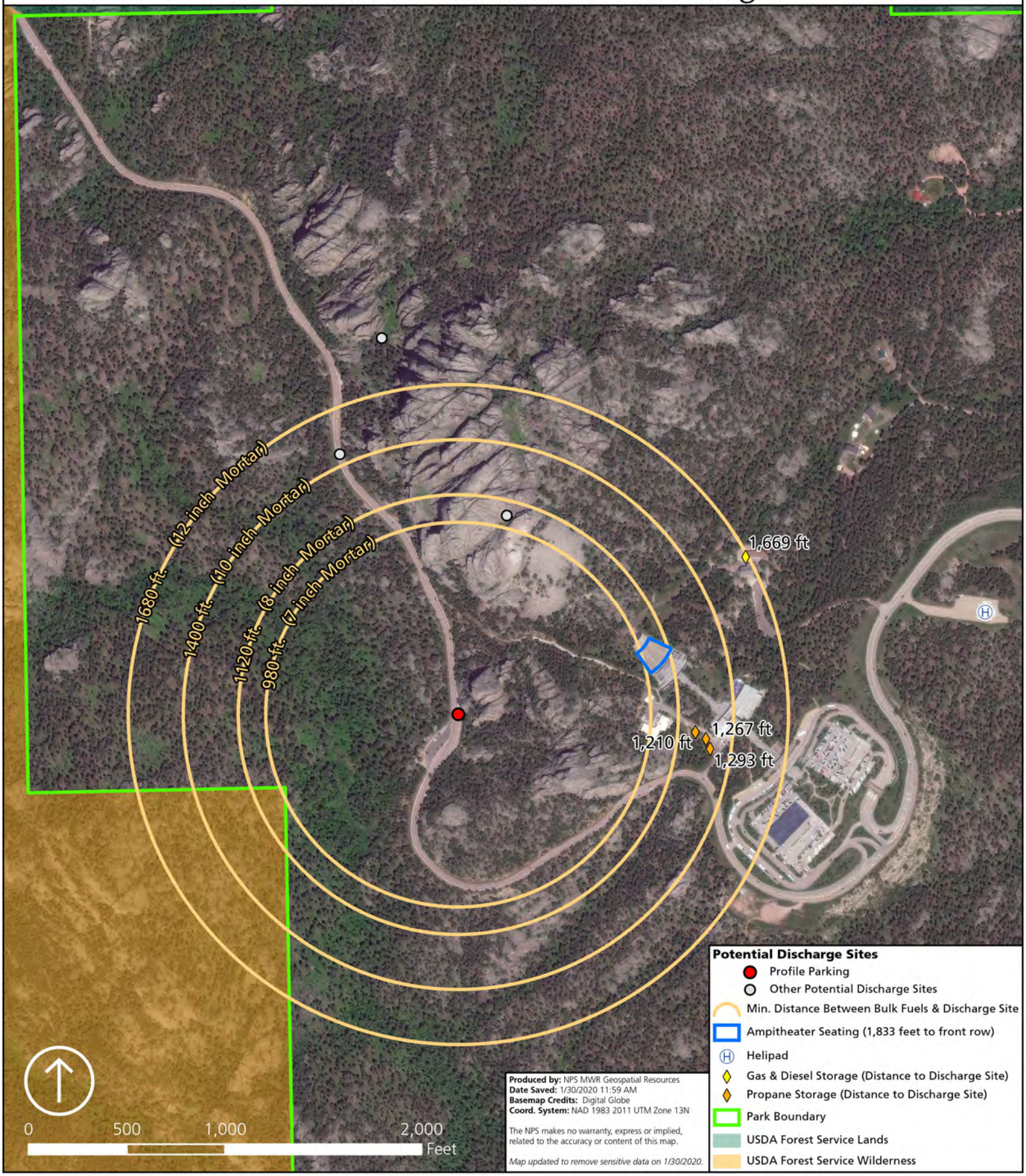
Profile Parking Discharge Site
Minimum Distance Between Bulk Fuels & Discharge Site



Potential Discharge Sites
- Profile Parking
- Other Potential Discharge Sites
- Min. Distance Between Bulk Fuels & Discharge Site
- Ampitheater Seating (1,833 feet to front row)
- Helipad
- Gas & Diesel Storage (Distance to Discharge Site)
- Propane Storage (Distance to Discharge Site)
- Park Boundary
- USDA Forest Service Lands
- USDA Forest Service Wilderness

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Profile Parking Discharge Site
Minimum Distance Between Spectators & Discharge Site

Potential Discharge Sites
- Profile Parking
- Other Potential Discharge Sites
- Min. Distance Between Spectators & Discharge Site
- Ampitheater Seating
- Helipad
- Gas & Diesel Storage (Distance to Discharge Site)
- Propane Storage (Distance to Discharge Site)
- Park Boundary
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Profile Parking Discharge Site

The Profile Parking Discharge Site is located about 1,000 feet to the side (stage right, house left) and slightly in front of the carvings and about 1,000 feet from the Amphitheater.

Profile Parking Discharge Site is to the side and just in front of the carvings. It slopes steeply away from MORU.

This discharge site is adjacent to South Dakota Highway 244 and presents a good, hard, smooth surface, although the slope is both relatively steep and away from the carvings.

The Profile Parking Discharge Site would support mortars buried in troughs or drums, or in large dumpsters. It would support mortars in above ground racks, whether on the surface of the parking lot or on trailers. Dumpsters or trailers could be set up at some other location and moved to this discharge site for loading and firing. It may also be feasible to load the mortars in the dumpsters and trailers at some nearby location, close the highway and move them to the discharge site the day of the show.

Issues: Profile Parking Discharge Site

The Profile Parking Discharge Site presents a number of significant issues, including:

- Requires road closure in order to set up the mortars and load the fireworks, or place the dumpsters or trailers with the mortars loaded with the fireworks.

- Surrounded by forest on steep, rocky ground making it difficult if not impossible for Spotters to watch for normal or hazardous debris, duds, and blind stars or effects.
- Surrounded by forest on steep, rocky ground making it difficult if not impossible for fire fighters to stage equipment and personnel in safe locations to respond to any potential wildland fires in the dark.
- No ready source of water for wetting down dry vegetation or to fight wildland fires.
- The carvings between it and the Amphitheater would necessitate using aerial fireworks 8” or larger as aerial fireworks smaller than 8” would likely not be visible to spectators in the Amphitheater.
- The steep slope away from the carvings would necessitate compensating by severely angling the mortars in an attempt to have bursts above the carvings.
- Severe angling of mortars buried in dumpsters would require heavy bracing with concrete barricades or similar strong, heavy material capable of withstanding the recoil. (An equivalent method could be developed using heavy duty steel 2” square steel holders with reinforced concrete bracing capable of withstanding the recoil, but this would require significant development and testing).
- The location slightly in front of the carvings would necessitate compensating by severe angling the mortars to shoot aerial shells over a nearby rock formation in an attempt to have bursts behind and above the carvings.

- Aerial fireworks 8” or larger fired at these severe angles behind and above the carvings would likely not meet the separation distances required by 1123 - 5.1.3.1 and 1123 - 5.1.4.3 and best practices

Conclusion: Profile Parking Discharge Site

The Author’s conclusion is that using the Profile Parking Discharge Site to shoot some articles pyrotechnic 2” or less might be done safely if in strict compliance with NFPA 1126 and best practices, but only if wildland fire conditions in July are ideal, and subject to the other recommendations in this Report; however the only practical place spectators could view such a show would be from the road.

Although the minimum separation distances may provide for larger aerial shells, the other factors at this display site, the steep slope away from the carvings requiring offsetting mortar angles aimed towards the carvings combined with the distance necessitating using larger diameter aerial shells[56], the mountainous forest with a heavy fuel load, the likely conditions in early July, the challenges with spotting hazardous debris, the limitations on fire prevention and fire protection measures, and the potential for equipment failures and fireworks malfunctions, firing larger aerial shells pose a significant and unacceptable risk.

[56] It is quite likely that any such attempt to fire large diameter shells at such steep angles would result in the shells bursting on or striking the rock formations, the forest, the carvings and possibly even into the Amphitheater and surrounding areas with buildings and spectators. Any aerial fireworks 8” or larger that burst low or on the ground would likely result in starting a wildland fire in a multitude of locations over many hundreds of feet wide.

Amphitheater Discharge Site

The Amphitheater Discharge Site was identified by NPS staff as the primary location for spectators to view a show at MORU. It would be suitable only for articles pyrotechnics used according to NFPA 1126 and best practices.[57] It is located directly in front of and below the carvings (stage center, house center).

Photo 30 The Amphitheater and Grand View Terrace have many different elevations with the backstage or tree branches blocking the view of the carvings from some locations. [Photo credit: Eoin Care, NPS]

The Amphitheater Discharge Site consists of the stage and backstage, but not the area or road behind the Amphitheater.

The stage is slightly elliptical and approximately 73 feet wide and 24 feet deep. The backstage is in in two different levels, with the tallest level in the center and the shorter levels on either side.

The aisle between the front of the stage and the first row of seats is approximately 13 feet wide. It is approximately 38 feet from the front of the backstage to the first row of seats.

Issues: Amphitheater Discharge Site

The Amphitheater Discharge Site presents a number of issues, including:

[57] The *Special Effects Manual*, Natural Resources Canada, (2014) provides best practices that compliment NFPA 1126 for proximate pyrotechnics.

- It would be limited to articles pyrotechnics that comply with 1126 – 8.4 and best practices (proximate audience)
- Some articles pyrotechnic mounted on the stage or the backstage would likely not be visible to spectators behind the first few rows spectators in the Grand View Terrace.
- The view by the spectators of the carvings and any fireworks bursting above the carvings from the fireworks portion of a show would be obstructed by some articles pyrotechnic mounted on the stage or the backstage and fired at the same time during the show.

Conclusion: Amphitheater Discharge Site

The Author's conclusion is that the Amphitheater Discharge Site to shoot articles pyrotechnic (proximate audience) can be done safely subject to strict compliance with NFPA 1126 and best practices, if wildland fire conditions in July are low to moderate, with favorable wind speeds and directions, as well as dew points, and subject to the other recommendations in this Report.

Author Proposed Discharge Sites

The Author proposed additional discharge sites on the basis that fireworks devices and articles pyrotechnic could potentially be placed in these discharge sites and comply with NFPA 1123 and/or NFPA 1126 and best practices. The Author intended that no potential discharge site at MORU would be overlooked and evaluated, no matter how farfetched it might seem.

The Author proposed discharge sites are as follows:

Amphitheater Road Discharge Site

The Amphitheater Road Discharge Site was identified by the Author because it is a potential discharge site, but only for ground level fireworks and articles pyrotechnic 2" or less under NFPA 1126 and best practices given its proximity to the Amphitheater. It is just behind the Amphitheater and located directly in front of and below the carvings (stage center, house center), as well as to one side (stage left, house right).

Photo 31 The Amphitheater Road Discharge Site likely will need to remain open and available for emergency access and fire equipment providing fire protection to MORU

The Amphitheater Road Discharge Site consists of a blacktop road and turn around circle. The area considered is approximately 100 feet long and 12 feet wide with a 40 feet wide in the turnaround circle. It is about 5 to 10 feet below the Amphitheater.

There are also open, grassy areas on either side of the road.

Issues: Amphitheater Road Discharge Site

The Amphitheater Discharge Road Site presents a number of issues, including:

- It would be limited to ground level fireworks and articles pyrotechnic 2" or less (proximate audience)
- Only some types of articles pyrotechnic 2" or less mounted on the road would shoot up high enough to be visible to most spectators in the Amphitheater, but

those in the first few rows of the Amphitheater will only see the top portions of the effects.

- The view by the spectators of the carvings and any fireworks bursting above the carvings from the fireworks portion of a show would be obstructed by any articles pyrotechnic 2" or less mounted on the stage or the backstage and fired at the same time during the show.
- Strobe pots and perhaps some other types of illuminations on the road would be a useful effect at this location. Strobes pots would illuminate the forest and base of the mountain and build suspense and during quieter portions of any music track.

Conclusion: Amphitheater Road Discharge Site

The Author's conclusion is that the Amphitheater Road Discharge Site to shoot some ground level fireworks and articles pyrotechnic 2" or less (proximate audience) can be done safely subject to strict compliance with NFPA 1126 and best practices, if wildland fire conditions in July are low to moderate, with favorable wind speeds and directions, as well as dew points, and subject to the other recommendations in this Report. Aggressive and comprehensive fire prevention measures to reduce the fuel load in the vicinity as well as fire prevention measures to mitigate the potential for wildland fires are essential. A thorough technical performance evaluation (performance height, spread, duration, trajectory, etc.) of every device in each specific location is also vital.

Presidential Trail Discharge Site

The Presidential Trail Discharge Site was identified by the Author because it is a potential discharge site, but only for ground level fireworks and some articles pyrotechnic 2" or less under NFPA 1123 and best practices. It meanders to and from the Visitor Center and across the base of the mountain.

The Presidential Trail Discharge Site consists of a concrete path and landings in combination with composite deck walkways with steps and landings. The area considered is approximately 400 to 500 feet from the Amphitheater and 600 feet long, however only the portions that have opening in the tree canopy are considered. Elevations also vary along the trail and range from about 50 to 100 feet above the Amphitheater.

