By Way of Introduction

THE CHICKEN GUN HAS a sixty-foot barrel, putting it solidly in the class of an artillery piece. While a four-pound chicken hurtling in excess of 400 miles per hour is a lethal projectile, the intent is not to kill. On the contrary, the chicken gun was designed to keep people alive. The carcasses are fired at jets, standing empty or occupied by "simulated crew," to test their ability to withstand what the Air Force and the aviation industry, with signature clipped machismo, call *birdstrike*. The chickens are stunt doubles for geese, gulls, ducks, and the rest of the collective bird mass that three thousand or so times a year collide with US Air Force jets, costing $50 million to $80 million in damage and, once every few years, the lives of the people on board.

As a bird to represent all birds, the chicken is an unusual choice, in that it doesn't fly. It does not strike a jet in the manner in which a mallard or goose strikes a jet—wings outstretched, legs trailing long. It hits it like a flung grocery item. Domestic chickens are, furthermore, denser than birds that fly or float around in wetlands.

At 0.92 grams per centimetre cubed, the average body density of *Gallus gallus domesticus* is a third again that of a herring gull or a Canada goose. Nonetheless, the chicken was the standard "material" approved by the US Department of Defense for testing jet canopy windows. Not only are chickens easier to obtain and standardize, but they serve as a sort of worst-case scenario.

Except when they don't. A small, compact bird like a starling can pierce a canopy windscreen like a bullet, and apparently does so often enough that someone saw fit to launch some jargon (the "feathered bullet phenomenon"). Would it be simpler to just keep birds away from runways? You'd think. But birds habituate. They quickly adjust to whatever predator sound or alarm call you broadcast or minor explosives you set off, just "singing or calling more loudly"* and going about their lives as they always have.

Enter Malcolm Kelley and the Bird Aircraft Strike Hazard (BASH) team of the United States Air Force. Kelley and his team took a cross-disciplinary approach. Engineering, say hello to biology. Ornithology, meet statistics. Let's break this down, they said. Let's start with turkey vultures. Though implicated in only 1 percent of Air Force birdstrikes, the weighty raptors are, by one accounting, responsible for 40 percent of the damage. Kelley and the team attached transmitters to eight of them, tracked their flight habits and patterns, and combined this with other data to create a Bird Avoidance Model (BAM) that would enable flight schedulers to avoid high-risk times and air space. A simple "improvement in

* I quote the paper "What Can Birds Hear?" The author, Robert Beason, notes that acoustic signals work best when "reinforced with activities that produce death or a painful experience . . ." He meant for some members of the flock, whereupon the rest would presumably take note. As would animal rights activists, producing a painful experience for public affairs staff.

Turkey Vulture understanding" had, Kelley projected, the potential to save the Air Force $5 million per year, as well as the lives of unknown numbers of pilots (and turkey vultures).

Sifting through the data, Kelley noticed that when the frequency range of a jet engine sound overlapped with the frequency range of a species' distress call, the likelihood of birdstrike appeared to be lower. "Are we talking to the birds without realizing it?" he wrote in a 1998 paper. Might there be a way to build on this? One problem, he knew, is that both birds and planes take off facing into the wind. Thus the former often do not see the latter bearing down on them from behind. It was Kelley's idea to add a meaningful signal to an aircraft's radar beam, something that would alert birds to the danger sooner, so they'd have time to react and get out of the way.

This is the sort of story that drew me to military science—the quiet, esoteric battles with less considered adversaries: exhaustion, shock, bacteria, panic, ducks. Surprising, occasionally game-changing things happen when flights of unorthodox thinking* collide with large, abiding research budgets. People tend to think of military science as strategy and weapons—fighting, bombing, advancing. All that I leave to the memoir writers and historians. I'm interested in the parts no one makes movies about—not the killing but the keeping alive. Even if what people are being kept alive for is fighting and taking other lives. Let's not let that get in the way. This book is a salute to the scientists and the surgeons, running along in the

* Kelley's furthest foray outside the box came at a 1994 Wright Laboratory brainstorming session on non-lethal weapons. In the category of "chemicals to spray on enemy positions," he came up with "strong aphrodisiacs." Was the idea to develop a compound that would generate feelings of love for the enemy? "No," Kelley said. "The idea was to ruin their morale because they're worried their buddy is going to come in their foxhole and make fond advances." And come in their foxhole.

wake of combat, lab coats flapping. Building safer tanks, waging war on filth flies. Understanding turkey vultures.

