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About the Cover

The cover depicts an important episode in aerosol history—the Pasadena experiment and ACHEX. It includes a photograph of three of the key organizers and an illustration of a major concept of atmospheric aerosol particle size distribution. The photograph is from Chapter 8, Figure 1. The front row shows Kenneth Whitby, George Hidy, Sheldon Friedlander, and Peter Mueller; the back row shows Dale Lundgren and Josef Pich. The background figure is from Chapter 9, Figure 13, illustrating the trimodal atmospheric aerosol volume size distribution. This concept has been the basis of atmospheric aerosol research and regulation since the late 1970s.

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CHAPTER 14

From China's Great Wall to Hollywood's Great Spy

The Story of Military Smokes and Obscurants

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Introduction

Military smokes, also known as obscurants, have been exploited in battlefield environments for several millennia for the purposes of communicating remotely, screening from enemies, and marking intended targets. Historic records of obscurants date back to approximately 1500 BC and were first employed for military functions in the Middle East. One early application of obscurants used as smoke signals was to communicate enemy threats along the Great Wall of China. Obscurants were used, or at least described, by many of the most well-known military leaders in history, including Moses, Sun Tzu, Hannibal, and Julius Caesar. Today, obscurants are no longer used exclusively by military forces but have expanded in scope to uses as varied as recreation, engineering, religion, and even entertainment, as typified by the smoke screen deployed by James Bond's highly accessorized spy car.

Obscurants in Context

In the earliest days of obscurant use, smoke was created by the most practical and simplest means known, through the burning of wood, twigs, vegetation, animal dung, oil, pitch, or naphtha. Smoke from such fires could produce a plume of smoke that was used to signal friendly forces by sending coded messages or, on dispersing the fuel, could be used to create a smoke screen through which the enemy could not see. As an alternative to smoke—airborne particulate matter derived from incomplete combustion—fine soil and dust also were used as obscurants to create visual screens (Echols, 1952). In military applications, obscuring smokes overlap two distinct disciplines: chemical warfare and communications.

Technically, obscurants are a specific class of chemical weapons (i.e., chemical substances that are used for offensive or defensive military functions), which can be divided into the following broad categories (Mayor, 2003; Smart, 1997):

- poisons that have a specific toxic effect on cells or organs,
- caustics that chemically burn or corrode cells or tissues,
- incendiaries that create or intensify fire,
- explosives that can be used for weapons or pyrotechnics, and
- obscurants that communicate or screen.

Military application of all categories of chemical weapons goes back over a thousand years—often, several thousands of years (Bodeau, 1993; Smart, 1997)—and, in many cases, extends into the realms of myth and folklore (Mayor, 2003). In contrast to all other chemical weapons, obscurants are not intended to cause physical damage to the environment, structures, or people. In fact, modern studies have been performed to evaluate possible health effects on combat soldiers and on the environment to minimize their deleterious influences (US National Research Council, 1997).

Because of their role in signaling, obscuring smokes also have been strongly tied to remote and secret communication from their earliest inception (Chakravarthi, 1992; Leighton, 1969; Southern, 1990). In frontier and embattled regions, beacon towers were often collocated with troop fortifications to transmit military intelligence to a nearby troop outpost for supplies or reinforcements. Beacon towers commonly used fire signals for night communications and smoke signals for daylight communications. Such beacon towers may have been stand-alone structures but more likely were part of a communication chain that might have included tens to hundreds of similar towers for transmitting military intelligence rapidly over distances of tens to hundreds of kilometers.

Both historic and modern documentation of obscurants are associated mainly with military applications and maneuvers, but records of such are found in obscure sources ranging from religious texts to oral traditions to artwork. And, though smoke signals and screens have played critical roles in military battles—at times being the difference between victory and defeat—historic records tend to report their use as an afterthought, sometimes with only a brief phrase or even a single word. The purpose of this chapter is to

provide historical highlights of the use of military smokes that, as with world history and culture, first arose in the Levant before drifting to the Far East and westward around the Mediterranean.

