# *APPENDIX C*
# *CHARACTERISTICS OF CHAFF*

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# APPENDIX C CHARACTERISTICS OF CHAFF

Defensive countermeasures are used by military aircraft during training in response to simulated threats. Chaff is a self-protection device that permits an aircraft threatened by enemy radar-directed munitions to distract and/or avoid the threat.

Chaff consists of extremely small strands (or dipoles) of an aluminum-coated crystalline silica core. When released from an aircraft, chaff initially forms a sphere, then disperses in the air and eventually drifts to the ground. The chaff effectively reflects radar signals in various bands (depending on the length of the chaff fibers) and forms a very large image or electronic “cloud” of reflected signals on a radar screen. When the aircraft is obscured from radar detection by the cloud, the aircraft can safely maneuver or leave an area.

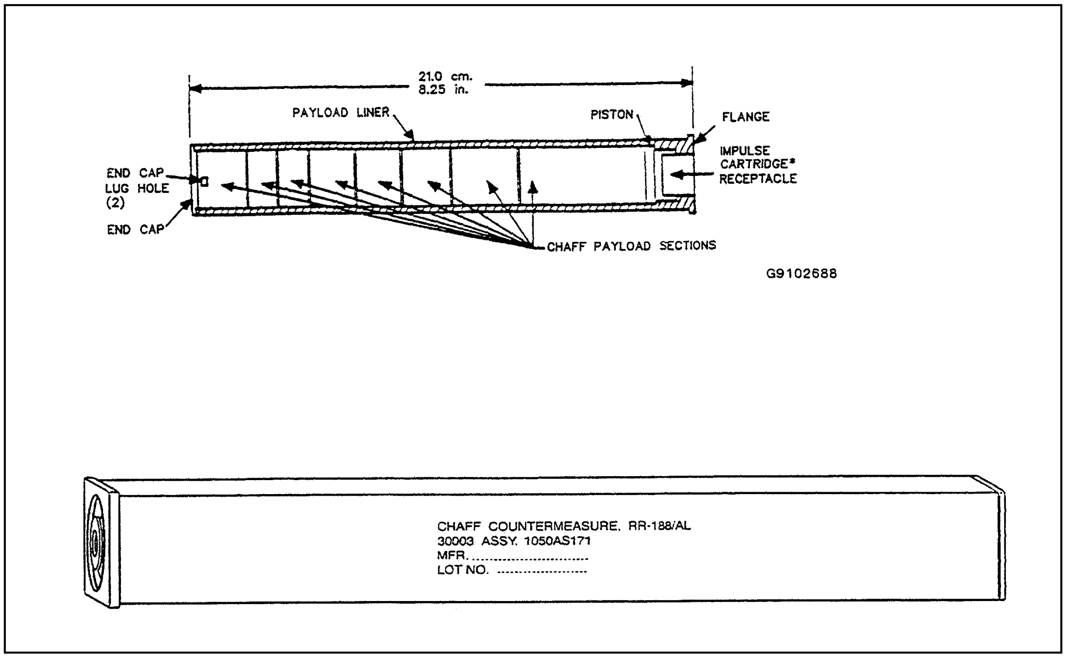
Chaff is made as small and light as possible so that it will remain in the air long enough to confuse enemy radar. The chaff fibers are thinner than a human hair (i.e., generally 25.4 microns in diameter), and range in length from 0.3 to over 1 inch. The weight of chaff material in the RR-170 or RR-188 cartridge is approximately 95 grams or 3.35 ounces (United States Air Force [Air Force] 1997). Since chaff can obstruct radar, its use is coordinated with the Federal Aviation Administration (FAA). RR-170 and RR-188 chaff are the same size. RR-188 chaff has D and E band dipoles removed to avoid interference with FAA radar. RR-170 chaff dipoles are cut to disguise the aircraft and produce a more realistic training experience in threat avoidance.