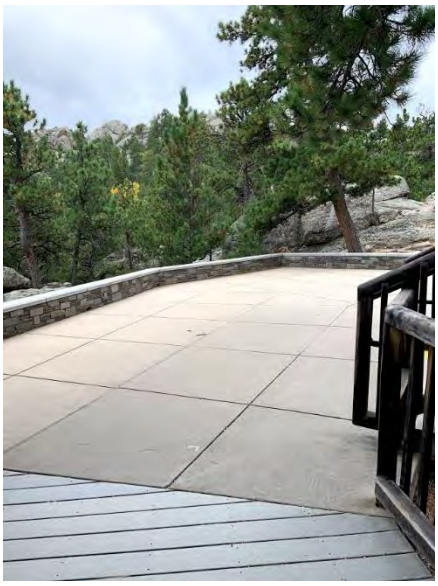

Photo 32 The Presidential Trail has a number of landings and a few segments along the trail with limited openings between the nearby the trees. These locations may serve well for strobe pots and articles pyrotechnic comets and mines up to 2", provided there is due diligence with fire prevention and fire protection measures, a technical performance evaluation of the effects for each location, sufficient clearance from the trees, etc. and favorable conditions.

Issues: Presidential Trail Discharge Site

The Presidential Trail Discharge Site presents a number of issues, including:

- Anything other than ground level or articles pyrotechnic 2" or less that are mines or comets are likely not to comply with the Minimum Separation Distances in 1123 - 5.1.3.1 and 5.1.4.3 and best practices.
- The tree canopy limits the placement of articles pyrotechnic 2" or less to the openings along the trail, at the landings and a few other spots along the trail.

- All articles pyrotechnic 2” or less mounted on the trail should shoot up high enough to be visible to most spectators in the Amphitheater, but those in the first few rows of the Amphitheater may only see the top portions of the effects.
- The view by the spectators of the carvings and any fireworks bursting above the carvings from the fireworks portion of a show should not be obstructed by any articles pyrotechnic 2” or less mounted on the trail.
- Articles pyrotechnic 2” or less would need to be placed in metal holders with plywood or metal bases
- Ground level fireworks would need to be placed on metal plates or in pan mortars.

Conclusion: Presidential Trail Discharge Site

The Author’s conclusion is that the Presidential Trail Discharge Site to shoot ground level fireworks and some articles pyrotechnic 2” or less that are comets and mines can be done safely subject to strict compliance with NFPA 1123 and best practices, if wildland fire conditions in July are low to moderate, with favorable wind speeds and directions, as well as dew points, and subject to the other recommendations in this Report. Aggressive and comprehensive fire prevention measures to reduce the fuel load in the vicinity as well as fire prevention measures to mitigate the potential for wildland fires are essential. A thorough technical performance evaluation (performance height, spread, duration, trajectory, etc.) of every device in each specific location is also vital.

Forest Openings Discharge Site

The Forest Openings Discharge Site was identified by the Author because it is a potential discharge site, but only for ground level fireworks and some articles pyrotechnic 2" or less under NFPA 1123 and best practices. It is made up of the rocky and forested areas on both sides of the Presidential Trail at the base of the mountain.

The Forest Openings Discharge Site consists only of the areas with openings in the tree canopy. Elevations also vary and range from about 50 to 100 feet above the Amphitheater.

Photo 33 A burned tree trunk adjacent to the Presidential Trail serves as a reminder how fragile this National Memorial is, and how important it will be to make the correct decisions on a Show at MORU.

Issues: Forest Openings Discharge Site

The Forest Openings Discharge Site presents the same issues as the Presidential Trail Discharge Site, with the exception that the ground is rocky and uneven, and is covered with pine needles and other combustible vegetation.

Conclusion: Forest Openings Discharge Site

The Author's conclusion is the same as for the Presidential Trail Discharge Site, with the exception that some rock formations may be used to place some ground level fireworks and articles pyrotechnic 2" or less. Any ground with pine needles and other combustible vegetation

would need additional protections, such as raking areas of pine needles and combustible vegetation, wetting down the immediate area, etc.

Talus Field Discharge Site

The Talus Field Discharge Site was identified by the Author because it is a potential discharge site, but only for ground level fireworks and some articles pyrotechnic 2" or less under NFPA 1123 and best practices. It is across the base of the mountain and roughly 500 feet wide and long, and 500 feet from the Amphitheater.

The Talus Field Discharge Site consists of the rock tailings from the blasting of the carvings with a few small trees at the base and along the sides. Elevations also vary from the top to the bottom and side to side. They range from about 100 to400 above the Amphitheater.

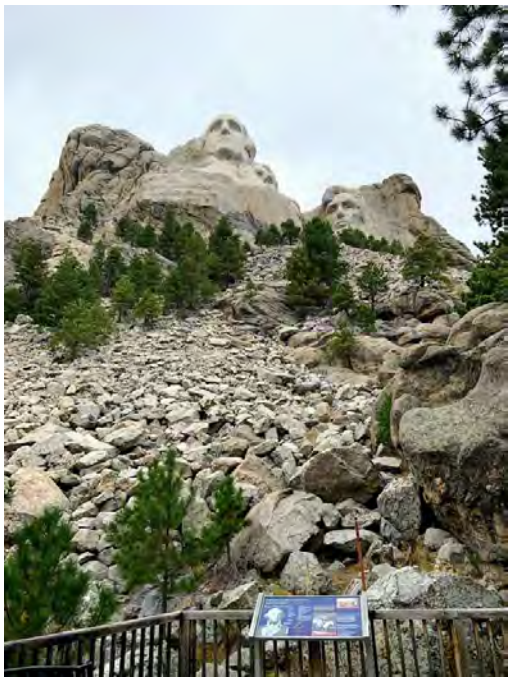

Photo 34 The Talus Field has some potential for articles pyrotechnic, however climbing it to place the devices poses significant risks. Strobe pots and 2" comets and mines at the lower levels that are safer to climb may be viable.

Issues: Talus Field Discharge Site

The Talus Field Discharge Site presents a number of issues, including:

- Anything other than ground level or articles pyrotechnic 2" or less that are mines or comets and placed in the lower portion of the Talus Field are likely not to comply with the Minimum Separation Distances in 1123 - 5.1.3.1 and 5.1.4.3.

- articles pyrotechnic 2” or less that are aerial shells and placed in the middle to the top of the Talus Field are likely to comply with the Minimum Separation Distances in 1123 - 5.1.3.1 and 5.1.4.3
- articles pyrotechnic 2” or less that are aerial shells and placed in the middle to the top of the Talus Field are likely to burst in front of the carvings
- The rock tailings are loose and unstable, and very difficult to climb.
- All articles pyrotechnic 2” or less mounted on the Talus Field should shoot up high enough to be visible to most spectators in the Amphitheater, but those in the first few rows of the Amphitheater may only see the top portions of the effects.

Conclusion: Talus Field Discharge Site

The Author’s conclusion is the same as for the Presidential Trail Discharge Site, with the exception that some portions of the lower talus field may be used to place some ground level fireworks and articles pyrotechnic 2” or less, and any ground with pine needles and other combustible vegetation would need additional protections, such as raking areas of pine needles and combustible vegetation, wetting down the immediate area, etc.

Sides of Carvings Discharge Site

The Sides of Carvings Discharge Site was identified by the Author because it is a potential discharge site, but only for ground level fireworks and some articles pyrotechnic 2” or less under NFPA 1123 and best practices. It is both sides of the carvings and roughly 100 feet below the top of the carvings. The Washington side (stage right, house left) of the carvings is

about 750 feet away from the Amphitheater and the Lincoln side (stage left, house right) of the carvings is about 850 feet away from the Amphitheater.

The Sides of Carvings Discharge Site consists of fine granite rock with a few small trees below. Elevations also vary from the about 500 feet at the top to about 400 feet at the bottom above the Amphitheater.

Photo 35 Waterfalls strung across the famous Edinburgh Castle create a fabulous and long lasting effect, however the rising smoke would obscure the carvings on the mountain and the sparks and hot dross would pose a hazard to the small trees below in the talus field. [Photo credit: Eoin Care, Allied Edinburgh Theater]

Issues: Sides of Carvings Discharge Site

The Sides of Carvings Discharge Site presents a number of issues, including:

- Anything other than ground level fireworks and article pyrotechnic 2” or less would be difficult to place and secure

- Niagara falls and some other illuminations would drop burning sparks or hot dross on the small trees below, and smoke would rise up in front of the carvings
- Anything that is hung over the side on ropes or cables and is not secured is likely to move about by any small breeze or updraft.
- Only skilled, capable rock climbers with the right equipment and support should rappel over the front of the mountain, and only subject to NPS approval
- All ground level fireworks and articles pyrotechnic 2" or less would be visible to most spectators in the Amphitheater, but those in the first few rows of the Amphitheater may not see any or all of the effects.

Conclusion: Sides of Carvings Discharge Site

The Author's conclusion is that the Sides of Carvings Discharge Site to shoot ground level fireworks and articles pyrotechnic 2" or less can be done safely, if wildland fire conditions in July are low to moderate, with favorable wind speeds and directions, as well as dew points, and subject to the other recommendations in this Report.

In particular, only comets and mines with effects that could not reach the small trees below or that were aimed over the talus field should be used. No Niagara falls or other illuminations that could drop sparks or hot dross on the small trees below should be used.

General Author Conclusions

A fireworks display and/or proximate pyrotechnic Show can be done at MORU and comply with the applicable NFPA codes and standards as well as best practices, and the

recommendations in this Report; however in order to do so will require extraordinary due diligence by the Operator, Sponsor(s) and AHJ(s).

It is important to keep in mind that planning, preparing and scheduling a Show is one thing, but the weather and conditions at MORU can easily and quickly change everything, so all involved must be aware of that reality. Whatever is planned will change; and then change AGAIN!

Any Show at MORU that complies with the applicable NFPA codes and standards as well as best practices and the recommendations in this Report <u>will be different than those performed from the Hall of Records in the past</u>.[58]

Photo 36 The Operator will need to conduct a detailed viewshed analysis that determines what aerial fireworks and articles pyrotechnic based on their performance heights and performance spread will be visible to the spectators in the Amphitheater

[58] The Author notes that many news reports and social media posts regarding the return of Independence Day fireworks to MORU in 2020 hint or even state that the show will be the same as in the past. The expectation also seems to be that anyone and everyone that wants to, will be able to drive to MORU to watch the show. Discussions with NPS staff and the South Dakota State Fire Marshal however indicate that there will be limits on the number of spectators in the Visitor Center Complex, as well as other controls due to security, traffic, parking, public safety and other concerns given the limitations of the infrastructure and resources.

Photo 37 A 4" catastrophic aerial shell malfunction in a cardboard mortar. This single break color shell has destroyed the above ground wood frame mortar rack and the sandbags that were used to brace it. Note the entire rack is coming up and out of the blast with the fireball, along with pieces of the mortar rack and the burning stars. Cakes and finale boxes with cardboard tubes, which are chain fused, will experience similar results in the event of a blowout, but because cakes and finale boxes are chain fused, they likely will continue to fire any remaining effects at steep angles until it blows itself out, or is spent.

Author Recommendations

The Author recommends the following:

Informational Package for Prospective Operators

Given the shortened timeline for a Show at MORU on July 3, 2020, to facilitate the process for soliciting bids in response to Requests for Proposals (RFPs) by the Sponsor(s), the NPS and other AHJs with the Sponsor(s) should develop an detailed MORU Fireworks Show Informational Package with the NPS criteria for a Show at MORU on July 3, 2020.

Prior to the Sponsor(s) awarding a contract to an Operator, the NPS should:

- hold an informational meeting with the other AHJs and explain what the NPS is considering, if any, for discharge site(s), operational limitations, resource limitations, expected resource needs, permit application requirements, etc. to develop the MORU Fireworks Show Informational Package
- hold an informational meeting with the Sponsor(s) and explain the MORU Fireworks Show Informational Package.
- after the Sponsor(s) decides what their goals and plans are for a show at MORU, the NPS should hold an informational meeting for prospective Operators to explain the MORU Fireworks Show Informational Package.
- schedule a walk through (when feasible) of the NPS approved discharge site(s) for the Sponsor(s) and prospective Operators.

Photo 38 Round stars are the most common type of stars used in display fireworks. There are also pumped stars that are conical in shape and cut stars that are cube in shape. Stars typically consist of a fuel, an oxidizer and a binder and burn at 800 to 1,000° C creating the bright colors we see in the sky.

Permit Application and Approval

The NPS as well as other AHJs should require a permit application from both the Operator and Sponsor(s) as required by NFPA 1123[59], NFPA 1126[60], Federal regulations[61] and South Dakota state law.[62]

MORU is in an incorporated area of Pennington County and a fireworks permit is required under § 34-37-13 would be issued by their Fire Administration.

Pennington County may need to revise their existing Fireworks Ordinance, which prohibits the use of fireworks under *SDCL* §34-37-19 and *SDCL* §34-36-7 because *SDCL* §34-

[59] 1123 10.3

[60] 1126 6.1

[61] Title 36, *Code of Federal Regulations* (*CFR)* § 2.38 Explosives (b) Using or possessing fireworks and firecrackers is prohibited, except pursuant to the terms and conditions of a permit or in designated areas under such conditions as the superintendent may establish, and in accordance with applicable State law.