Obscurants in History

Israel

Likely the earliest dateable written records of both the smoke signal and smoke screen are found in the Bible associated with the Israelite exodus from Egypt (ca. 1500 BC) (Gum & Weeks, 1996). According to the biblical account, immediately following the escape of the Israelites, Egypt's Pharaoh regretted releasing the Israelites from servitude and sent his army to retrieve them (Orr, 1915). As the Egyptian army approached, the fleeing Israelites found themselves trapped between their enemy and the western banks of the Red Sea. As the pursuers gained ground, a miraculous cloud—essentially, the first smoke screen—settled between the two encampments, confounding the Egyptians and preventing them from locating their prey (Canney, 1921; Gabriel, 2003). This obscuring cloud protected Israel throughout the night and into the next day, when the Israelites escaped through the Sea. Following this victory, the Israelites wandered in the deserts of the Arabian Peninsula for 40 years, living seminomadic lives. During this time, social and religious life was centered, literally, on the Levitical tabernacle that was physically located at the middle of the national camp. Over this centralized place of worship, a signal cloud indicated to the people the national state of preparedness with a simple predefined code. When the cloud remained directly over the tabernacle, the people knew that they were to remain in their current camp location and go about the business of their daily lives. However, by lifting away from the tabernacle, the signal cloud informed the people to disassemble and bundle their tents, pack their belongings, and mobilize for relocation. For a nomadic people with a population of probably several million, this visual signal likely was the most efficient method of internal communication.

China

In his seminal work *The Art of War*, Sun Tzu briefly mentions a wartime scenario that advocates the use of smoke screens by lighting fires upwind of an enemy (ca. 500 BC) (Griffith, 1971). However, we know little more until the earliest days of imperial China (ca. 200 BC) when smoke signals were used as a threat warning system along China's Great Wall (Lovell, 2006; Turnbull,

2007). Beacon towers were situated along the length of the Wall at distances ranging from a few tenths of a kilometer up to several kilometers apart. Watchmen stationed at the beacon towers would collect grass, straw, and wolf dung as fuel for their signal fires to communicate with neighboring beacon towers. During the night, the fire itself would suffice to signal neighboring beacon towers to an imminent threat, and warned watchmen would respond by relaying the message along the signal chain until it reached a garrison that could deploy the needed soldiers. However, during daylight hours the fires often went unnoticed. So simple smoke signals were created based on the number of fires and, therefore, the number of smoke plumes rising from any given beacon tower. Though there is evidence that smoke signals were used early in China's history, the codification of China's smoke signaling system was not formalized until 1468 AD under the rule of the Ming dynasty, which brought the Great Wall to its current state of completion. Under the formalized coding, one smoke column represented up to 100 enemies, two columns indicated 500, and three columns indicated 1,000, based on the best, quick estimate by the watchmen (Guo et al., 2003). At this time, cannon fire was added to the warning routine to provide both visual and audible signaling. Using these remote communication methods, watchmen could send warnings that would travel hundreds of kilometers in a few hours, although the response could still take days to weeks depending on the distance to and the terrain between the nearest adequately equipped outpost.

India

The *Arthashastra*—an Indian political and military treatise written by Kautilya (ca. 300 BC)—provides specific recipes for different types of military smokes, as well as poisons, potions, and tonics (Chaturvedi, 2001; Mayor, 2003). Ingredients for these concoctions are quite exotic, including pigeon dung, elephant urine, peacock tail, frog eyes, insects, and lizards. And the effects of these mixtures were nearly as varied as the ingredients, ranging from insanity to "biting madness" (possibly rabies) to immediate death. The smoke of several of the powders, when burned, was purported to cause blindness. Although the resulting blindness might be the perceived result of some shamanistic curse, it also might be the simple result of an effective obscurant.

Carthage

During his legendary march to Rome in the Second Punic War (ca. 220 BC), Hannibal's army of about 50,000 Carthaginian soldiers—it was originally closer to 100,000 when Hannibal set out from New Carthage, but disease and desertion had led to a reduction in ranks—encountered Gallic resistance encamped along the eastern shore of the Rhone River (Abbott, 1902; Arnold, 1868; Church & Gilman, 1886). Hannibal used the next 3 days to rest his troops, construct boats for crossing the river, and strategize about the crossing. Knowing that his troops would be challenged by archers during the river crossing and that they would face more heated opposition on reaching the Rhone's eastern shore, Hannibal needed a means to distract the Gauls from their river watch. On the third evening at the western shore, Hannibal called Hanno, a trusted officer, to his tent and laid out plans for a secondary force to secretly cross the Rhone and circle behind the Gauls for a stealthy attack. That very night, Hanno set out with about 10,000 soldiers who traveled upriver about 30 kilometers before crossing the river and turning back to encircle the Gauls for an ambush. Two days later, when Hannibal saw Hanno's smoke signal—a predetermined indicator that Hanno's troops were in place—Hannibal led his men across the Rhone and engaged the Gauls in battle. At the same time, Hanno's force attacked the Gauls from the rear, sending the Gauls into great confusion and ending with a conclusive victory for Hannibal. Following the rout of the Gauls, Hannibal proceeded to bring his war elephants across the Rhone by raft. Several of them panicked during the crossing and fell into the river. Although all 37 elephants eventually made it across, several mahouts—elephant drivers—died during the crossing.