## 1.0 CHAFF CHARACTERISTICS

Chaff is comprised of silica, aluminum, and stearic acid, which are generally prevalent in the environment. Silica (silicon dioxide) belongs to the most common mineral group, silicate minerals. Silica is inert in the environment and does not present an environmental concern with respect to soil chemistry. Aluminum is the third most abundant element in the earth’s crust, forming some of the most common minerals, such as feldspars, micas, and clays. Natural soil concentrations of aluminum ranging from 10,000 to 300,000 parts per million have been documented (Lindsay 1979). These levels vary depending on numerous environmental factors, including climate, parent rock materials from which the soils were formed, vegetation, and soil moisture alkalinity/acidity. The solubility of aluminum is greater in acidic and highly alkaline soils than in neutral pH conditions. Aluminum eventually oxidizes to $Al_2O_3$ (aluminum oxide) over time, depending on its size and form and the environmental conditions.

The chaff fibers have an anti-clumping agent (Neofat – 90 percent stearic acid and 10 percent palmitic acid) to assist with rapid dispersal of the fibers during deployment (Air Force 1997). Stearic acid is an animal fat that degrades when exposed to light and air.

A single bundle of chaff consists of the chaff fibers in an 8-inch long rectangular tube or cartridge, a plastic piston, a cushioned spacer, and two plastic end caps (1/8-inch thick, 1-inch x 1-inch or 1-inch x 2-inch). The chaff dispenser remains in the aircraft. The plastic end caps and spacer fall to the ground when chaff is dispensed. The spacer is a spongy material (felt) designed to absorb the force of release. Figure 1 illustrates the components of a chaff cartridge. Table 1 lists the components of the silica core and the aluminum coating. Table 2 presents the characteristics of RR-188 or RR-170 chaff.




## Figure 1. RR-188 or RR-170 Chaff Cartridge

## Table 1. Components of RR-188 or RR-170 Chaff

| *Element* | *Chemical Symbol* | *Percent (by weight)* |
|---|---|---|
| **Silica Core** | | |
| Silicon dioxide | $SiO_2$ | 52-56 |
| Alumina | $Al_2O_3$ | 12-16 |
| Calcium Oxide and Magnesium Oxide | CaO and MgO | 16-25 |
| Boron Oxide | $B_2O_3$ | 8-13 |
| Sodium Oxide and Potassium Oxide | $Na_2O$ and $K_2O$ | 1-4 |
| Iron Oxide | $Fe_2O_3$ | 1 or less |
| **Aluminum Coating** (Typically Alloy 1145) | | |
| Aluminum | Al | 99.45 minimum |
| Silicon and Iron | Si and Fe | 0.55 maximum |
| Copper | Cu | 0.05 maximum |
| Manganese | Mn | 0.05 maximum |
| Magnesium | Mg | 0.05 maximum |
| Zinc | Zn | 0.05 maximum |
| Vanadium | V | 0.05 maximum |
| Titanium | Ti | 0.03 maximum |
| Others | | 0.03 maximum |

Source: Air Force 1997

## Table 2. Characteristics of RR-188 or RR-170 Chaff

| ***Attribute*** | ***RR-188 or RR-170*** |
|---|---|
| Composition | Aluminum coated silica |
| Ejection Mode | Pyrotechnic |
| Configuration | Rectangular tube cartridge |
| Size | 8 x 1 x 1 inches (8 cubic inches) |
| Number of Dipoles | 5.46 million |
| Dipole Size (cross-section) | 1 mil (diameter) |
| Impulse Cartridge | BBU-35/B |
| Other Comments | Cartridge stays in aircraft; less interference with FAA radar (no D and E bands) |

Source: Air Force 1997

The B-1 uses RR-170 A/AL chaff. Figure 2 is a photograph of an open RR-170 chaff cartridge with all the pieces. RR-170 A/AL has the same material as the RR-188 chaff cartridge. The RR-170 A/AL has chaff dipoles cut differently from the RR-188 chaff. RR-188 chaff was originally used for tracking because the dipole did not interfere with FAA radars, but newer radars can now also detect RR-188 chaff.

The B-52 uses RR-112/AC chaff which is not deployed from a cartridge. RR-112/AC chaff comes in rolls which are like the chaff in Figure 2. The rolls are in a box which is installed in the B-52. A mechanical system then measures out the chaff to form a brief electronic cloud to mask the B-52 from radar threats.