[62] *South Dakota Codified Law (SDCL)* § 34-37-13 A person using display fireworks at a public or private event shall obtain a permit from the governing body of the municipality, township, or county where the display fireworks are to be used permit be issued.

36-7 has subsequently been repealed. The current language of the Fireworks Ordinance makes no mention of a permit for the use of fireworks and it may be prudent to establish a permit process.

MORU is also located within the Black Hills Fire Protection District. South Dakota state law prohibits the use of fireworks or pyrotechnics without a permit.[63]

MORU is also surrounded by the Black Hills National Forest administered by the U.S. Forest Service. A Show at MORU presents issues they will need address because the laws of physics and chemistry are not governed by the invisible lines created by human beings.

The NPS may need to consult with the U.S. Forest Service, the SD SFM, the Black Hills Fire Protection District, and the Pennington County Fire Administration regarding the issuance of permits, waivers or a memorandum of understanding for a Show at MORU.

The NPS permit application and approval process should comply with NFPA 1, NFPA 101, NFPA 1123, NFPA 1124 and NFPA 1126 and best practices, as well as applicable NPS policies. The permit application should also require, the Operator and/or the Sponsor(s) provide the information in NFPA 1123 Appendix E Display Planning and Preparation and NFPA 1126 6.3 Content of Plans.

The NPS permit application and process should include the criteria the NPS and possibly other AHJs will consider for approval of a Show at MORU.

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[63] *SDCL* §34-37-11 "No person may sell or cause to be sold, use, or cause to be used, any pyrotechnics of any description or any consumer fireworks within the exterior boundaries of the Black Hills Forest Fire Protection District. No person may use or cause to be used, any pyrotechnics or consumer fireworks within a zone that extends three hundred feet beyond the exterior boundaries of the Black Hills Forest Fire Protection District in this state. No person may sell or cause to be sold, use or cause to be used, any pyrotechnics of any description or any consumer fireworks within any national forest, national park, state forest, or any land owned or leased by the Department of Game, Fish and Parks without written authorization by the department permitting the use of pyrotechnics or consumer fireworks, pyrotechnic displays, sales, or exhibits on land owned or leased by the department, unless the department is otherwise prohibited by law from providing the written authorization."

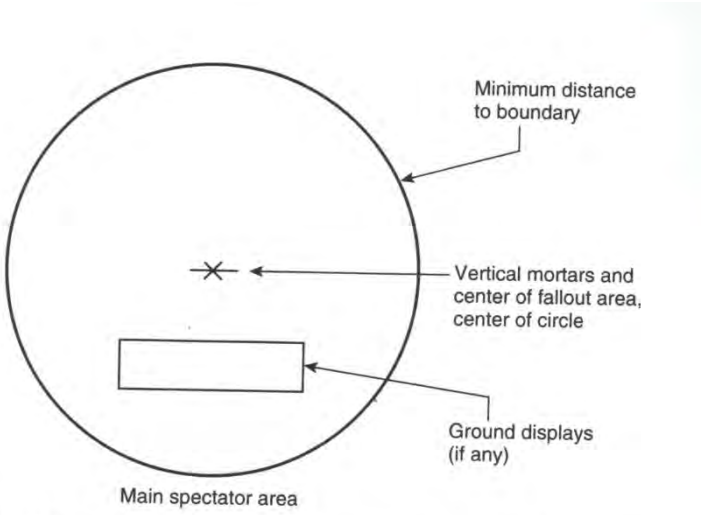

FIGURE A.5.2.1.1 Typical Layout for a Display Site with Vertically Positioned Mortars.

Photo 39 Figure A.5.2.1.1 from NFPA 1123 showing a very basic display site with a single discharge site for aerial fireworks and a single fallout area. This diagram assumes a level display site with single break shells fired from buried mortars that are vertical and with zero wind.

Permit Approval

The approval process of a permit application should include as a minimum:

- a mandatory personal survey by the permit applicant(s) of the potential discharge site(s) approved by the NPS AHJ and other AHJs.

Photo 40 Figure A.5.2.1.1 from NFPA 1123 showing a very basic display site with a single discharge site for aerial fireworks and a single fallout area. This diagram assumes a level display site with single break shells fired from buried mortars that are vertical and with zero wind.

- a detailed Display Site diagram with the discharge site(s), fallout area(s) and spectator viewing area(s) [The Display site].
- a detailed diagram showing storage area(s), preparation area(s), equipment staging areas(s), etc.

- detailed descriptions with specifications of the equipment (mortars, mortar racks, holders, securement and stabilization methods, shields and materials, firing system, etc.) to be used with photos,
- detailed descriptions of the fireworks and/or pyrotechnics to be used including brand names, sizes, effects descriptions, mortar and device locations with angles, durations, performance heights and performance spread
- a detailed viewshed analysis that determines what aerial fireworks and articles pyrotechnic based on their performance heights and performance spread will be visible to the spectators in the Amphitheater [64]
- US Department of Transportation (DOT) Explosive number (EX#) with the manufacturer's applications listing the chemical compositions of all fireworks and articles pyrotechnic[65]
- Safety Data Sheets (SDS) for all of all fireworks and articles pyrotechnic
- lists of other complex, large scale shows produced by the permit applicant with the contact names of the sponsors and the AHJs
- name, credentials, show experience, curriculum vitae (CV) of the Operator and key Assistants
- Proposed schedules

[64] Only a detailed viewshed analysis will determine with a high degree of accuracy what aerial fireworks and articles pyrotechnic will be visible to the spectators in the Amphitheater

[65] U. S. Department of Transportation (DOT) Explosive number (EX#) applications will list the approved chemical compositions for each fireworks or articles pyrotechnic effect, including the fuels, oxidizers and binders for the stars and burst charge.

Show Design

The safe performance of any show starts with the selection of both the discharge site(s) and the design of the show from that discharge site(s).

Anyone can design an impressive show that looks good on paper because of the volume of product used. A "shoot a hole in the sky" show also wows spectators with volley after volley of various sizes and types of fireworks, but this type of show requires more gear, which in turn requires more labor and logistics. This type of show generally relies on using large quantities of cheaper, lower quality product, which do not have the same vibrant colors and duration of higher quality fireworks; hence the need to rapidly fire larger numbers of fireworks devices.

More importantly, a "shoot a hole in the sky" show using large quantities of cheaper, lower quality product has a higher malfunction and failure rate, which in turn increases safety risks. Reducing the number of fireworks/pyrotechnic devices and using higher quality fireworks/pyrotechnic devices reduces, but does not eliminate, the odds of an equipment failure or fireworks malfunction, and thus reduces the risks of potential fires, property damage, injuries and even deaths.

Differences in the "Same" Fireworks

Compare a low quality 5" Chinese peony shell with a performance duration of about 1 second with a high quality American or Chinese 5" peony with a performance duration about 2 seconds. The low-quality Chinese peony colors will not be as vibrant and rich as the high quality American or Chinese peony simply because of the quality of the chemicals used and the better-quality controls in the manufacturing process.

The low-quality Chinese peony has only about 2/3 of the star composition by weight as a high quality American or Chinese peony. The low-quality Chinese peony may have a star ignition rate of only 90-95% while the high quality American or Chinese peony has a star ignition rate of 99.9%.

The more blind stars and effects that came down on the ground during a fireworks, the greater the potential for a hazardous situation. Blind stars and effects laying on the ground can still be ignited, provided there is sufficient fire transfer, such as from a direct and sustained flame from a prescribed burn or wildland fire. It may take weeks or months for blind stars and effects laying on the ground to dissolve to the point this hazard is diminished or mitigated.

Differences in the Show Pace

A "shoot a hole in the sky" generally has volley after volley of fireworks until the finale. Some volleys are a bit bigger or faster than others, but the pace of the show remains fairly constant until the finale. Sometimes the smoke from a show at this constant pace builds up to the point that the fireworks are obscured before the finale even begins.

The music is almost always continuous with shortened clips of songs that run one into the next. It is often mixed, so the beat is relatively constant from start to finish.

In the US and many other markets around the world, price is the dominant factor while in many other Western countries such as Japan, Canada, Australia and Western Europe quality is the dominant factor. Sponsors here tend to focus on how many "bangs for the buck" they get in a proposal rather than the entertainment value of the fireworks display.

Photo 41 An example of the volume of smoke generated from a small finale of cakes and chain fused 3" salutes on a very windy night. Note the burning stars going up as well as coming down from the cakes.

A show with a music mix of entire songs or at least portions of songs with an opening, a verse and a chorus with breaks between songs allows the spectators to clap and cheer between songs. It also builds anticipation, while allowing the smoke to dissipate.

The pace of each song remains as it was originally and the mix can go from hard and loud to soft and slow, back to hard and loud. Ebbs and flows to the music allow ebbs and flows to the fireworks, so one can shoot fewer, but higher quality fireworks and still entertain the spectators.

A show that tells a story, even one with narration between songs, can extend the show length and remain very entertaining. It just takes a bit of creativity.

Fireworks Alternatives: Lights, Lasers, Holograms and Drones

Some shows with the right venues, such as at theme parks and major attractions like the Eiffel Tower, the Seattle Space Needle and others utilize alternatives to fireworks, such as lights, lasers, holograms and now even squadrons of drones. Often these are used in conjunction with fireworks and articles pyrotechnic and enhance the story being told by the show, while allowing the smoke to clear from the fireworks.

MORU would be an ideal venue for some of these alternatives, especially projected lights and holograms onto the talus field and the carvings, which would serve as an excellent screen and backdrop. These alternatives may also prove to be as entertaining and cost effective as a much larger and longer fireworks display.

Fireworks Company Qualifications

Given the extreme challenges with any show at MORU, the fireworks/special effects company chosen should have extensive experience with similar challenging venues. The company should have the creativity to design a show that not only meets but exceeds the minimum standards in NFPA 1123 and/or NFPA 1126 and best practices.

The company should also have the experience and creativity to design a Show that is logistically feasible and entertaining, as well as on time and on budget.

Show Plan

Prior to the Show, the Fireworks Company and the Operator should develop a detailed show plan[66] that includes:

- schedule detailing each step in the Show from the acceptance by the Operator of the contract with Sponsor(s), meetings and communications with the MORU staff and AHJs, the planning and design, the preparation and loading of the equipment, fireworks and articles pyrotechnic for transport to MORU, the transport to MORU, the receiving at MORU, the preparation at MORU and the transport to the discharge site(s), the set up of the equipment and the loading, the testing, the sound check of the music and time code, the firing of the show, the policing for duds, the striking of the equipment, the transport from the discharge sites(a), and the loading and transport from MORU
- schedule with contingency plans and emergency plans.
- contact information including mobile phone numbers and email addresses of the Operator and key Assistants
- display site(s) diagram with the locations for all equipment, fireworks and articles pyrotechnic, the Operator[67], the Shooter(s) and the Shooter's Assistant(s), the Spotters and the Command Center with the AHJ(s) and the

[66] 1126 6.3 and 1123 – Appendix E as well as best practices in other documents provide guidance on what a comprehensive show plan should consider and contain.

[67] The Operator may be a Shooter, a Shooter's Assistant or a Spotter. It may be advisable for the Operator to be in the Command Center during the display to communicate with the AHJs, the Shooter(s), Shooter's Assistant(s) and Spotters as well as coordinate the music and time code feeds.

- diagram(s) with preparation areas, temporary fireworks storage, equipment storage, staging areas, etc.
- fireworks and article pyrotechnic inventory
- equipment inventory
- any other pertinent information the Operator, AHJs or Sponsor(s) deem necessary or useful (See NFPA 1123 Appendix E and 1126 6.3)
- reference best trade practices that meet the goals of a safe show

Operator & Crew Qualifications

The Operator the fireworks company chooses for any show at MORU should also have the experience, technical capability and creativity to make everything happen safely as well as on time and on budget. The Operator should have a clear understanding of NFPA 1123 and 1126 as well as best practices for every facet of a show from start to finish.

The key Assistants to the Operator should have similar experience, technical capability and creativity. The crew may contain less experienced Assistants for general labor and basic set up, however their roles should be limited.

The Operator and all Assistants must be physically and mentally capable of performing their respective duties. The Operator and any Assistants that will set up, operate and strike the Show must be physically capable of climbing up and down to any discharge site(s) that is selected for the

Photo 42 The Shooter, who is the Operator for this fireworks display, controlling three computer firing panels as well as a computer with the music and the time code to the computer firing panels. This fireworks display has just under 1,000 cues with 1,400 fireworks devices and over 10,000 shots fired in 20 minutes to music.

show. The Operator and Assistants will also have a great number of responsibilities to address and must be capable of making the correct decisions.

Separation Distances from Discharge Sites

The Author recommends the following regarding the separation distances from the potential discharge sites to spectator viewing and parking area areas, bulk storage areas of materials that have a flammable, explosive or toxic hazard, and dwelling buildings and structures.

- At a minimum, the table of distances in 1123 5.1.3.1 as modified by the applicable provisions in Chapter 5 and best practices should be adhered to for all mortars and tubes that are vertical (90°) and with zero wind, with appropriate increases in distances for mortars that are angled (≥60°) and in consideration of updrafts and wind.[68]
- Under no circumstances should any mortars firing aerial shells be angled or aimed towards the spectator viewing areas, bulk storage areas of materials that have a flammable, explosive or toxic hazard, or dwelling buildings and structures.
- Mortars firing aerial shells should be vertical (90°) or angled slightly (85-80°) away from spectator viewing areas, bulk storage areas of materials that have a flammable, explosive or toxic hazard, or dwelling buildings and structures.