THE CHICKEN gun is most of what I have to say about guns. If you're wanting to read about the science of military armaments, this is not the book you're wanting to read. Likewise, this is no *Zero Dark Thirty*. I talk to Special Operations men—Navy SEALs and Army Rangers—but not about battling insurgents. Here they're battling extreme heat, cataclysmic noise, ill-timed gastrointestinal urgency.

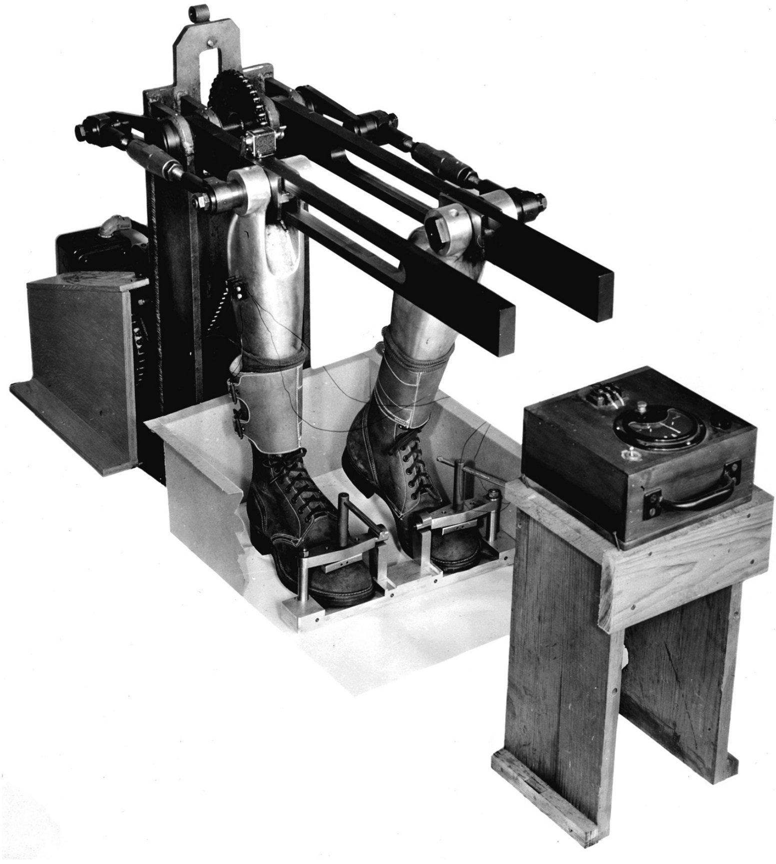
For every general and Medal of Honor winner, there are a hundred military scientists whose names you'll never hear. The work I write about represents a fraction of a percent of all that goes on. I have omitted whole disciplines of worthy endeavour. There is no chapter on countermeasures for post-traumatic stress disorder, for example, not because PTSD doesn't deserve coverage but because it has had so much, and so much of it is so very good. These books and articles aim the spotlight where it belongs. I am not, by trade or character, a spotlight operator. I'm the goober with a flashlight, stumbling into corners and crannies, not looking for anything specific but knowing when I've found it.

Courage doesn't always carry a gun or a flag or even a stretcher. Courage is Navy flight surgeon Angus Rupert, flying blindfolded and upside down to test a vibrating suit that lets pilots fly by feel should they become blinded or disoriented. It's Lieutenant Commander Charles "Swede" Momsen, saluting onlookers as he's lowered into the Potomac to test the first-ever submarine escape lung, or Captain Herschel Flowers of the Army Medical Research Laboratory, injecting himself with cobra venom to test the possibility of building immunity. Sometimes courage is nothing more than a willingness to think differently than those around you. In a culture of conformity, that's braver than it sounds. Courage is World War I medic William Baer, saving limbs and lives by letting maggots debride wounds. It's Dr. Herman Muller, volunteering to inject himself with cadaver blood to test the safety of transfusions from the dead to the wounded, a practice carried out on the battlefields of the Spanish-American War.

Heroism doesn't always happen in a burst of glory. Sometimes small triumphs and large hearts change the course of history. Sometimes a chicken can save a man's life.