The F-22 uses the same chaff material in a slightly different chaff cartridge to expedite clean ejection of the chaff. The chaff cartridge design is less likely to leave debris of any kind in the dispenser bay yet still provides robust chaff dispensing. F-22 delayed-opening chaff is packaged in two sets of soft packs that retain approximately the same number of dipoles per cut as RR-170 chaff. The differences are two end caps and six parchment paper wraps that facilitate deployment. Two end caps, two pistons, six approximately 2-inch by 4-inch paper pieces, and chaff fibers fall to the ground with each chaff cartridge deployed. Other aircraft participating in LFE training discharge comparable chaff fibers and similar residual pieces to those described for RR-170 chaff.

# 2.0 CHAFF EJECTION

Chaff is ejected from aircraft pyrotechnically using a BBU-35/B impulse cartridge. Pyrotechnic ejection uses hot gases generated by an explosive impulse charge. The gases push the small piston down the chaff-filled tube. A small plastic end cap is ejected, followed by the chaff fibers, and, in the case of F-22 chaff, three mylar pieces. The plastic tube remains within the aircraft. Debris from the ejection consists of two small, square pieces of plastic 1/8-inch thick (i.e., the piston and the end cap), three mylar strips, and the felt spacer. Table 3 lists the characteristics of BBU-35/B impulse cartridges used to pyrotechnically eject chaff.