[68] The *Display Fireworks Manual* (2010) and from Natural Resources Canada and the *Study Guide for Display Operator Training Program* (2017) from the Pyrotechnics Guild International, Inc. (PGI) address many of the issues related to increasing or decreasing separation distances.

- Mortars firing aerial shells may be angled to the sides at angle as low as 60° and the separation distances to the sides should be increased accordingly.
- Mortars and tubes firing mines and comets may be angled to the sides at angle as low as 30° and the separation distances to the sides should be increased accordingly.

Photo 43 A 2004 still photo of the fireworks above the carvings. Note the trailing effects from the large diameter aerial shells coming down below ground level (hazardous debris) and the small tree (lower right) burning at the top of the Talus Field [Photo credit: NPS]

Fallout Area(s), Normal and Hazardous Debris, Duds, Blind Stars & Effects

The Author recommends following regarding the fallout area(s), normal and hazardous debris, and duds, blind stars and effects.

- Use aerial shells with comets to aid Spotters in tracking aerial shells to increase their ability to determine where any duds might land in the fallout area
- Fire aerial shells at a pace that Spotters can better track their trajectories to increase their ability to determine where any normal or hazardous debris, duds, and blind stars or effects might land in the fallout area(s)
- Place Spotters near the edges of the display site as well as elevated locations near the discharge site(s) to increase their ability to determine where any normal or hazardous debris, duds, and blind stars or effects might land in the fallout area(s)
- Place Spotters that are wearing the appropriate Personal Protective Equipment (PPE)[69] and that have been trained by the Operator in their duties[70] within the fallout area(s) in order to increase their ability to determine where any normal or hazardous debris, duds, and blind stars or effects might land in the fallout area(s)
- Use fluorescent spray paint on aerial shells to aid in finding duds in the fallout area(s)[71]

[69] 1123 8.1.3.4 establishes the PPE required for personnel in the discharge site. At the least American National Standards Institute (ANSI) rated head protection and eye protection should be worn by any authorized personnel in the display site.

[70] Spotters are generally instructed to mentally mark where any duds may have landed and not to approach until at least 15 minutes after the display. See 1123 8.2.12.1

[71] Spray paint will only cover the top portion of an aerial shell. The outer wrapping for the lift charge and label will come off when the shell fires.

- Develop a plan for a grid search of duds in the fallout area(s) that can be safely and effectively policed in the dark after the display, as well as at first light the morning after[72]
- Identify the portions of the fallout area(s) that can NOT be safely and effectively policed for duds and blind stars and effects in the dark after the display as well as at first light the morning after. Include provisions for addressing potential duds and blind stars and effects in locations that can NOT be accessed (Examples: rocky crevasses, steep slopes, etc.)[73]
- Develop a plan for future utility servicing, security sweeps, vegetation mitigation, prescribed burns, surveys and any other entries into the fallout areas to address any duds or blind stars and effects that may be encountered
- Develop a plan for future prescribed burns and any wildland fires that may involve any duds or blind stars that may be encountered in the fallout area(s) to reduce risks to any personnel
- Develop a plan to provide for any emergency services in the fallout area(s)

[72] 1123 – 8.2.12.3
[73] Locating duds and blind stars and effects may be a task better suited to bomb sniffing dogs

Photo 44 An example of Spotters just outside of the discharge site at a fireworks display.

Many fireworks displays are now fired by computer with thousands of devices launching many thousands of aerial devices into the sky. The rapid pace of these fireworks displays makes it difficult for the Shooter to keep an eye on the computer firing panel, the mortars and tubes, much less the effects flying and bursting into the sky.

These shows are often spread out over hundreds of feet as well, making it an even greater challenge. Multiple Spotters assist the Shooter by tracking certain portions of the show.

The Spotters here are wearing all the required PPE. They are perpendicular to the mortar racks, which are all individually secured to the ground and 100 feet or more away from the nearest devices.

Some of the Spotters are located near cable junctions between the computer firing panel and the firing modules that are connected to the electric matches on the aerial fireworks devices. The Spotters can alert the Shooter using LED lights to any problems. Spotters can also disconnect the cables to halt the firing of a specific portion of the display.

The Spotters also have pressurized water fire extinguishers or 5-gallon plastic buckets with a wet straw broom located around the discharge site to deal with any small fires that may need attention after the fireworks display. Spotters have been trained in their duties by the Operator. They are instructed NOT to enter the discharge site during the fireworks display.

Limited Egress Discharge Site(s)

The Author recommends following regarding the use of any limited egress discharge site(s).

- Analyze each potential discharge site for compliance with 1123 Chapter 7 and best practices
- Develop a plan to provide for the safe evacuation of the Shooter and an Assistant from a limited egress discharge site(s) in the event of a catastrophic malfunction or other similar event
- Develop a plan to provide for any emergency services to the Shooter and an Assistant in a limited egress discharge site(s) in the event of a catastrophic malfunction or other similar event

Monitor Wind Speeds and Directions

The Author recommends following similar methods of monitoring of wind speeds and directions at many of the leading venues with fireworks displays/pyrotechnic performances, such as theme parks, sports stadiums, etc. in order to more accurately gauge the possible negative impacts of high winds blowing towards spectator viewing area(s) from the discharge site(s) or the possible negative impact on potential wildland fire risk.

Place anemometers at key locations at MORU, including but not limited to:

- Hall of Records - On top of the carvings
- Hall of Records Ridge
- Indian Camp – tallest accessible rock formation
- Amphitheater – Backstage roof

- Talus field – Base above stairway of Presidential Trail
- Grandview Terrace - Top of columns
- Information Center – Top of building
- Sculptor's Studio – Top of building
- Top of rock formation – Stage right/house left
- Other

Utilize a system that can record windspeeds and directions with software that can analyze and chart to determine any trends, such as windspeeds that tend to die down after sunset, updrafts by rock formations as the heat rises during the day and as the rocks cool in the evening, tunnel effects between rock formations, etc.

Wildland Fire Conditions for a Show

The Author recommends the MORU AHJ and other AHJs establish a bright line of the wildland fire conditions that could be approved for a show at MORU on July 3, 2020. The wildland fire conditions should be assessed at least weekly from now until the proposed date, with daily assessments starting in April or May.

The wildland fire conditions that could be approved for a show at MORU should include the fuel load in and around the MORU display site along with the temperature range, dew point range, wind speed(s) and directions, and other factors.

Photo 45 MORU has water access and capabilities, but it is limited to around the buildings at the base of the mountain.

It should be noted that weather is not the ONLY criteria in assessing wildland fire conditions. A wet fall and spring may prevent controlled burns and vegetation removal resulting in a much heavier fuel load going into the summer. A few warm sunny days in late June or early July, and suddenly even more fuel load can "appear".

And most importantly, fireworks debris, in particular burning stars at 800-1,000° C, can and will easily ignite even the greenest of vegetation.

Potential Potassium perchlorate (KClO4) and Other Chemical Contamination

The Author recommends the following regarding the potential for potassium perchlorate (KClO4) and other chemical contamination:

- Limit the size and number of display fireworks with KClO4 and use as many articles pyrotechnic that are nitrate based as possible[74]
- Use higher quality display fireworks that are more likely to have fuller burn of compositions and less likely to result in duds and blind stars
- Use more articles pyrotechnics, which are usually even higher quality than display fireworks with far less normal debris and almost no hazardous debris

Show GO/NO GO Schedule

The Author recommends that the MORU AHJ and other AHJs establish a series of Show GO/NO GO criteria be established starting no later than May 1, 2020. The purpose is to facilitate

[74] Nitrate based compositions are not readily available in display fireworks, especially from China. The few nitrate based display fireworks and articles pyrotechnic available are from American, Japanese and Western European manufacturers.

planning, Show and fire prevention measures in advance to reduce the needless use of resources in the event conditions are such that the Show is likely to be cancelled.

Generally, if the wildland fire conditions are poor in April, May and early June, they are unlikely to improve by July 3, 2020. Weather and wildland fire conditions can change rapidly in the Black Hills so what might have been ideal conditions on June 26 can become poor if not unacceptable conditions on July 3

The Show GO/NO Schedule should at a minimum:

- Fuel load management schedule
- Fuel load mitigation (Prescribed burns, vegetation removal, etc.)
- Operator selects music and designs
- Operator selects fireworks and articles pyrotechnics
- Operator fuses and matches fireworks and articles pyrotechnics
- Operator loads and ships equipment to MORU
- Operator loads and ships fireworks and articles pyrotechnics to MORU
- Operator unloads and stages equipment at MORU
- Operator unloads and stores fireworks and articles pyrotechnics at MORU
- Operator transports and sets up equipment to discharge site(s)
- Operator transports and loads fireworks and articles pyrotechnic to discharge site(s)
- Operator finalizes continuity check of firing circuits
- July 1, 2020 @ 3:00 PM (Prior to evening TV news)
- July 2, 2020 @ 3:00 PM

- July 3, 2020 @ 6:00 AM (Prior to morning drive time radio news)
- July 3, 2020 @ 11:00 AM (Prior to Noon TV news)
- July 3, 2020 @ 3:00 PM (Prior to evening TV news)
- July 3, 2020 @ 5:30 PM (Prior to 6:00 PM TV news)
- July 3, 2020 @ 7:30 PM
- July 3, 2020 @ 8:30 PM
- July 3, 2020 @ 9:30 PM

Include Show GO/NO GO time lines for the following:

- Locations of traffic control devices around MORU
- Schedule for placement and removal of traffic control devices around MORU
- Road closures to MORU
- Deployment of fire prevention measures at MORU (Water cisterns, hoses, etc.)
- Muster of fire protection from supporting fire departments
- Deployment of fire protection from supporting fire departments
- Display site securement
- Deployment of Monitors and supporting fire fighters around display site
- Sound and time code check
- Final checks that all systems, equipment and personnel are ready
- Final check on weather and wildland fire conditions

Trail Improvements & Lighting

The Author recommends any natural trails to discharge site(s) be improved with temporary trail markings, such as survey flags or colored ropes to assist members of the fireworks crew and other authorized personnel find their way.

Temporary rock or wooden steps and climbing ropes tied to rocks and/or tree trunks should be placed at locations where the grade is particularly steep or slippery to reduce the potential for falls. These temporary steps and climbing ropes can be removed and return the natural trails to their former condition after the show.

Paths to dead ends or areas that are too steep or slippery should be marked with color ropes and small signs to prevent people from going into riskier areas, particularly after dark.

Solar lights should be placed along any natural and existing trails to assist the fireworks crew, fire fighters and other authorized personnel in and around the display site after dark.

Fireworks Transportation

The transportation of fireworks on public roads and highways are subject to Federal and state regulations regarding hazardous materials. There are also Federal regulations regarding the transportation of hazardous materials by air, such as by helicopter.[75]

[75] Title 49, CFR, Parts 100-185, U. S. Department of Transportation (DOT), Pipeline and Hazardous Materials Safety Administration (PHMSA), Hazardous Materials Regulations (HMR) and Title 49, CFR, Parts 300-399, U.S. DOT, Federal Motor Carrier Safety Administration (FMCSA), General Regulations

Transportation by motor carrier of display fireworks that are classified as FIREWORKS UN0335 1.3G or FIREWORKS UN0333 1.1G generally requires the following:

Photo 46 Temporary fireworks storage prior to the show setup can be as simple as a truck or trailer that complies with the US DOT requirements for transportation and ATF requirements for temporary storage. It must be located in a secure area away [the distance will depend on the quantity of fireworks] from occupied buildings and public roads, along with other requirements to secure the vehicle from unauthorized movement.

The shipper of display fireworks must:

- be registered with the US DOT as a shipper of hazardous materials
- have a security plan
- train all employees on the proper identification, marking, labeling, packing and packaging of hazardous materials
- properly identify, mark, label, pack and package all shipments of hazardous materials
- properly prepare the bill of lading and all other shipping papers and documents, and maintain certain records for every shipment of hazardous materials
- provide the correct placards for the hazardous materials to the driver

The motor carrier of display fireworks must generally:

- register with the US DOT as a motor carrier

- carry $5,000,000 minimum liability insurance [76]
- own or lease motor vehicles that meet the requirements for carrying Class 1 explosives
- verify and maintain driver licenses, TSA endorsements and DOT medical cards
- establish a random drug test program for all drivers
- maintain certain records for all vehicles and drivers

The driver of a commercial motor vehicle carrying display fireworks must:

- have a commercial driver license (CDL) with a hazmat "H" endorsement
- pass a Transportation Security Administration (TSA) background check and provide fingerprints
- pass a CDL physical and provide the carrier with DOT medical card
- have been issued an ATF responsible persons or employee possessor letter for that particular company that holds the ATF explosives license or user permit
- inspect the commercial motor vehicle before starting any trips
- inspect the load in the commercial motor vehicle before starting any trips
- properly placard the commercial motor vehicle before starting any trips
- review bill of lading and shipping papers, and sign receipt of the shipment
- stop to reinspect the commercial motor vehicle and the load during the trips
- stop and take the required breaks during the trip

[76] See DOT Form MCS-90 - Endorsement for Motor Carrier Policies of Insurance for Public Liability under Sections 29 and 30 of the Motor Carrier Act of 1980

- properly maintain a driver's daily log
- follow the requirements for hours of service (14 hours on duty, 11 hours driving, 10 hours off duty and no more than 60 hours on duty over 7 consecutive days)

The requirements for shippers of FIREWORKS UN0336 1.4G as well as ARTICLES PYROTECHNIC (for technical purposes) UN0341 1.4G or UN0432 1.4S are the same as for other Class 1 Explosives. The requirements carriers and drivers are similar as those described above, with a few differences.