1 Second Skin

What to wear to war



AN ARMY CHAPLAIN IS a man of the cloth, but which cloth? If he's travelling with a field artillery unit, he is a man of moderately flame-resistant, insect-repellent rayon-nylon with 25 percent Kevlar for added durability. Inside a tank, he's a man of Nomex—highly flame-resistant but too expensive for everyday wear. In the relative safety of a large base, the chaplain is a man of 50/50 nylon-cotton—the cloth of the basic Army Combat Uniform, as well as the camouflage-print vestments that hang in the chaplain's office here at Natick Labs.

The full and formal title of the complex of labs known casually as "Natick" is US Army Natick Soldier Research, Development and Engineering Center. Everything a soldier wears, eats, sleeps on, or lives in is developed or at least tested here. That has included, over the years and through the various incarnations of this place: self-heating parkas, freeze-dried coffee, Gore-Tex, Kevlar, permethrin, concealable body armour, synthetic goose down, recombinant spider silk, restructured steaks, radappertized ham, and an emergency ration chocolate bar with a dash of kerosene to prevent ad libitum snacking. Natick chaplains, for their part, have devised portable confessionals, containerized chapels, and extended shelf life* communion wafers.

It's a balmy 68 degrees at Natick this afternoon. It may, at the same time, be 70 below zero with horizontally blown snow or 110 in the shade, depending on what's being tested over in the Doriot. The Doriot Climatic Chambers were the centrepiece of the complex when it opened in 1954. Never again would troops be sent to the Aleutian Islands with seeping, uninsulated boots or to equatorial jungles with no mildew-proofing on their tents. Soldiers fight on their stomachs, but also on their toes and fingers and a decent night's sleep.

These days, the snow and rain machines are rented out to outdoor retailers like L.L. Bean or Cabela's as often as they're used to test military outerwear. Repelling the elements is the least of what the US Army needs its uniforms to do. If possible, the army would like to dress its men and women in uniforms that protect them against all that modern warfare has to throw at them: flames, explosives, bullets, lasers, bomb-blasted dirt, blister agents, anthrax, sand fleas. They would like these same uniforms to keep soldiers cool and dry in extreme heat, to stand up to the ruthless rigours of the Army field laundry, to feel good against the skin, to look smart, and

* Natick Labs and precursor the Quartermaster Subsistence Research Laboratory have extended shelf lives to near immortality. They currently make a sandwich that keeps for three years. Meat, in particular, has come a long way since the Revolutionary and Civil wars, when beef came fresh off cattle driven alongside the troops. During World War II, the aptly named subsistence lab developed partly hydrogenated, no-melt "war lard" and heavily salted and cured, extra-dry "war hams" that kept for six months without refrigeration and earned the not exactly over-the-moon descriptors "palatable and satisfactory." I quote there the July–August 1943 *Breeder's Gazette*, sister publication of the *Poultry Tribune*, a newspaper either about or for barnyard fowl.

to come in under budget. It might be easier to resolve the conflicts in the Middle East.

LET US begin at Building 110, which is what everyone calls it. Officially it was christened the Ouellette* Thermal Test Facility, lending a flirtatious French flair to lethal explosions and disfiguring burns. The head textile technologist is a slim, classy, fiftyish woman of fine-grained good looks, dressed today in a cream-coloured cable-knit wool tunic. I took her to be the Ouellette, and then she opened her mouth to speak and a hammered-flat Boston accent flew out and slammed into my ear. She is an Auerbach, Margaret Auerbach, but around 110 she's just Peggy, or "flame goddess."

When someone in industry thinks they've built a better flame-resistant fabric, a sample comes to Auerbach for testing. Some people submit swatches; others optimistically ship off whole bolts. Their hopes may be undone by a single strand of thread. "To see what our guys might be inhaling," Auerbach heats a few centimetres of thread to around 1500 degrees Fahrenheit. The fumes produced by this are identified by gas chromatography. Flame-resistant textiles—some, anyway—work via heat-released chemicals. Auerbach needs to be sure the chemicals aren't more dangerous than the flames themselves.

Once it's established that the textile is non-toxic, Auerbach sets about testing its flame-stopping mettle. This is done in part with a Big Scary Laser (as the sticker on its side reads). Auerbach places a swatch in the laser's sights. And here is the best part: to activate this laser, you push a *giant red button*. The beam is calibrated to deliver a

* Misspelled as "Uoellette" on the Natick Building Inventory, and "Oullette" on the sign outside the building. Somebody burned for that one.

scaled-down burst of energy representative of an insurgent's bomb—a teacup IED. A sensor behind the swatch measures the heat passing through, yielding a figure for how much protection the fabric provides and what degree burn would result.