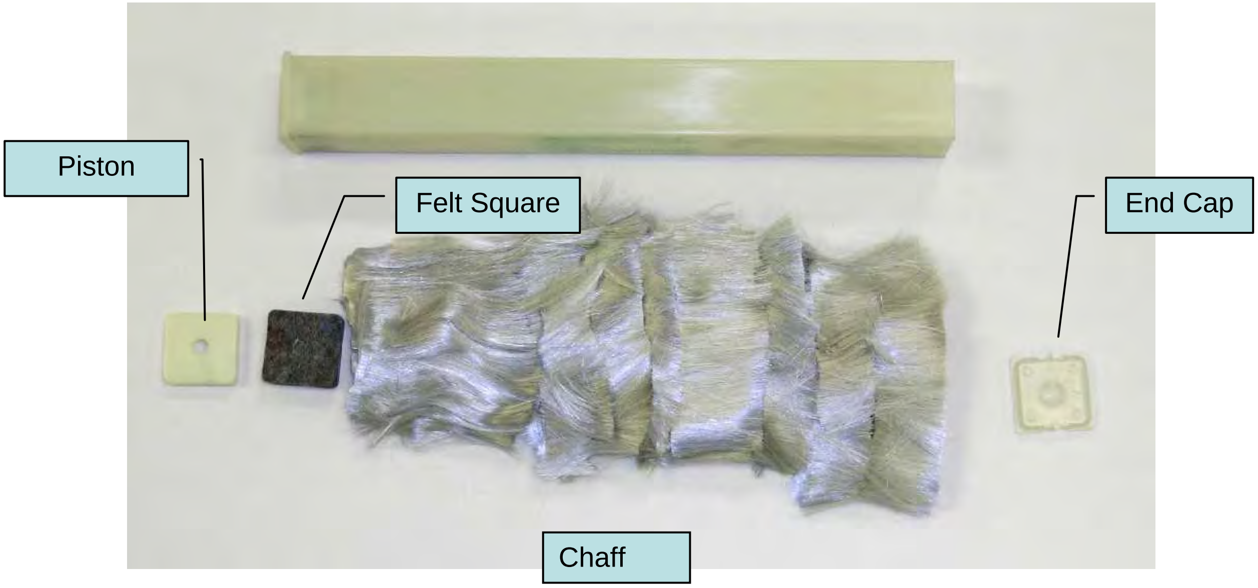



**Figure 2. RR-170 A/AL Chaff**

## Table 3. BBU-35/B Impulse Charges Used to Eject Chaff

| ***Component*** | ***BBU-35/B*** |
|---|---|
| Overall Size<br>Overall Volume<br>Total Explosive Volume | 0.625 inches x 0.530 inches<br>0.163 inches$^3$<br>0.034 inches$^3$ |
| Bridgewire | Trophet A<br>0.0025 inches x 0.15 inches |
| Initiation Charge | 0.008 cubic inches<br>130 mg<br>7,650 psi<br>boron 20%<br>potassium perchlorate 80% * |
| Booster Charge | 0.008 cubic inches<br>105 mg<br>7030 psi<br>boron 18%<br>potassium nitrate 82% |
| Main Charge | 0.017 cubic inches<br>250 mg<br>loose fill<br>RDX ** pellets 38.2%<br>potassium perchlorate 30.5%<br>boron 3.9%<br>potassium nitrate 15.3%<br>super floss 4.6%<br>Viton A 7.6% |

Source: Air Force 1997

Upon release from an aircraft, chaff forms a cloud approximately 30 meters in diameter in less than one second under normal conditions. Quality standards for chaff cartridges require that they demonstrate ejection of 98 percent of the chaff in undamaged condition, with a reliability of 95 percent at a 95 percent confidence level. They must also be able to withstand a variety of environmental conditions that might be encountered during storage, shipment, and operation. The net result is that chaff is normally manufactured to tolerance levels in excess of 99 percent reliability.

Table 4 lists performance requirements for chaff.

**Table 4. Performance Requirements for Chaff**

| ***Condition*** | ***Performance Requirement*** | |
|---|---|---|
| High Temperature | Up to +165 degrees Fahrenheit | |
| Low Temperature | Down to –65 °F | |
| Temperature Shock | Shock from –70 °F to +165 °F | |
| Temperature Altitude | Combined temperature altitude conditions up to 70,000 feet | |
| Humidity | Up to 95 percent relative humidity | |
| Sand and Dust | Sand and dust encountered in desert regions subject to high sand dust conditions and blowing sand and dust particles | |
| Accelerations/Axis | G-Level | Time (minute) |
| Transverse-Left (X) | 9.0 | 1 |
| Transverse-Right (-X) | 3.0 | 1 |
| Transverse (Z) | 4.5 | 1 |
| Transverse (-Z) | 13.5 | 1 |
| Lateral-Aft (-Y) | 6.0 | 1 |
| Lateral-Forward (Y) | 6.0 | 1 |
| Shock (Transmit) | Shock encountered during aircraft flight | |
| Vibration | Vibration encountered during aircraft flight | |
| Free Fall Drop | Shock encountered during unpackaged item drop | |
| Vibration (Repetitive) | Vibration encountered during rough handling of packaged item | |
| Three Foot Drop | Shock encountered during rough handling of packaged item | |

Note: Cartridge must be capable of total ejection of chaff from the cartridge liner under these conditions.
Source: Air Force 1997

# 3.0 POLICIES AND REGULATIONS ON CHAFF USE

Current Air Force policy on use of chaff and flares was established by the Airspace Subgroup of Headquarter Air Force Flight Standards Agency in 1993. It requires units to obtain frequency clearance from the Air Force Frequency Management Center and the FAA prior to using chaff to ensure that training with chaff is conducted on a non-interference basis. This ensures electromagnetic compatibility between the FAA, the Federal Communications Commission, and Department of Defense (DoD) agencies. The Air Force does not place any restrictions on the use of chaff provided those conditions are met (Air Force 1997).

**Air Force Instruction (AFI) 13-201, U.S. Air Force Airspace Management**, September 2001. This guidance establishes practices to decrease disturbance from flight operations that might cause adverse public reaction. It emphasizes the Air Force's responsibility to ensure that the public is protected to the maximum extent practicable from hazards and effects associated with flight operations.

**AFI 11-214 Aircrew and Weapons Director and Terminal Attack Controller Procedures for Air Operations**, July 1994. This instruction delineates procedures for chaff and flare use. It prohibits use unless in an approved area.