Fireworks/Pyrotechnics Storage Prior to the Show Setup

The Author recommends that the temporary storage of the fireworks and/or pyrotechnics prior to the show comply with the applicable requirements of NFPA 1124, Chapter 5, as well as the applicable Federal and state laws and regulations.

Storage at a discharge site(s) prior to the show but during the set up should also meet the same standards.[77]

Security & Attendance of the Fireworks Loaded at the Discharge Site(s)

The Author anticipates that fireworks will likely be loaded into the mortars and article pyrotechnics into holders at the discharge (s) many days in advance of the show. A discharge site

[77] The Ohio State Fire Marshal indicates what some of the best practices are with "Fireworks at the Exhibition Site"

with fireworks or articles pyrotechnics must be secured from unescorted public access[78] and best practices.

Any fireworks that are not stored in an ATF approved magazine or articles pyrotechnic that are not stored in appropriate locked storage must be attended to by authorized personnel or secured by some other means approved by the AHJ.[79]

The Author recommends the Operator develop a security and attendance plan that secures any fireworks will likely be loaded into the mortars and article pyrotechnics into holders at the discharge (s) from the time they are loaded until the discharge site is secured after the show.[80]

Mortars, Mortar Racks and Securement

The types of mortars, mortar racks and methods of securement have a major impact on the potential negative impacts if an aerial shell functions prematurely in a mortar. Mortars made of paper, high density polyethylene (HDPE) or fiberglass in above ground wood frame racks are the standard in the trade. Fiberglass mortars made in China are the most common, followed by HDPE and some fiberglass mortars made in the USA. Paper mortars are rarely used anymore.

[78] 1123 8.1.2.5

[79] 27 CFR, Part 555, Subpart K Storage. ATF considers storage to be anything other than: Fireworks in the process of manufacture; being physically handled in the operating process of a licensee or user; being used; or being transported to a place of storage or use by licensee or permittee or by a person who has lawfully acquired explosive materials under Sec. 555. 106.

[80] A discharge site that is enclosed by fences and monitored 24 hours a day by security cameras at a facility with limited public access could be approved, subject to other security provisions.

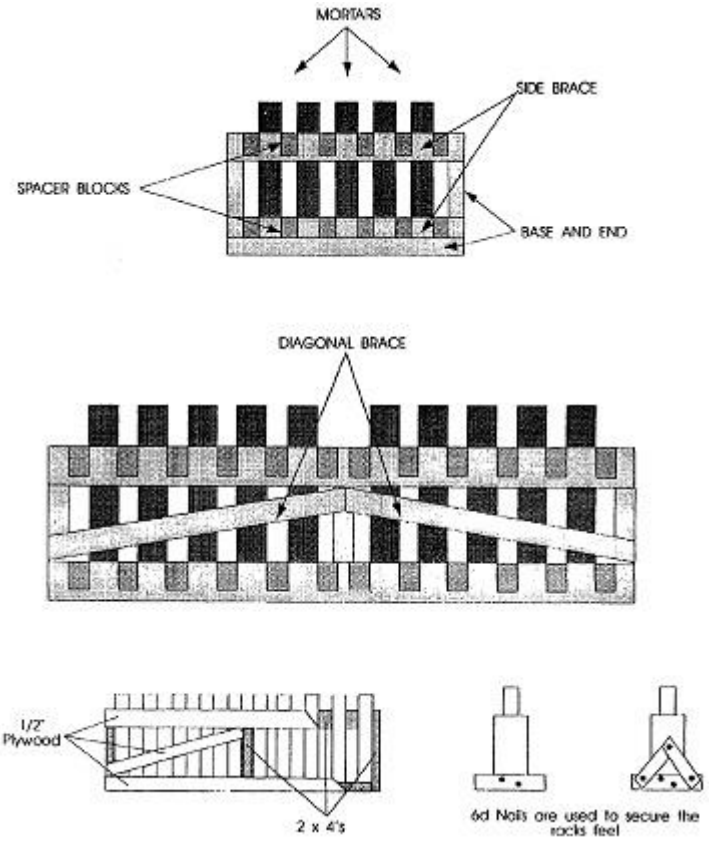

Photo 47 The California State Fire Marshal is one of the few AHJs that has published standards for mortar rack design and construction, as well as placement.

Above ground wood frame mortar racks are the typical type used in the trade. Some mortar racks are better than others in their design, materials and construction, however with the exception of the smaller 2" and 2.5" and perhaps some 3" aerial color shells that malfunction in HDPE mortars that are in an above ground wood frame rack with spacers between each mortar and the end boards, and that has been glued and screwed together with deck screws, with the holes drilled in the wood to prevent splitting, **very few, if any other mortar racks – particularly for 5" and larger aerial shells, will withstand a catastrophic aerial shell malfunction in a mortar**.[81]

If a group of above ground wood frame mortar racks are densely packed together and/or rely on the same supporting materials, such as wood stringers nailed or screwed to the sides of the racks, the whole assembly of mortar racks can be damaged or destroyed.

[81] A.4.6.1 ….. Aboveground wood frame mortar racks with lightweight mortar materials such as paper, HDPE, or fiberglass generally will not withstand a catastrophic aerial shell malfunction in a mortar

When a catastrophic aerial shell malfunction occurs in a mortar, it can cause other nearby mortars and/or mortar racks to tipover or realign. The fireball and effects from that shell and/or the firing system can fire other aerial shells, comets or mines in those mortars at steep angles at distances far greater than those in 5.1.3.1.

The research and experience of the Author and others with mortar designs, materials and construction methods indicate fiberglass, HDPE and paper are acceptable for use in fireworks displays, provided the mortars are constructed properly (the bases or plugs and fasteners are critical), the walls are the appropriate thickness, they are properly maintained, etc.

There are differences in how each type of mortar material combined with the plug and fasteners performs in the event of a premature aerial shell malfunction in the mortar, and how that can not only damage or destroy the mortar, but damage or destroy adjacent mortars, as well as nearby mortar racks.

Generally, fiberglass mortars are the strongest of the three materials, which also confines the blast of a premature aerial shell malfunction in the mortar making it a more powerful explosion. Fiberglass is also very brittle, so normal handling can cause hidden cracks and that weaken the mortar and especially the plug. A premature aerial shell malfunction in a fiberglass mortar tends to shatter it into many pieces.

Most of the trade now uses fiberglass mortars made in China. Quality can vary widely, with some mortars so poorly constructed they can fail on the first shot, especially larger diameter mortars such as 8”, 10” and 12”. The failure is usually due to the fiberglass tube and/or plug not having the right mix of fiberglass and resin and/or not having the plug secured well enough to the fiberglass tube.

HDPE mortars are only about 1/3 as strong as fiberglass, which lessens the confinement of the blast of a premature aerial shell malfunction in the mortar. HDPE is a thermoplastic that stretches before it fails, so the HDPE absorbs some of the energy of the blast in such an event. A premature aerial shell malfunction in an HDPE mortar tends to stretch the HDPE into a banana peel shape.

Paper mortars are also only about 1/3 as strong as fiberglass, which lessens the confinement of the blast of a premature aerial shell malfunction in the mortar. The blast from such an event is less powerful than in a fiberglass mortar, but a bit more powerful than an HDPE mortar. Paper breaks apart into a few large pieces (top and bottom with plug), with the portion of the paper mortar closet to the aerial shell shredded by the blast into many smaller piece

Photo 48 The metal steps up from the Hall of Records Canyon to the Guard Shack. Articles pyrotechnic holders could be secured to the outside of this structure.

Photo 49 An example of a heavy duty above ground metal frame rack with medium level mortars. Here a shell as just fired electrically from a Chinese fiberglass mortar Note: The sparks on the outside are from the leader fuse and the light of the lift charge illuminates the inside of the fiberglass mortar. This type of rack can withstand a catastrophic malfunction in a mortar from single break color shells. [Photo credit: Fireworks FX, Inc]

The Author recommends the use of heavy duty above ground, square tube metal frame mortar rack holders that can withstand a catastrophic malfunction in a mortar without repositioning the mortars in the rack, the mortar rack itself or other nearby mortar racks, or equivalent.

Weather Protection of the Fireworks

The Author anticipates it will take a number of days to load the fireworks for the show, thus the fireworks will need to be protected from the weather, even if no rain is forecast. Morning dew can accumulate inside mortars and tubes. Condensation can and will form over

mortars and tubes covered with plastic. Fog can roll in overnight and water droplets collect on cooler surfaces.

The Operator should have a detailed plan for how to protect the fireworks from the weather after the fireworks are loaded until the show. The plan should also take into account when and how whatever coverings are used will be removed before the fireworks display starts and/or and will be recovered after the fireworks display.

Fireworks Types & Styles[82]

The Author recommends the use of the following types and styles of fireworks and articles pyrotechnic[83]:

- Aerial fireworks and that are constructed of 100% biodegradable casings, tapes, glues and strings (paper, cardboard, wheat paste, cotton, flax, etc.)[84]
- Single break aerial color shells with blackpowder break charges, with or without tails (Peonies, chrysanthemums, dahlias, gamoges, palm trees, patterns and rings, saturns, etc.)
- Aerial mines with non-bursting and non-splitting effects

[82] Best practices in the trade are to use the types and styles as well as the sizes and power of the display fireworks and/or articles pyrotechnic that fit the unique features of the venue (occupied buildings with windows, tents, animals, air traffic, water traffic, combustible materials, hazardous materials, etc.) the potential weather conditions (windy, dry, wet, etc.), available resources (fire prevention, fire protection, traffic control, security, etc.) scheduling (other entertainment, construction, pedestrian and vehicular traffic demands, etc.), environmental sensitivity (forestland, grassland, golf course, stadium, historic site, etc.)

[83] The recommended types and styles of fireworks and articles pyrotechnic pose less of a potential hazard from normal functioning as well as potential malfunctions (See Author defined term Malfunction).

[84] These materials are generally considered to biodegradable. The remnants of any ground level fireworks can be recovered after the fireworks display.

- Aerial comets with non-bursting and non-splitting effects
- Single shot aerial mines and comets with non-bursting and non-splitting effects
- Roman candles with non-bursting and non-splitting effects
- Illuminations (Flares, strobes, Bengal pots, lances, etc.)
- Gerbs and fountains

Photo 50 A handheld anemometer is useful for determining wind speeds at ground level; however, it cannot determine windspeeds above the discharge site or other locations around a display site. The larger the aerial shells, the larger the display site and the higher the bursts in the sky, making wind speed and direction both more critical and more difficult to assess in order to conduct a safe Show

Photo 51 A cutaway of a Chinese 6" single break peony with a pistil and rising tails shell. The leader fuse fits through a string loop at the tope to the lift charge of black powder in a plastic bag at the bottom. Two time fuses with crossmatch are glued into place through the paper casing from the lift charge to the burst charge in the center, which consists of dry rice hulls coated with black powder. The smaller round stars in a circle inside the burst are the pistil round stars are the petals of the peony. The rising tails are glued on the outside top of the casing and ignited by the lift charge.

The Author recommends prohibiting the use of the following types and styles of aerial fireworks.[85]

- Any aerial fireworks with plastic casings or components, or polyester based string or reinforced tape (Fuse holders, spacers, etc.)[86]
- Single break salutes and artillery shells, and any aerial shells or mines with reports or siateens (Any shells with flash powder based concussive affects)[87]
- Aerial mines with bursting or splitting effects
- Aerial comets with bursting or splitting effects
- Single shot aerial mines and comets with bursting or splitting effects
- Roman candles with bursting or splitting effects
- Single break color shells with any fine metallic powder enhanced break charges [88]
- Aerial shells with inserts[89] (Whistles, hummers, serpents, fish, tourbillions, etc.)
- Multiple break canister, double bubble or peanut aerial shells (two round shells)

[85] The types and styles of fireworks and articles pyrotechnic recommended to be prohibited pose a greater potential hazard from normal functioning and/or malfunction because they are more complex and prone to malfunction, more powerful, produce more normal burning debris, produce trailing effects that may reach the ground, are chain fused (cakes), more prone to issues with blowouts (Roman candles and cakes), can burn longer and hotter, etc. (See Author defined terms).

[86] These materials are generally considered not to be biodegradable

[87] Concussive effects pose a potential hazard to the carvings and the Hall of Records because of their greater power than single break color shells. A rough rule of thumb is a 3" aerial salute with 2.5 ounces of flash powder has the same explosive power as a 5" color shell.

[88] American Pyrotechnics (APA) Standard 87-1 4.1.1 classifies such shells as FIREWORKS, UN0333, 1.1G, which is the same as for aerial shells larger than 10" and aerial salutes with more than 2.5 oz of flash powder.