Auerbach switches on a vacuum pump that sucks the swatch tight against the sensor. This is done to approximate an explosion's pressure wave—the dense pile-up of accelerated air that can knock a person flat. More subtly, it forces clothing flush against the skin, which can heighten the heat transfer and worsen the burn. One of the winning attributes of Defender M, the textile of the current Flame Resistant Army Combat Uniform, or FR ACU ("the guys call it 'frack you'"), is that it balloons away from the body as it burns.

The downside to Defender M has been that it tears easily. (They're working on this.) The same thing that keeps it comfortable in hot weather also makes it weaker; it's mostly rayon, which draws moisture but has low "wet strength." If a garment tears open in the chaos of an explosion, now the protective thermal barrier is gone. Now you're toast. The manufacturer throws a little Kevlar in, but it still isn't as strong as Nomex, a fibre often used for firefighter uniforms. Nomex also has superior flame resistance: it buys you at least five seconds before your clothes ignite.

Auerbach explains that this is especially important for crews inside tanks and aircraft. "Where they can't roll, drop, and . . ." She rewinds. "Drop, stop . . . what is it?"

"Stop, drop, and roll?"

"Thank you."

Why not make all army uniforms out of Nomex? Poor moisture management. Not the best choice for troops running around sweating in the Middle East. And Nomex is expensive. And difficult to print with camouflage.

This is how it goes with protective textiles: everything is a trade-off. Everything is a *problem*. Even the colour. Darker colours reflect less heat; they absorb and transfer more of it to the skin. Auerbach goes across the lab to get a swatch of camouflage print cloth. She points to a black area. "You can see this has a pucker where it was absorbing more heat."

"It has a what?" I heard her, but I need to hear her say *pucka* again. The fabulous Boston accent.

I would have guessed the military to be a fan of polyester: strong, cheap, doesn't ignite. The problem is that it melts and, like wax and other melted items, it drips and sticks to nearby surfaces, thereby prolonging the contact time and worsening the burn. What you really don't want to be wearing inside a burning army tank is polyester tights.*

To determine what degree of injury the heat would produce, Auerbach runs the reading from the sensor behind the cloth through a burn prediction model—in this case, one developed after World War II by original flame goddess Alice Stoll. Stoll did burn research for the Navy. To work out first- and second-degree burn models, she gamely volunteered the skin of her own forearm. You may excuse her for letting someone else help out with the third-degree burn curve. Anaesthetized animals were recruited for this—rats, mostly, and pigs. Pig skin reflects and absorbs heat in a manner more like our own than that of any other commonly available animal. The pig as a species deserves a Purple Heart, or maybe Pink.

* I went on the National Electronic Injury Surveillance System to find you a figure for the number of burns caused each year by tights. Alas, NEISS doesn't break clothing injuries down by specific garment. I skimmed "thermal burns, daywear" until I ran out of patience, somewhere around the thirty-seven-year-old man who tried to iron his trousers while wearing them.

What Stoll learned: when flesh reaches 111 degrees Fahrenheit, it starts to burn. The Stoll burn prediction model is a sort of mathematical meat thermometer. The heat of the meat and how deeply into the skin that heat penetrates are the critical factors that determine the degree of the burn. A brief exposure to flame or high heat cooks, if anything, just the outer layer, creating a first-degree burn or, to continue our culinary analogy, lightly seared ahi tuna. A longer exposure to the same heat cooks the inner layers, too. Now you have a second- or third-degree burn, or a medium-rare steak.

Even without a flame, clothing can catch fire. The auto-ignition temperature for cotton, for instance, is around 700 degrees Fahrenheit. Exposure time is key. The heat pulse from a nuclear blast is extremely hot, but it's travelling at the speed of light. Might it pass too quickly to ignite a man's uniform? Natick's early precursor, Quartermaster Research and Development, actually looked into this.

Operation Upshot-Knothole was a series of eleven experimental nuclear detonations at the Nevada Proving Grounds in the 1950s. The Upshot-Knothole scientists were mainly interested in the blastworthiness of building materials and tanks and bomb shelters, but they agreed to let the uniform guys truck over some pigs. Anaesthetized Chester White swine, 111 in total, were outfitted in specially designed animal "ensembles" sewn from different fabric combinations—some flame-resistant and some not—and secured at increasing intervals from the blast.