# 4.0 ENVIRONMENTAL EFFECTS OF CHAFF

The potential for effects of chaff deposition and fragmentation in the environment has been of interest to agencies and the public. There has also been interest by land management agencies in the military use of chaff. This interest is largely driven by concern that the fragmentation of chaff fibers was not documented. Does chaff begin breaking down almost immediately following ejection? Does it become small enough to be inhaled by man or by wildlife? Conversely, if the chaff does not fragment, could chaff particles be ingested by livestock or wildlife? What would be the environmental effects of chaff particles?

A variety of studies on the effects of chaff have been conducted over the past 40 years for the Army, Navy, Air Force, National Guard Bureau, and Canadian Forces Headquarters (Government Accountability Office [GAO] 1998). The focus of these studies ranged from effects on livestock from ingestion of chaff (Canada Department of Agriculture 1972) to environmental impacts from the deposition of chaff fibers on marine and terrestrial ecosystems (Air Force 1997). In the early 1990s, ACC prepared a study on the known environmental consequences of chaff and other defensive measures (Air Force 1997). None of the studies demonstrated significant environmental effects of chaff.

In response to continuing concern on the part of private citizens with the military's use of chaff, Senator Harry Reid (Nevada) requested that the GAO conduct an independent evaluation of chaff use. The subsequent GAO report (1998) acknowledged that citizens and various public interest groups continued to express concerns of potentially harmful or undesirable effects of chaff on the environment. The report recommended that the Secretaries of the Air Force, Army, and Navy determine the merits of open questions made in previous chaff reports and whether additional actions are needed to address them.

## 4.1 Atmospheric Effects

The DoD engaged a "Select Blue Ribbon Panel" of independent, non-government scientists to 1) review the environmental effects of radio frequency (RF) chaff used by the United States (U.S.) military; and 2) to make recommendations to decrease scientific uncertainty where significant environmental effects of RF chaff are possible. The report of the Blue Ribbon Panel (Spargo 1999) identified a variety of issues of interest, and included specific recommendations for the further evaluation of chaff use.

The fate of chaff fibers after release was of particular interest to the Blue Ribbon Panel. The panel requested additional data on the degree of chaff fragmentation and the potential for re-suspension of chaff or chaff fragments in the natural environment. Two issues related to chaff fragmentation and re-suspension were identified (Spargo 1999).

> **Atmospheric effects:** What fraction of emitted chaff breaks up from mid-air turbulence into respirable particles?
>
> **Ground effects:** What fraction of chaff reaching the ground is subsequently abraded, re-suspended, and reduced to respirable sized particles?

An independent study on chaff fragmentation and re-suspension rates was initiated to evaluate these issues. *The Fate and Distribution of Radio-Frequency Chaff*, Desert Research Institute (DRI) was released on 1 April 2002. A parallel independent study also addressed chaff fragmentation and resuspension (Cook 2002).

Both studies used atmospheric chaff fragmentation tests and a fluidized bed to simulate chaff fragmentation in the atmosphere. The ground chaff fragmentation tests used wind generation in a portable environmental chamber to simulate chaff fragmentation after it falls to the ground.

## 4.2 Mid-Air Turbulence Effects

Chaff in the military training environment released at altitudes below 30,000 feet above ground level (AGL) are typically deposited on the ground within ten hours of formation (DRI 2002). Atmospheric fragmentation, which appears to occur, takes place within the first 2 hours of release, likely immediately after release, when the density of fibers within the cloud is at its greatest. The DRI findings suggest that in the simulated mid-air column, relatively little fragmentation occurs between 2 and 8 hours (DRI 2002).

The experimental data obtained from tests were not sufficiently robust to definitively conclude when most chaff fragmentation occurs. Most fragmentation could occur immediately upon ejection or within the first 2 hours after ejection. While chaff fragmentation in the DRI tests appeared to be minor, some fragmentation did occur, and there was some degree of formation of particles sufficiently small as to be considered respirable. Abrasion tests suggested that on the order of one part mass in $10^7$ may be abraded to particulate matter less than 10 micrograms in diameter ($PM_{10}$) or smaller (DRI 2002). The data sampling and testing did result in a small fraction of chaff being converted to respirable particles. The data suggest that this is not a significant factor in the fate of training chaff in the mid-air column. DRI concluded that virtually none of the airborne chaff was degraded to respirable size particles of $PM_{10}$ or less. Based on these tests, there is little environmental risk from airborne chaff abrading to respirable particles prior to the chaff being deposited on the surface.