[89] Inserts are plastic, paper or cardboard tubes with loose or pressed pyrotechnic compositions and a clay plug(s) that continue to function after the aerial shell bursts in the sky

- Aerial shells with any long lasting or draping effects (Crossettes, diadems, falling flowers or leaves, kamuros, parachutes[90], shells of shells, willows, crackles, etc.)
- Any aerial shells, comets or mines with strobes or magnesium-based effects
- Cakes (multiple tube aerial devices) or finale boxes[91]

Firing Methods & Equipment

The Author recommends any Show at MORU should be electrically fired in accordance with NFPA 1123 Chapter 9. No display fireworks or pyrotechnics should be manually fired with a fusee, portfire or other open flame.

If any theatrical performer in the Amphitheater acts as if they are firing a gun or cannon, it should be a simulation.

Inspection, Matching & Fusing of Fireworks and Articles Pyrotechnic

The Author recommends the following for the inspection, matching and fusing of fireworks and articles pyrotechnic prior to the Show:

- inspection, matching and fusing should be conducted at a Bureau of Alcohol, Tobacco, Firearms & Explosives (ATF) licensed manufacturing facility in an ATF

[90] 1123 – A.4.1.3

[91] Cakes (multiple tube aerial devices) and finale boxes consist of cardboard tubes bundled together in shipping cartons with liners. Cakes and finale boxes have a tendency to burn, which can damage the ground and/or start grass fires as well as distract the spectators with flame and smoke. Cakes and finale boxes also can bounce or tip over and shoot at low angles resulting in low breaks and ground breaks if not properly secured with stakes, sandbags or other means. The cardboard tubes in cakes also can experience blowouts, which can shoot at low angles resulting in low breaks and ground breaks.

approved process building and/or area and in accordance with NFPA 1124 Chapters 4 and 5 and best practices.

- All aerial display fireworks (Aerial shells, mines and comets) should have electric matches with the shroud intact installed into the top of the lift charges in direct contact with the blackpowder (avoid placing the matchhead between layers of paper or any plastic bag that contains the blackpowder). The hole should be punched with a wooden dowel, brass punch or other non-sparking hand tool and sealed with masking or paper tape.
- The electric match leg wires should be secured with strain relief (to prevent the electric matches from being unintentionally pulled out suddenly).
- All leader fuses and any pigtail fuses with plastic T connectors should be removed and no chain fuses, with or without time delays, should be used[92].
- Natural fiber string or twine (cotton, flax or jute, etc.) or electric match wires should be attached to the loops on the tops of all aerial shells, comets and mines for the purpose of lowering into the mortars and possibly retrieving from the mortars.
- All other display fireworks (Roman candles, single shots, illuminations, gerbs and fountains) should have electric matches installed directly into the nozzle or fuse hole to the lift charge or ignition port the leg wires secured with strain relief (to

[92] Many leader fuses are now plastic coated and any remnants that do not completely burn when fired can remain for years (such as the piece found 10 years after the last fireworks display in 2009). Burning leader fuse paper that flies about the discharge area is also a potential ignition source of combustible vegetation and the burning fuses add to the level of smoke that can obscure the Shooter and Shooter's Assistant from observing the mortars during the fireworks display

prevent the electric matches from being unintentionally pulled out suddenly). Any leader fuses should be removed.

- All electric matches should remain shunted until ready to connect to the firing module.
- All electric match leg wires and string or twine should be neatly folded or coiled, and secured with masking tape to the fireworks.
- All fireworks with the electric matches and string should be neatly packed into the approved inner packaging and liner inside the US DOT approved shipping carton for that particular fireworks device. The fireworks should be packed in such a manner that no electric matchhead is in contact with the bottom, sides or top of the shipping carton, or an adjacent aerial shell, mine or comet.
- Under no circumstances should any fireworks with electric matches attached be packed in such a manner that impact or friction from normal handling and transportation could ignite a matchhead.
- Alternatively, electric matches with the shrouds intact could be installed into plastic bags with the requisite amount of blackpowder for the lift charge for each type and caliber of aerial shell, mine or comet. A natural fiber string or twine could be attached to the loop on top of each aerial shell, mine or comet to lower it into the mortar, with a temporary paper cap or cup protecting the time fuses on the aerial shells. The appropriate lift charge is loaded into the mortar using the leg wires of the electric match, then the paper cap or cup protecting the time fuses is removed, and then the aerial shell, mine or comet is loaded into the mortar using the natural fiber string or twine (Japanese method).

- Articles pyrotechnics typically have the electric matches installed during manufacturing. Any that do not have electric matches installed should be matched in the same manner as other display fireworks (Roman candles, single shots, illuminations, gerbs and fountains).
- All fireworks and articles pyrotechnic or the shipping cartons should be marked with their cues or locations in the Show. Alternatively, the Show plan should list the cue or location for every fireworks device and article pyrotechnic.

Preparation of the Fireworks and Articles Pyrotechnics at MORU

The Author anticipates that the preparation of the fireworks and articles pyrotechnic any Show at MORU may take a number of days prior to July 3, 2020, and recommends the following:

- Any preparation area at MORU should be secured just as if were at an ATF approved manufacturing facility and meet the requirements of NFPA 1124 Chapter 4 and best practices.
- Under no circumstances should the preparation of fireworks and articles pyrotechnic be conducted in an area open to the public or unauthorized persons, at distances to other preparation areas, magazines or temporary fireworks storage, bulk storage of hazardous materials including flammables liquids and gasses, inhabited buildings, public roads less than those prescribed in NFPA 1124 4.6.2 and 4.6.3.
- Any preparation area at MORU should be limited to containing a single carton of fireworks or articles pyrotechnic and a limited number of personnel at any one

time. Once the fireworks and articles pyrotechnic in that carton have been prepared, they should be placed back into the magazine or temporary storage or transported to the discharge site(s) for loading before another carton of fireworks and articles pyrotechnic is brought into the preparation area.

- Preparation should be limited to such activities as inspections, organizing the fireworks or articles pyrotechnic for proper loading order into mortars or holders, loading articles pyrotechnic into their respective holders and connecting the electric matches to the firing modules, making minor repairs, etc.

Protection of the Carvings and Hall of Records

The Carvings of the Presidents as well as the Hall of Records are considered antiquities and must be protected. The use of cakes by the carvings have left burn marks that are present to this day and there are concerns that concussive effects, such as those from salutes, reports or bottom shots could potentially damage the carvings or Hall of Records.

The actual Hall of Records can be protected by ¾" plywood sheets or equivalent. The other recommendations in this Report should provide reasonable and acceptable methods of protecting these national treasures.

Protection of Property & Critical Utilities

The NPS policies require protection of property and critical utilities. The NPS and the Author have identified the Guard Shack in the Hall of Records as well as the cameras and cables in the Hall of Records, Indian Camp and around the carvings in need of protection.

The Author recommends that the use of low level aerial fireworks (aerial fireworks 2" or less) such as comets and mines up to 2" (50 mm) mounted individually in aluminum holders in the immediate vicinity of the Guard Shack, and the prohibition of the use of cakes. The aluminum holders can be mounted on the risers and supports of the steps and landing.

Photo 52 A cake with crackling effects being fired. Note how many of the crackling effects function in close proximity to the cake and even on the ground. Cakes can burn, which distracts from the show and creates additional risks to any nearby combustibles or property. Cakes and finale boxes can experience blowouts and continue to shoot aerial effects in all directions until it blows itself out or is spent.

The windows may be protected with ¾" plywood or ¼" Lexan™ shields.

The author also recommends not using any salutes or aerial shells with reports or bottom shots to minimize the potential damage from the concussive effects of these types of aerial shells and effects.

The cameras and especially the cables are difficult to protect. Even if the cameras are enclosed in a ¾" plywood or ¼" Lexan™ shield, any direct hit from a fireworks shell, comet or mine stars could potentially damage or destroy a camera. Any shield would also render a camera useless or limit the usefulness of the camera.

Any ground fire, even a small one, could damage or destroy a cable, requiring an expensive and difficult repair or replacement.

Prior to the fireworks display, the NPS and the Sponsor and/or Operator should come to some agreement regarding the repair or replacement of property that is damaged or destroyed as a result of the fireworks display.

Protection of Forest and Natural Habitat

The surrounding forest and natural habitat also must be protected from unreasonable risk. The Author recommends the NPS together with other AHJs develop a comprehensive wildland fire protection plan and address everything from water flow rates of the existing water supply from the exiting fire hydrants, to fuel load management and mitigation, to contingency plans based on worst case scenarios.

Fire Prevention Prior to a Show

The Author recommend placing portable firefighting water tanks at the base of MORU and other key locations prior to the display. These should be filled so they are at the ready if needed rather than after a potential wildland fire occurs.

The above ground and below ground bulk storage of propane and the above ground storage of flammable liquids (fuels) present additional hazards that must be accounted for carefully. Although these should not be within the display site[93], additional fire protection measures may be prudent.

[93] 1123 – 5.1.4.3*

One potential hazard is small bits of burning paper debris from aerial shell bursts can be carried by the wind well outside of the designated fallout area. Although the odds any will reach the ground with any active firebrand are small, in the event any lands near the bulk storage of propane or flammable liquids with leaking vapors, the consequences could be catastrophic.

The Author recommends running garden sprinklers around the bulk storage of propane or flammable liquids prior to and during the fireworks display to keep the ground wet and to disperse any flammable vapors that often are present.

Photo 53 A 4" dud shell. Note the two times fuses on the bottom that both failed to transfer fire from the lift charge to the burst charge inside the shell. Duds are difficult to fine in the dark, even in an open field of short grass. They are even more difficult to find in a pine forest on steep, rock mountains.

Fire Protection During & Post Show

The Author recommends that during and after the Show, fire fighters be stationed in and around the display site. The fire fighters stationed in and around the display site should wear the appropriate personal protective equipment (PPE)[94] and instructed by the Operator on what to

[94] 1123 8.1.3.4 establishes the PPE required for personnel in the discharge site. At the least ANSI rated head protection and eye protection should be worn by any authorized personnel in the display site.

look for and how to react to hazardous debris, especially duds as well as blind stars and effects.[95] The AHJs should also instruct the Spotters on how to react to potential wildland fires.[96]

Often when a show is finished, everyone smiles and breathes a sigh of relief on the false belief everything is good to go. **Burning debris is normal during a fireworks display and ALWAYS comes back down to the ground somewhere – sometimes even outside of the display site**. Most of the larger debris will be pieces of burning paper and cardboard that will land in and around the discharge site. The smaller debris will also be pieces of burning paper and cardboard that will land in and around the discharge site, but some will land in the fallout area and some may even helicopter outside of the display site.

Once on the ground, this debris will usually smolder for a short time and eventually go out; but there are times it can smolder for hours and suddenly flare up and start a fire in the middle of the night.

Along with the mandatory dud sweep after the show[97], a sweep for smoldering debris in the discharge site(s), the fallout area(s) and especially any area downwind of the fallout area should be conducted.

A fire watch should also be maintained overnight at the display site with at least one wildland fire team and apparatus at MORU on standby.

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[95] Spotters are generally instructed to mentally mark where any duds may have landed and not to approach until at least 15 minutes after the display. See 1123 8.2.12.1

[96] Spotters and fire fighters will need to know what reactions and actions are expected based on a prescribes set of circumstances. Overreacting to a non-situation can result in negative consequences just as under reacting to a real dangerous situation.

[97] 1123 8.2.12*

Establish Rainwater Cisterns & Hoses Prior to Show

The Author recommends that prior to any fireworks display at any discharge site outside of the range of the existing fire hydrants and fire apparatus, rainwater collection cisterns are placed at key locations on top of and around MORU. These cisterns may be livestock watering troughs, 55-gallon plastic drums (with the top lids removed) or collapsible water troughs covered with screens to prevent pine needles and other debris from collecting in the water. Each should be fitted with a brass spigot with the standard hose ¾" fitting. Place the appropriate length (100 feet minimum) ¾" ID garden hoses with nozzles at each cistern.

These water cisterns can be used to wet down any dry areas prior to the display and wet down any spent fireworks, hangfires or duds after the display.

Portable pump extinguishers can also be placed by the cisterns and other key locations. The cisterns can be used to refill portable pump extinguishers as needed.

It may also be advisable to run 2 ½" lines up from the base of MORU to the cisterns to initially fill the cisterns. These 2 ½" lines can be charged prior to the display and used to wet down larger areas as needed, and to be at the ready during and after the Show.

Show Command Center

The Author recommends a Command Center for the Show be established. It should be in a location that has clear lines of site to the Shooter(s) and Shooter's Assistant(s) in the discharge site(s), or to a relay point(s) between the Command Center and the discharge site(s), as well as to and from the Spotters and fire fighters stationed in and around the display site.

The Command Center should ideally be located where the MORU closed circuit television (CCTV) system can be monitored.

Show Communications Prior to the Show

The Author recommends that prior to shipping any fireworks or equipment to MORU, the Operator and key Assistants meet with the NPS staff and other AHJs to finalize the show plan.

The Operator and/or a key Assistant should be at MORU to deliver or receive the fireworks and ensure proper temporary storage according to the Show Plan.

The Operator and key Assistant(s) should meet daily with MORU staff for a safety meeting and to discuss the daily plans and conditions.