Greece

In the declining days of Hellenistic Greece, the Greek states sought external aid from the Seleucid Empire in removing Roman influence from the Greek mainland (ca. 190 BC). In one extended battle, Roman troops had surrounded the walled city of Ambracia and laid siege to it. Because efforts to break through the walls were continually thwarted by the besieged Greeks, the Romans changed tactics and attempted to tunnel underneath the city wall (Campbell, 2005; Gillies, 1820; Ihne, 1877). Alarmed by the growing mounds of soil outside their walls, the Greeks realized what the Romans were attempting and counter-tunneled to meet the invaders. Initially the Greeks tried to repel the Romans with standard weapons but quickly realized that

this was a frustratingly slow means of rebuffing the attack. Instead, the Greeks devised a smoke machine—a large jar filled with burning feathers and fueled with oxygen by pumping blacksmith bellows—and forced smoke into the tunnel. Whether due to the pungent odor of burning feathers or the inability to advance down the tunnel unaware of where traps or enemies might be, the Roman soldiers withdrew from the tunnel, and the undermining effort was ceased. Despite the lack of Roman progress at this front of the war, Roman troops elsewhere were defeating the Greek's Seleucid allies in several decisive battles. In hearing of the final defeat of the Seleucids, Ambracia surrendered to the Romans.

Rome

During the waning days of the Roman Republic and the corresponding waxing of the Roman Empire, Gaius Julius Caesar found himself at odds with the Roman Senate (ca. 50 BC) (Roberts, 2006). By this time in his career, Caesar had demonstrated himself to be an accomplished politician as well as an adept military general. Fearing Caesar's aspirations as much as his army, the Senate ordered Caesar to disband his army and return to Rome. Caesar was selective in complying with the Senate and, though he did return to Rome, he brought one legion of his army with him across the Rubicon River, thus igniting the Roman Civil War (Cawthorne, 2005a). During the intervening months, Caesar engaged in several battles with the Senate's primary defender, General Gnaeus Pompey, a former friend and political ally. In one campaign, Caesar laid siege to Pompey at Dyrrhachium, one of Pompey's vital military depots (Cawthorne, 2005b; Sheppard & Hook, 2006). After several unsuccessful attempts by Pompey to break the siege, the course of the engagement was decisively altered by defectors from Caesar's army. Two cavalry commanders betrayed Caesar's army and crossed over to the besieged Pompey, bringing news of weaknesses in Caesar's lines—a small portion that had not yet completed its fortifications—of which Pompey took immediate advantage. In the subsequent battle, Caesar's lines broke and his troops were routed. Only one thing prevented the siege from turning completely to Pompey's advantage, namely reinforcements from Mark Antony and, later, Caesar himself who were summoned to the melee by a prearranged smoke signal that had been prepared for just such a contingency (Sheppard & Hook, 2006). This loss by Caesar represented one of only a few rare military defeats in Caesar's career, but it could have been much worse. Caesar himself

observed, "Today my enemies would have finished the war if they had a commander who knew how to win a victory."

Americas

Because of a lack of written records, setting specific dates when Native Americans began using the smoke signal is difficult, but it is clear that this form of communication already was well established among many tribes when explorers from the Old World made their way to the New World (Woods & Woods, 2000). Smoke signaling may well have been used as early as 500 or 600 AD in the Americas. In general, the smoke signal is thought to have been used more broadly among plains and southwestern Indians than among woodland tribes, because highly forested areas would tend to make viewing of such signals difficult. Because one of the primary uses of the smoke signal was during wartime, smoke signal coding tended to be specific to each tribe so that enemies in the area would not be able to decipher the encoded message (Eastman, 1974; Tomkins, 1969). Thus, there was no standard signal code. Messages that were commonly sent via smoke signals might communicate the number of horses retrieved from a successful raiding party, the number of enemy scalps won in battle, the success or failure of a game hunt, or a call for help. One of the earliest dated uses of the Indian smoke signal was in 1542 AD (Debo, 1970). Francisco Vásquez de Coronado, the Spanish conquistador, had been living as the governor in Mexico where he heard from explorers of a wealthy "city of gold" in the north called Cíbola. Mounting an expedition, he led a group of approximately 1,500 people to capture the riches of the north. His journey led him through modern day Arizona and New Mexico, until he met the native Zunis of the pueblo Cíbola. As the Cíbolan warriors retreated before Coronado in battle, they used simple smoke signals to communicate the progress of the retreat back to their tribe. Eventually, Coronado captured Cíbola but was deeply disappointed by the lack of gold.