## 4.3 Surface Effects and Fragmentation

The 1998 GAO report recommended that the Secretaries of the Air Force, Army, and Navy determine the merits of open questions made in previous chaff reports and whether additional actions were needed to address them. The Select Blue-Ribbon Panel of independent, non-government scientists (Spargo 1999) identified a need for further investigation of the re-suspension of chaff and chaff fragments once deposited on the surface.

### *4.3.1 Ground Surface Effects*

Following deposition on the ground, chaff is subjected to various physical processes that may break the individual fibers into fragments. Processes that may induce fragmentation on the ground include wind-driven re-suspension and deposition, wind-driven interaction with soils, wind-driven interaction with plants, disturbance by animals, and vehicular traffic. Processes that may induce fragmentation on water include wind and wave action. Field studies on ground fragmentation were conducted to gain information on the relative importance of these processes and to address different test approaches to evaluate post-deposition fragmentation (DRI 2002; Cook 2002).

Results of these studies indicate that, once deposited on the ground, chaff undergoes rapid fragmentation. Typically between 5 and 10 percent of the chaff in these tests was reduced to particles less than 10 microns in length over a 2-hour period. In nature, assuming similar wind, soil interaction, and other processes are at work, it seems likely that most chaff would be reduced to fragments less than 10 microns within a matter of days of deposition. Chaff fragmentation on the ground surface is primarily wind driven. Increasing airflow in these studies resulted in increasing fragmentation. This suggests that higher wind levels in the ambient environment would lead to increased fragmentation (DRI 2002).

Baseline sampling results from this study indicated minimal chaff concentrations (1 microgram/square foot) in the soil of an area heavily utilized for military aircraft training using chaff. This may indicate extensive fragmentation and dispersal of chaff used for training purposes on the range. The naturally occurring materials that comprise chaff, wind driven turbulence, fragmentation, and dispersal of $PM_{10}$ size particles provide a sufficient basis to explain this finding. In essence, chaff particles, once on the ground, appear to rapidly degrade and become indiscernible from ambient silica and aluminum soil materials (DRI 2002, Cook 2002).

## *4.3.2 Aquatic Surface and Substrate Effects*

Potential aquatic and marine effects of chaff have been of interest to both the Air Force and the Navy. Aquatic environments are sensitive to any chemicals released from any sources. The questions asked regarding chaff in an aquatic environment deal with the dissolution of the chaff in the water or marine environment, the potential resulting release of chemicals which could be mobile within the aquatic ecosystems, and the potential sensitivity of aquatic organisms to released chemicals (Farrell and Siciliano 2005). Although not specifically tested, chaff fragments in a marine environment would be subject to both wind and wave action. This suggests that chaff fragmentation in an aquatic marine environment would be similar to chaff fragmentation observed in ground fragmentation tests.

Chaff deposition on the water surface would be subject to physical factors and would be expected to become part of the underlying sediment. The Navy sponsored a series of studies to address the potential for chaff materials to concentrate in the sediment. An area in the Chesapeake Bay was identified as a location for Navy-sponsored studies. A series of studies were performed in the Chesapeake Bay to address whether chaff release was contributing to aluminum levels in the Chesapeake Bay (Wilson *et al.* 2001). An estimated 500 tons of chaff had been deposited over the bay during aircraft and Navy maneuvers for both research and training purposes from the mid-1970s to 1995. As part of the Wilson study, a series of sediment sampling locations were tested at various sampling depths to determine whether increased aluminum could be detected. A background sampling location at approximately the same depths was sampled in an area not subject to chaff deposition.