Show Communications During the Show

The Author recommends the following for communications during the Show:

- Establish at least three 3 methods of communications between the AHJs and Operator or key Assistant in the Command Center and the Shooter(s) and Shooter's Assistant(s) in the discharge site(s), the Spotters[98] around the display site, and the personnel in any relay station(s).
- Use mobile phones with voice and text capabilities, MORU radios with a unique channel for use only by the Operator and Assistants and the Command Center, and a colored light system with relay stations.
- Recognize that mobile phone and radio communications are not always reliable at a fireworks display. Mobile phone signals can be weak or non-existent with

[98] 1123 8.1.4.3.2 requires the Spotters "be in direct communication with the Shooter during the conduct of the display"

network towers in remote areas, especially those with hills. Even with a good mobile phone signal, the large numbers of people with mobile phones can overwhelm the capacity of a network resulting in poor quality voice connections and significant delays in text reception. Radio reception can also be problematic in mountains and canyons, such as those at MORU.

- Also recognize that mobile phones limit voice communications to just two people at a time unless a conference call is initiated. If other people call the same phone at the same time, the most important communication can be missed.
- Establish a group text between the Operator, key Assistants and AHJs for communications before, during and after the Show.
- Establish another group text between the Operator, key Assistants and AHJs as well as the Spotters and fire fighters for just prior to, during and after the Show.
- Realize that both mobile and radio communications become difficult if not impossible during the firing of a Show. People may not hear a phone ring or a call on the radio due to the loud explosions of the fireworks, especially with rock walls and formations acting as a sound board to amplify the noise.
- Appreciate that hearing and being heard, and more importantly being understood with the loud explosions can be difficult because the microphones on mobile phones and radios can cut out when there is any loud noise in the background.
- Establish basic radio protocols to limit unnecessary chatter along with keywords for people, places and situations

Photo 54 Remnants of a 4" aerial shell casing (paper, cotton string and glue) on the ground after a fireworks display. This is the normal debris expected to come down to the ground in the discharge site or fallout area. The edges can have burning embers and there is likely some fireworks composition residue on the inside of the remnants

Be aware that the MORU discharge sites present additional challenges with communications because there are no clear lines of site around the display site. Spotters on the back side and sides of Mount Rushmore have no clear lines of site with the likely location of the Command Center in the Visitor Center Complex, much less some of the potential discharge site(s).

If a Spotter detects a dangerous situation, such as hazardous debris falling from the sky from the fireworks or a wildland fire, a significant amount of time could pass before that

information is relayed back to the Command Center and then up to the Shooter(s) and Shooter's Assistant(s) in the discharge site(s) to halt the show.

- A colored light signaling scheme can be utilized to communicate between the Command Center, the Operator, the Shooter(s) and Shooter's Assistant(s) in the discharge site(s), the personnel in any relay station(s) and the Spotters. It can be a simple GREEN/BLUE for GO and RED for STOP on high intensity LED flashlights. This type of LED light can be waved from one person to another to relay any STOP signal quickly around the display site.
- Establish lines of site for the Show between the Shooter(s) and Shooter's Assistant(s) to the aerial fireworks devices in the discharge site(s),
- Establish relay stations between the Shooter(s) and Shooter's Assistant(s) with an Assistant(s) to the Command Center so that they can shine a bright LED lights from one position to the next to get their attention; and likewise back from the Shooter(s) and Shooter's Assistant(s) to the Command Center.
- If it is feasible, use the existing power and network cables to the security cameras to establish a password protected wi-fi network at the discharge site(s) to provide improved voice and text capabilities around the display site.

Monitor Drone(s) with Cameras

The Author recommends the use of monitor drones outside of the display site if feasible. These monitor drones should be used to look for unauthorized access to the display site, watch for hazardous debris from the Show and any wildland fires that may arise during and afterwards, as well as a STOP signal from any Monitors.

These drones should have communication capabilities that rely on bandwidths not used by civilian mobile phone systems. The visual and audible signals should be available in the Command Center.

Crew and Fire Fighter Positions & Visibility

The Author recommends that the Operator and all Assistants, as well as all authorized personnel, wear high visibility vests or gear whenever working at MORU. At night, all personnel should also have a vest or head mounted LED flashlight that is on while in the forest and climbing up and down the mountain in the dark.

The Show Plan should also designate the locations where the Operator and all Assistants as well as all authorized personnel, including fire fighters, will be located inside and around the display site just before, during and after the fireworks display.

The purpose of these measures is to more readily differentiate every member of the fireworks crew and all authorized personnel in and around the display site for security purposes, and to make it easier to locate anyone that becomes lost or falls while climbing up and down the mountain in the dark.[99]

[99] The Author was advised that during one past fireworks display some of the fire fighters in the forest who were out on the mountain in the dark putting out small fires that started from burning debris became lost for a period of time.

Show Fireworks/Pyrotechnics Recovery & Storage

The Author recommends the Operator together with the MORU AHJ develop a plan for the recovery of any unfired fireworks, misfires, duds, blind stars and effects, etc. after the display.

Storage of any unfired fireworks, misfires, duds, blind stars and effects at MORU until they can be properly and safely transported should follow the same standards as the storage of fireworks prior to the show.[100]

Photo 55 An example of dozens of "Single shots" secured to metal holders with nylon wire ties. Single shots are a cardboard tube with a single aerial shell, mine or comet. They can either be display fireworks

[100] See NFPA 1124, Chapter 5 and 27 CFR, Part 555, Subpart K Storage

or articles pyrotechnic. They are typically 2" or less in diameter and come from the manufacturer with an electric match. [Photo credit: Fireworks FX, Inc]

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Appendix A -Definitions and Standards

NFPA Universal Definitions

To assist the reader with understanding this Report, the Author has included a number of key definitions from the applicable fire codes for a fireworks display & pyrotechnic performance (show) at MORU.

The *National Fire Codes*® include a number of universal definitions, including:

Approved. Acceptable to the authority having jurisdiction.

(The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with the NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.)

Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

(The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a

federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction).

Code. A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

(The decision to designate a standard a "code" is based on such factors as the size and scope of the document, its intended use and form of adoption, and whether it contains substantial enforcement and administrative provisions).

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose. (The means for identifying listed equipment may vary for each organization

concerned with product evaluation; some organization do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product).

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase "standards development process" or "standards development activities," the term "standards" includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

NFPA Universal Standards

The *National Fire Codes*® include a number of universal standards, including:

1-# **Equivalency**. Nothing in this code/standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistances, effectiveness, durability, and safety over those prescribed by this code.

1-#.1 Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

1-#.2 The system, method or device shall be approved for the intended purpose by the authority having jurisdiction.

NFPA 1123 & NFPA 1126 Key Definitions

Assistant. A person who works under supervision of the pyrotechnic Operator. (The duties of an Assistant include tasks such as setting up the equipment and fireworks, loading mortars, (Loader), spotting the bursting location of aerial shells (Spotter) tending a ready box (Ready Box Tender), igniting the fireworks (Shooter), and striking the equipment, and cleaning the discharge site). [1123 – 3.3.2]

Cake. A chain-fused firework that propels a series of aerial shell, comet or mine effects into the air from collectively attached tubes. [1123 – 3.3.6]

Fallout area: The designated area in which both normal and hazardous debris is intended to fall after a pyrotechnic device is fired. (The shells burst over the area, and unsafe, debris and malfunctioning aerial shells fall into the area. The fallout area is the location where a typical aerial shell dud falls to the ground, depending on the wind and angle of mortar placement. The term does not include the area where cardboard and nonhazardous remnants of pyrotechnic devices might fall). [1123 – 3.3.11]

Fireworks display. A presentation of fireworks for a public or private gathering. [1123 – 3.3.16]

Hazardous debris: Any debris produced or expelled by the functioning of a fireworks device that is capable of causing personal injury or unpredicted property damage. (Confetti, lightweight foam pieces, feathers, novelties, and so forth, are not to be construed as hazardous debris). [1123 – 3.3.11]

Operator: The person with overall responsibility for the operation and safety of a fireworks display. [1123 – 3.3.39] and **Pyrotechnic Operator**: The person who has overall

responsibility for the operation and safety of a pyrotechnic display (The Operator is also responsible for storing, setting up, and removing pyrotechnic materials and devices after a performance). [1126 – 3.3.42]

Performance. The enactment of a musical, dramatic, operatic, or other entertainment production. [1126 – 3.3.33]

Proximate audience. An audience closer to pyrotechnic devices than permitted in NFPA 1123. [1126 – 3.3.39]

Shooter. A member of the fireworks display crew (either the Operator or an Assistant) who performs that actual ignition of the fireworks, either by manual or electrical means. [1123 – 3.3.40]

Spotter. A member of the fireworks display crew (either the Operator or an Assistant) who observes the firing and bursting of aerial shells and other display fireworks for the purpose of detecting proper mortar angling, noting the occurrence of duds, and observing for other potentially hazardous situations. [1123 – 3.3.40]

Site: [1123 – 3.3.41]

Discharge site: The area immediately surrounding the location where fireworks and other devices are ignited for a display. [1123 – 3.3.41.1]

Display site: The immediate are where a fireworks display is conducted, including the discharge site, the fallout area, and the required separation distance from mortars to spectator viewing areas, but not spectator viewing areas or vehicle parking areas. [1123 – 3.3.41.2]

Sponsor(s) The organization (person, group, or government agency) that arranges with a duly authorized fireworks supplier for its services in presenting a fireworks display or in

providing fireworks for use in a display. [1123 – 3.3.42] **Producer**: An individual who has overall responsibility for the operation and management of the performance where the pyrotechnics are to be used. (Generally, the producer is an employee of the promotion company, entertainment company, festival, theme park, or other entertainment group). [1126 – 3.3.37].

NFPA 1123 Terms - Undefined

Monitor: A member of the Sponsor's crew that keeps the audience in the spectator viewing area and out of the display site. [1123 – Undefined]

Spectator viewing area: An area where spectators view a fireworks display and is not within the display site. [1123 – Undefined]

Vehicle parking area: An area where spectators park their vehicles and is not within the display site. [1123 – Undefined]

Other NFPA Key Definitions

Assembly Occupancy. An occupancy (1) used for a gathering of 50 or more persons for deliberation, worship, entertainment, eating, drinking, amusement, awaiting transportation, or similar uses: or (2) used as a special amusement building, regardless of occupant load. [NFPA 101 – 3.3.196.2]

Combustible (Material). A material that, in the form in which it is used and under the conditions anticipated, will ignite and burn; a material that does not meet the definition of noncombustible or limited combustible. [NFPA 1 – 3.3.177.1]

Exit. That portion of a means of egress that is separated from all other spaces of the building or structure by construction, location, or equipment as required to provide a protected way of travel to the exit discharge. [NFPA 101 – 3.3.86]

Load. [NFPA 1 – 3.3.170]

Fuel load. The total quantity of combustible contents of a building, space, or fire area. [NFPA 1 – 3.3.170.1]

Occupant load. The total number of persons that might occupy a building or portion thereof at any one time. [NFPA 1 – 3.3.170.2]

Means of Egress. A continuous and unobstructed way of travel from any point in a building or structure to a public way consisting of three separate and distinct parts: (1) the exit access, (2) the exit, and (3) the exit discharge. [NFPA 101 – 3.3.178]

Accessible Means of Egress. A means of egress that provides an accessible route to an area of refuge, a horizontal exit, or a public way. [NFPA 101 – 3.3.178.1]

Means of Escape. A way out of a building or structure that does not conform to the strict definition of means of egress but does provide an alternate way out. [NFPA 101 – 3.3.179]

Wildland. Land in an uncultivated, more or less natural state and covered by timber, woodland, brush, and/or grass. [NFPA 1141 – 3.3.36]

Wildland Fire. An unplanned and uncontrolled fire spreading through vegetative fuels, including any structures or other improvements thereon. [NFPA 1141 – 3.3.37]

Author's Terms

In order to assist the reader better understand this report, the author will use the following specific terms:

Fireworks vs. Pyrotechnics (a/k/a Articles pyrotechnic). Fireworks are typically considered to be those used in traditional fireworks displays under NFPA 1123 and usually classified for transportation purposes as FIREWORKS UN0336 1.4G, UN0335 1.3G or UN0333 1.1.G. Pyrotechnics are typically considered to be those used in proximate pyrotechnic performances under NFPA 1126 and usually classified for transportation purposes as ARTICLES PYROTECHNIC (for technical purposes) UN0341 1.4G or UN0432 1.4S.

Note: Articles pyrotechnic generally produce significantly less smoke and debris than fireworks, even if the same size and effect.

Ground level fireworks (ground level). Illuminations (Strobes, flares, Bengal fires, etc.) Niagara Falls, line rockets, lance setpieces, etc.

Low level aerial fireworks (a/k/a aerial fireworks 2" or less). Aerial fireworks or articles pyrotechnic shells, comets and mines as well as gerbs and fountains that are 2" (50mm) or less

Medium level aerial fireworks (a/k/a aerial fireworks 2.5" to 6"). Aerial shells, comets and mines and Roman candles that are larger than 2" (50mm) and up to 6" (155 mm).

High level aerial fireworks (a/k/a aerial fireworks 8" or larger). Aerial shells 8" (180 mm) and larger.