Obscurants in Modernity

Highlights

World War I (WWI) signified the dawn of the modern age of military smokes. Although obscurants were used only sparingly during WWI, their success during key naval engagements—when smoke screens were generated by changing the fuel-to-air ratio for the ship's engines—garnered the attention

of military commanders, ultimately leading to the advent of state-funded research and development (Brodie & Brodie, 1973). One of the early successful deployments of obscurants was in the Battle of Jutland, fought between Great Britain and Germany in 1918 in the waters of the North Sea just off the coast of Denmark (Allen, 1919; Griffiths, 2003). At a turning point in the battle, it appeared as though Germany had fallen into a trap from which they could not escape. However, the German fleet was able to escape and cover their retreat with a highly effective smoke screen, which prevented the British fleet from engagement and discouraged pursuit. Both Germany and Great Britain experienced significant losses during the battle, but there was no conclusive victory by either country.

Toward the end of WWI, the US Army established their Chemical Warfare Service (CWS) in response to the chemical gas weapons employed by Germany during the War. Among the tasks assigned to the CWS were the investigation, research, and development of military applications of smoke (Smart, 1997). One such study sought to determine the effectiveness of rifle fire during three potential battlefield scenarios (Butler, 1998). The first scenario was under a clear field of view to the target (i.e., no smoke), which resulted in a typical efficiency of 58% shot-fired to target-hit ratio. With smoke on the target, this ratio substantially dropped to only 11%. And with smoke on the firing line, the ratio again dropped to only 3%. Although a relatively simple experiment, this indicated the potential usefulness of smokes to prevent visual target acquisition in a wartime situation.

Doctrine

From a technical perspective, obscurants are chemical weapons and are even referred to as chemical smokes in obscurant literature. However, from a psychological perspective, obscurants are in a weapons class by themselves, playing a unique role in visual and electronic countermeasures (Smart, 1997). Therefore, obscurants have not been included in any international treaties banning chemical weapons; as a result, obscurants have been employed in virtually every major international conflict that has occurred since WWI, including World War II and the Korean, Vietnam, and Persian Gulf wars (Butler, 1998; Smart, 1997).

In the modern military, obscurants are referred to as a "force multiplier," meaning that using obscurants enhances or multiplies the combat effectiveness of soldiers, both individually and collectively. Essentially, force

multipliers allow two or three soldiers of today to perform the work of 20 to 30 soldiers of yesterday and, usually, to perform more safely and efficiently.

Obscurants may effectively increase the combat ability of troops in specific battlefield scenarios through any of five different generalized applications: obscuring smoke, screening smoke, protecting smoke, marking smoke, and deceptive smoke (US Army, 1986, 1990). Specific battlefield scenarios and tactics are laid out regarding wartime conditions under which different obscurants can be employed. Obscuring smoke is delivered among or directly in front of enemy forces and is intended to disorient enemy soldiers and confuse normal troop operations. Screening smoke is employed in the space between friendly and enemy forces and is meant to discourage combat fire—for example, gun, mortar, artillery, tank, aircraft, naval—by hindering target acquisition between the forces. Protecting smoke also is deployed in the area between friendly and enemy lines—typically close to friendly forces, depending on meteorological conditions—and is used to attenuate directed electromagnetic energy in the microwave and infrared regions, which defeats targeting and guidance systems. Marking smoke is delivered directly on top of or immediately adjacent to a site of interest and serves to visually highlight a friendly position, assembly point, or an enemy target in a way that is observable from a remote distance or from the air. Finally, deceptive smoke is used in an area removed from friendly forces but still within the greater battlespace arena and is intended to obfuscate enemy command and control by raising questions of friendly force strength, position, and action.

Obscurants in Postmodernity

In the postmodern world, obscurants that were originally developed for military functions have developed a much more diverse market in the entertainment, recreational, engineering, and even religious communities. In entertainment, obscurants have been used in varied formats ranging from colored smokes in pyrotechnic displays, to fogs in light shows and at haunted houses, and to special effects in movies and television shows. And, just as Hollywood stylized the smoke signal in western-themed productions, they also glorified the smoke screen in their adventure thrillers, particularly the spy genre. Anyone who is a fan of the James Bond franchise is familiar with the ultimate spy vehicle, 007's candy-apple red Aston Martin DB5, which allowed him to lose any tail through the smoke screen initiated with the touch of a button. In recreation, colored smokes are used in acrobatic flying and skydiving, and also as distress markers for boating and extreme hiking. In

industry, obscurants are used in wind tunnels to evaluate aerodynamic flow around model cars and airplanes. And, finally, in religion, smoke signals are used to indicate the results of papal elections—black smoke (*fumata nera*) indicating that a vote has not been decisive and white smoke (*fumata bianca*) indicating that a new pope has been selected.

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