The studies found no significant difference in mean aluminum concentrations between the sediments that were from the control site and those taken from areas of heavy chaff use. The results did demonstrate some variation in the types of aluminum at the test and control locations. Inorganic monometric aluminum concentrations were significantly lower under the chaff use areas than in the background conditions. Mean concentrations of organic monometric aluminum were significantly higher in the sediment under the high chaff use area than in the control area. Exchangeable aluminum ($AL_{EX}$) represents aluminum bound to the soil by an electrostatic charge. $AL_{EX}$ is a good indicator of soil acidity and of the concentration of potential toxic aluminum present. $AL_{EX}$ concentrations under the heavy chaff use area were numerically lower but not significantly different from those of the control area (Wilson *et al.* 2001).

Sediment sampling in the Chesapeake Bay area did not indicate that aluminum concentrations below the flight path were significantly increased as a result of chaff use. Aluminum concentrations in fish, plants, or other biota were not assessed in the sediment survey.

Aluminum is not known to accumulate to any great extent in most invertebrates under non-acid conditions. It is unlikely that much, if any, of the aluminum present as a result of chaff use would be available for uptake by aquatic plants, fish, or other biota. The conclusions reached by Wilson *et al.* suggested that deployment of chaff resulted in minimal but statistically significant increases in nontoxic aluminum in sediment under the flight path. Concentrations of aluminum of toxicological interest were significantly lower under the heavy chaff use area than in background sediment samples (Wilson *et al.* 2001).

Additional studies were conducted to evaluate the potential for chaff concentrations to be harmful to aquatic organisms. A Chesapeake Bay study by Systems Consultants for the U.S. Navy found no evidence that chaff was acutely toxic to six species of aquatic organisms (Arfsten *et al.* 2002). Concentrations of chaff between 10 to 100 times the exposure levels expected to be found in the Chesapeake Bay were placed in tanks containing a variety of aquatic organisms. American oysters, blue mussels, blue crab, and killifish were among the species tested. There was no significance in mortality as a result of exposure to concentrations of chaff of one to two orders of magnitude greater than expected chaff concentrations (Arfsten *et al.* 2002).

Chaff was not found to result in concentrations of aluminum which would produce environmental impacts in the Chesapeake Bay environment. Part of the reason for this may be that chaff is comprised of nearly entirely aluminum and silicate with some trace elements. Aluminum and silicate are the most common minerals in the earth's crust. Ocean waters are in constant exposure to crust materials, and there would be little reason to believe that the addition of small amounts of aluminum and silicate from chaff would have any effect on either the marine environment or sediment.

Before becoming part of the sediment, could chaff particles have environmental consequences? Chaff particles in the aquatic environment are similar to natural particles produced by sponges. The most abundant ocean shallow water sponges have siliceous spicules (small spikes) which are very similar to chaff. All fresh water sponges also contain spicules. Sponge spicules are simple, straight, needle-like silicon dioxide spikes, often with sharp pointed ends. Sponge spicules range from 1 to 30 micrometers (µm) in diameter and from 40 to 850 µm in length. Chaff fibers are approximately 25 µm in diameter and can break down to different lengths. Thus, naturally occurring sponge spicules are approximately the same diameter and can be the same length as chaff fibers. Both marine and fresh water sponges are abundant in the environment and aquatic animals regularly come in contact with spicules. A variety of species feed on sponges, including ring-necked ducks, crayfish, sea urchins, clams, shrimp, larval king crabs, and hawks-bill turtles. These species do not purposefully consume spicules but they do come in contact with spicules as a result of consuming sponges. Aquatic organisms are regularly exposed to and consume materials of the same size and similar composition to chaff fibers (Spargo 1999). This contact and consumption would reduce the likelihood that free floating chaff particles would result in environmental consequences.

Chaff in an aquatic environment has not been found to significantly increase the concentration of any toxic aluminum constituents in sediments under airspace that has undergone 25 years of chaff operations. Concentrations of chaff in test environments were not found to result in a significant change in mortality to a variety of marine organisms in the Chesapeake Bay area. No effect was seen in marine organisms exposed to concentrations of 10 times and 100 times the expected environmental exposure. Marine and fresh water sponges normally create chaff-like spicules and foraging species are exposed to and consume these spicules on a regular basis with no detrimental effect. Chaff release in airspace above an aquatic environment is not expected to affect the environment and likely is not discernible within the environment.