Blind stars/effects. Any stars or other effects (Ex: small shells, whistles, hummers, serpents, tourbillions, etc.) inside an aerial shell that fail to ignite when the shell bursts in the sky. Blind stars and effects always fall back to the ground and will generally be located near the discharge site. Blind stars and effects remain "live" and may ignite from a glowing ember or some other source of heat or flame. Blind stars and

effects can remain "live" until recovered or until the weather eventually breaks down any paper casing and dissolves the "live" fireworks compositions and blackpowder.[105]

Catastrophic aerial shell malfunction in a mortar (a/k/a blowout): An aerial shell that functions prematurely inside a mortar, but the mortar fails to maintain its integrity and the burst charge blast and burning stars are ejected, along with pieces of the failed mortar all around the discharge site.[106] (Contrast with Misfire a/k/a Flowerpot)

Coldfire. A fireworks device with an electric match attached that was initiated by the shooter or computer program via the firing panel, but the electric match fails to ignite, and no fire is transferred to the fireworks device.[107]

Dud. An aerial fireworks shell or other aerial device that upon ignition, fires out of the mortar, but the shell or device fails to burst/ignite. Duds always fall back to the ground and will generally be located near the discharge site. Duds remain "live" and may ignite from a glowing ember or some other source of heat or flame. Duds also remain

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[105] Blind stars and effects can remain "live" for weeks, months or even years. Blind stars tend to break down quickly because they are not inside a casing. Effects tend to take much longer to break down depending on whether it has a plastic or paper casing, the thickness of the paper casing, and the exposure to ultraviolet light and moisture

[106] A catastrophic aerial shell malfunction in a mortar will almost always heavily damage or destroy a mortar made of lightweight materials (cardboard, fiberglass or HDPE). The exploding shell, especially larger diameter aerial shells, salutes or aerial shells or mines with magnesium compositions or reports, can damage, destroy or realign any adjacent mortars, whether buried in the ground, troughs or drums, or mounted in above ground mortar racks. Above ground wood frame mortar racks are particularly susceptible to being damaged, destroyed or realigned in such an event, especially for larger or more powerful aerial shells, such as salutes or aerial shells with reports. Fire may also transfer via the fireball of the burst charge and burning stars from the catastrophic aerial shell malfunction to other aerial fireworks in the vicinity, causing them to function either in the mortar or shoot the aerial devices at whatever angle the mortar happens to be in at that moment in time, resulting in aerial shells being fired at significant distances down range.

[107] See 1123 8.2.10.1.2

"live" until recovered or until the weather eventually breaks down any paper casing and dissolves the "live" fireworks compositions and blackpowder.[108]

Hangfire. A fireworks device that receives ignition, but fails to function, usually because of some damage or defect in the ignition fuse, or in an aerial device the lift charge. It remains "live" and may ignite from a glowing ember or some other source of heat or flame.[109]

Misfire (a/k/a Flowerpot). An aerial shell that functions prematurely inside the mortar, but the mortar maintains its integrity and the burst charge blast and burning stars are ejected from the mortar into the sky similar to a mine (hence the term "flowerpot"). (Contrast with Catastrophic aerial shell malfunction in a mortar)

Low break. An aerial shell that functions anywhere other than near the normal zenith of its trajectory, either as it fires up into the sky or as it comes back to the ground. Typically, a low break is not a hazardous condition unless it occurs at an altitude where the burning stars or other effects come back down to the ground and there is combustible fuel on the ground or spectators.

Ground break. A low break on the ground.

Muzzle break. An aerial shell that functions at the muzzle of the mortar.

Errant firework. An aerial shell or device that does not follow the expected trajectory for that type of shell or device from a mortar or tube at a particular angle. Errant fireworks can be due to a mortar, tube, mortar rack or holder that was not properly

[108] Dud shells and other devices can remain "live" for weeks, months or even years depending on whether it has a plastic casing or a paper casing, the thickness of the paper casing, and the exposure to ultraviolet light and moisture.

[109] See 1123 8.2.10.1.1

braced or secured, a mortar, tube, mortar rack or holder mortar that failed, a blowout of a mortar or tube in a multiple tube device (cake) or a catastrophic aerial shell malfunction in a mortar rack and realigning adjacent and nearby tubes or mortars, a multiple tube device (cake) or mortar rack bouncing and/or tipping over, damaged tubes or mortars, and other causes.

Normal debris. The expected debris from aerial fireworks that falls or helicopters down to the ground and poses little to no risk to life and/or property. Every inert component of an aerial fireworks device that is not consumed when the device functions in the sky will come back down to the ground. Depending on the type and style of the aerial fireworks it could be almost nothing to approximately 3-5% of the gross weight of the device (Aerial shells with inserts have more paper, cardboard, glue and string than single break color shells). Aerial mines, comets and articles pyrotechnic usually has <1% of the gross weight of the device., which also tend to weigh less than typical aerial shells.

Hazardous debris.[110] Debris from aerial fireworks that falls or helicopters down to the ground and poses a risk to life and/or property. (What constitutes "hazardous" is dependent on the type, size, volume and frequency of the debris, where it is landing and what is nearby, and the current weather conditions. A dud landing in the discharge site or some small bits of paper that may helicopter outside of the display site may not be considered "hazardous". Burning stars consistently landing in areas with dense, combustible vegetation or large pieces of carboard with firebrand landing near or in the spectator viewing area should be considered "hazardous"[111]).

[110] 1123 8.1.4.3.1 Spotters primary duty is to detect and report any unsafe condition, such as hazardous debris falling into the audience.

[111] The Operator and the AHJs will need to establish what will be considered "hazardous" debris at MORU based in part on the conditions at the time. The debris an experienced pyrotechnist would

Inserts. Plastic, paper or cardboard tubes with loose or pressed pyrotechnic compositions and a clay plug(s) inside aerial shells. After the aerial shell bursts in the sky, the inserts create moving effects in the sky as the tubes fly or spin. Some hum or whistle as they move. Some end with small reports. The spent tubes or blind effects fall back down to the ground.

House left/center/right. The point of view of the audience (house) facing the stage.

Stage left/center/right. The point of view of a performer facing the audience (house).

Show. A fireworks display and/or proximate performance utilizing either or both fireworks and articles pyrotechnic according to both NFPA 1123 and/or NFPA 1126 and best practices.

Author's Note: Aerial shells, mines and comets as well as single shots and Roman candles are measured by the inside diameter (ID) of the mortar or tube use to fire the device, not the circumference of the device, which is less than the ID of the mortar or tube [1123 – 4.1.1].

Gerbs and fountains are measured either by the duration and height of the device (i.e. a 20 x 20 gerb has a duration of 20 seconds and a performance height of 20 feet a 1 x 65 gerb has a duration of 1 second and a performance height of 65 feet), or the ID of the tube (3/8", 1/2", 5/8", 3/4", 1", etc.).

Aerial shells, mines and comets as well as gerbs, fountains, strobes, flares, etc. can be either fireworks or articles pyrotechnics depending on the construction, composition, intended use and classification for transportation purposes.

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consider "normal" might be considered "hazardous" by someone with less experience. Likewise, the debris an experienced pyrotechnist would consider "normal" might be considered "hazardous" at MORU because of the potential for wildland fire.

Photo 56 A rare sight at a 21st Century Independence Day fireworks displays. An entire 4" mortar rack with American manufactured canister (cylindrical) aerial shells. Note how this rack is staked individually to the ground for support and the aerial shells are chain fused.

Appendix B – Wildland Fire Conditions

The U. S. Forest Service uses the following basic system to determine Wildland Fire Conditions.

Fire Danger Rating and Color Code	Description
Low (L) (Dark Green)	Fuels do not ignite readily from small firebrands although a more intense heat source, such as lightning, may start fires in duff or punky wood. Fires in open cured grasslands may bum freely a few hours after rain, but woods fires spread slowly by creeping or smoldering, and burn in irregular fingers. There is little danger of spotting.
Moderate (M) (Light Green or Blue)	Fires can start from most accidental causes, but with the exception of lightning fires in some areas, the number of starts is generally low. Fires in open cured grasslands will burn briskly and spread rapidly on windy days. Timber fires spread slowly to moderately fast. The average fire is of moderate intensity, although heavy concentrations of fuel, especially draped fuel, may burn hot. Short-distance spotting may occur, but is not persistent. Fires are not likely to become serious and control is relatively easy.
High (H) (Yellow)	All fine dead fuels ignite readily and fires start easily from most causes. Unattended brush and campfires are likely to escape. Fires spread rapidly and short-distance spotting is common. High-intensity burning may develop on slopes or in concentrations of fine fuels. Fires may become serious and their control difficult unless they are attacked successfully while small.
Very High (VH) (Orange)	Fires start easily from all causes and, immediately after ignition, spread rapidly and increase quickly in intensity. Spot fires are a constant danger. Fires burning in light fuels may quickly develop high intensity characteristics such as long-distance spotting and fire whirlwinds when they burn into heavier fuels.
Extreme (E) (Red)	Fires start quickly, spread furiously, and burn intensely. All fires are potentially serious. Development into high intensity burning will usually be faster and occur from smaller fires than in the very high fire danger class. Direct attack is rarely possible and may be dangerous except immediately after ignition. Fires that develop headway in heavy slash or in conifer stands may be unmanageable while the extreme burning condition lasts. Under these conditions the only effective and safe control action is on the flanks until the weather changes or the fuel supply lessens.

Photo 57 A time lapse photo of the Skyrockers annual New Year's Eve fireworks show from atop 600-foot Grandad's Bluff at the eastern edge of La Crosse, WI. This display has been a tradition since 1929 and is visible to about 100,000 people in three states along the Mississippi River.

Note: These are a 3" flash salute (left) fired at a steep angle out from the north point (red fusee is visible) and the 4", 5", and 6" color shells fired from the top, center. The rising tails show how the color shells trail off at slightly different angles even though the mortars are at or near vertical.

For reference, the flagpole is 70 feet AGL on the top of the Bluff. There are 3" to 6" mortars within 25 feet of the flagpole and flag but angled slightly away. [Photo credit: Wisconsin Trails Magazine]

Appendix C - Author's Biography

The Author, Charles P Weeth, has 35 years of experience planning, designing, operating and assisting with fireworks displays and pyrotechnics performances, including testing and planned malfunctions of fireworks and pyrotechnics and equipment, and manufacturing and assembly.

He has been involved in displays and pyromusicals from California to New York, Hawaii to Florida, and Mississippi to Minnesota, and many places in between. Beaches to baseball fields, bridges to barges, racetracks to riverbanks, fields to bluffs, parks to parking lots, stages to stadium rafters, and almost everything else imaginable – including his 1953 Ford F600 fire truck and a bicycle and trailer – have been the sites of fireworks displays or proximate pyrotechnic performances he has designed, operated or assisted at over the last three plus decades.

Photo 58 The Author with his 1953 Ford F600 fire truck. He uses it in parades and other events with proximate pyrotechnics and propane flame effects. [Photo credit: Bob Good]

He has also participated with fireworks displays and pyrotechnics performances of varying types and sizes in Canada, Spain, Italy, Colombia, Hong Kong, China and Japan.

The Author has been the manufacturer's representative for a Wisconsin company that makes high density polyethylene (HDPE) mortars for the fireworks trade since 1990. The company has supplied many fireworks display companies and theme parks around the world.

He has served on the National Fire Protection Association (NFPA) Technical Committee on Pyrotechnics since 1988 and the Technical Committee on Special Effects since 2003. These committees develop NFPA 1123 and 1124, and NFPA 1126 and 160 respectively, as well as the fire codes for model and sport rocketry.

The Author is a Certified Fireworks Display and Pyrotechnic Operator in Minnesota and was previously certified in Hawaii as well. He is an ATF Responsible Person for a number of ATF licensees/permittees. He held a Commercial Driver's License (CDL) with a hazardous materials and TSA endorsements until he retired from driving trucks with regulated explosive materials in 2018.

Mr. Weeth is a Certified Operator by the PGI and is also certified to conduct the PGI Display Operator Course. He assisted with the major revision to the PGI *Study Guide for Display Operator Training Program.*

Photo 59 The Author with his German shepherd dog Miss Dodger geared up and ready to shoot another show. His many German shepherd dogs have accompanied him to fireworks show over the last 35 years.

The Author is the Special Correspondent for American Fireworks News (AFN) and Fireworks Business, the monthly fireworks trade newsletters.

He has authored numerous papers and presentations, including his investigations of the SE Fireworks facility in Enschede, The Netherlands that resulted in 22 fatalities, almost 1,000 seriously injured and over 400 homes and businesses destroyed, as well as the alleged fireworks explosions aboard the 930 foot container vessel M/V Hanjin Pennsylvania that killed two sailors and resulted in a $235 million loss.

Mr. Weeth is frequently consulted in administrative, civil and criminal proceedings involving fireworks and pyrotechnics, He has been recognized as an expert witness in Federal and state courts.

Appendix E – Photo Credits

All photos credited to the Author unless otherwise noted. All photos used with permission or in the public domain.

Cover photo credit: Janet Williams (www.sharetheexperience.org).

Photo 60 A 3" blowmolded HDPE mortar with the shattered remnant of a 1" x 4" sideboard from an above ground wood frame mortar rack. This large splinter is piercing the bottom of the HDPE mortar, which gives an indication of the power of 3" salutes when there is a catastrophic aerial salute malfunction in a mortar.

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