## 4.4 Chaff Effects on Radar Systems

Chaff is designed to interfere with radar so that a maneuvering aircraft can escape a radar lock from an opposing radar. This use of chaff in training could affect weather monitoring radar. Weather radar has become increasingly important to predicting both flight and ground weather effects.

### *4.4.1 Weather Tracking Radar*

The primary weather surveillance radar operated by the National Weather Service (NWS), FAA, and the DoD is the Weather Surveillance Radar-1988 Doppler (WSR-88D system) (National Research Council 2002). DoD training uses chaff as a defensive countermeasure. Within the CONUS, the Air Force uses RR-188 chaff to reduce, but not eliminate, chaff caused echoes to weather and other radars. In certain regions of the CONUS, including near DoD training areas in the west and southwest, RR-188 chaff can be seen as a major radar echo contaminant (Elmore *et al.* 2004). Chaff deployed in the training areas can include RR-188 chaff, as well as combat coded chaff which creates a chaff echo.

The Next Generation Weather Radar (NEXRAD) system provides Doppler radar coverage to most of the U.S. Designed in the mid-1980s, NEXRAD is continuing to be upgraded to meet air traffic and weather prediction requirements (National Research Council 2002). As part of the ongoing NEXRAD modernization, the NWS is adding polarimetric capability to existing operational radars. These capabilities improve the radar's ability to identify and classify hydrameteor types, such as rain, hail, ice crystals, and to distinguish non-meteorological types, such as chaff (Ryzhkov *et al.* 2003). Several radar images have distinctive properties which can be differentiated using radar classification algorithms.

### *4.4.2 Airspace and Range Issues*

The improvements in NEXRAD have enhanced the ability of radar systems to detect RR-188 chaff. Investigations have been conducted to see whether RR-188 training chaff could be deployed and remain within the boundaries of a training airspace. By its very nature, chaff is light and designed to remain airborne to permit the evading aircraft to maneuver while the chaff cloud breaks radar contact. Could chaff be deployed at a low enough altitude that, under specific meteorological conditions, chaff particles would stay within the surface area under the training airspace? In most cases, this is not possible because the meteorological conditions and chaff fall rate are unpredictable. It has not been possible to determine where chaff particles would fall. The chaff plume migrates with the prevailing wind at altitude. In a series of case studies designed to track chaff plumes, the chaff plume from a release at altitudes between 15,000 to 22,000 feet above mean sea level (MSL), under moderate wind and stable atmosphere conditions, produced chaff plumes that traveled over 100 miles in two hours and could be expected to stay aloft for approximately another three hours. The total expected distance traveled by the deployed chaff prior to being deposited on the surface could be in the 120 to 300 mile range (DRI 2002).

The nature of chaff and the diversity of meteorological conditions mean that deployed chaff will continue to be an echo contaminant. This echo effect can be partially addressed through the radar operators understanding when and where chaff is deployed and, possibly, through additional software or hardware refinement to distinguish and differentiate the chaff echo contamination.

## 4.5 Chaff Conclusions

Although large numbers of chaff bundles are deployed in training, modern chaff is typically not easy to identify in the environment unless the chaff bundle fails to properly deploy and a clump of chaff is deposited on the surface. Chaff particles are difficult to identify in an environment subject to training chaff use for decades. The reasons for the difficulty in identifying chaff or chaff particles is because chaff is found to rapidly fragment on the surface and chaff is primarily composed of silica and aluminum, two of the most common elements in the earth's crust. Multiple studies to identify chaff particles or to locate elevated concentrations on the ground or in substrate have had limited success, primarily because chaff rapidly fragments in the environment and becomes indiscernible from ambient soil particles. No biological effects to marine organisms have been observed even when such organisms are subject to substantially higher concentrations than could be expected to occur as a result of training. The use of parchment paper in place of Mylar for delayed opening chaff reduces the deposition of plastic pieces to the environment to the level experienced with similar non delayed opening chaff.

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