Flame-resistant cool-weather uniforms with a layer of wool outperformed a series of thinner flame-resistant hot-weather uniforms—whose developers had surely, by "hot weather," not had in mind the extreme swelter of nuclear blast. The researchers marvelled to note “a complete lack of any qualitative evidence of thermal injury to the fabric-protected skin of animals dead on recovery at the [1,850-foot] station.” I don’t wish to be an upshot-knothole, but who worries about burns on subjects close enough to a nuclear explosion that they are, as the report succinctly terms it, “blown apart”? Despite the clanging absurdity of the scenario, it was a memorable demonstration of the importance of exposure time. With the fast-travelling heat from a bomb—including a more survivable one like an IED—a few seconds of flame resistance can make all the difference.

The wool helped, too, because hair is naturally flame-resistant. Natick has, of late, been looking into a return to natural fibres like silk and wool. Not only is wool flame-resistant and non-melting, it wicks moisture away from the body. Auerbach says she has seen some very nice, soft, flame-resistant cool-weather sheep’s wool underwear. The hairs have to be descaled so the wool isn’t itchy, and the garments need to be treated to keep them from shrinking, and both these processes add to the cost. As does the Berry Amendment, which gives preference to domestic suppliers of military gear. The Berry is additionally problematic in this case in that—despite the breathless, eager assurances of the American Sheep Farmer’s Industry—there may not be enough sheep in all of America to fill the bill.

So let’s say your new textile is comfortable and affordable. The flame resistance plays well with the insect-repellent treatment and the antimicrobial stink-proofing. Now what? Now you bring some over to the Textile Performance Testing Facility. You run it through the Nu-Martindale Abrasion and Pilling Tester to get a feel for how quickly the treatments will succumb to soldierly abuse. You subject it to a couple dozen wash and dry cycles. Laundering removes not only grime but also, bit by bit, the chemicals with which a cloth or fibre has been treated. When I visited the textile testing facility, a man named Steve was waiting for some trousers to get through an accelerated wash. One wash in the Launder-Ometer equals five normal washes, he told me.

"That's something," I said.

"Yup." He stuck out his lower lip in a contemplative way. "Steel balls bang against the fabric."

If only the minds of Natick could invent a fabric that didn't need laundering. If everything splashed, smeared, or spilled on a uniform just beaded up and rolled off, if uniforms could be cleaned with a quick spray of water, think how much longer they'd last. And how much safer they'd be in the event chemical weapons rained down on them.

The minds of Natick are on it. Over in the liquid repellency evaluation lab, they're putting to the test a new "super-shedding" fabric treatment technology. Escorting me to a demo will be Natick's calm, likeable public affairs officer, David Accetta. We meet up in his office, one side of which is piled with boxes from a recent move. A wall calendar features dog breeds. September is a large white poodle. Accetta was most recently deployed to Bagram Airfield in Afghanistan, where he spent his days writing press releases about the Army's humanitarian efforts. His superiors would ask him why the stories rarely got any play. "They didn't get it. It's not news." He relates this with no trace of anger. There are many irritating things about Accetta's job, but he never sounds irritated. He takes everything in stride, which is a bad cliché to use for him, because he's not a striding sort of guy. He's more of a moseyer. He has long eyelashes and a slow way of blinking. I almost wrote *doll-like* there, but the adjective seems out of place with the rest of Accetta's face, which is crossed by a thin, rakish scar that begins at one temple and curves down and around his cheek. I don't ask about it, preferring to supply my own made-up narrative of flashing sabres and staircase choreography.

We are early, so we take a walk along Lake Cochituate, which forms a property line for part of the Natick grounds. Sunlight is scattered on a low chop. Water from the lake, a deep blue-green in today's light, was at one time used to make Black Label lager. Natick activities pretty much put a stop to that. For a Superfund site, the grounds are quite pretty, with gazebos and meandering footpaths. Cylindrical grey-white Canada goose droppings add to the park-like atmosphere. It took a while to realize what these were, because I didn't see any geese. It's fall. Maybe they just flew south.

Accetta and I stop to watch an officer addressing a group of HRVs: human research volunteers—arms and feet and heads to go inside the parkas and boots and helmets. They are soldiers deployed to taste rations, sleep in new sleeping bags: test, report back, test something else. A temporary duty assignment at Natick is not necessarily a soft gig. I saw a photograph, from the sixties, of a group of soldiers in raincoats and waterproof trousers, heads bent, hoods dripping, walking in circles under a simulated downpour. Apparently this went on for hours.

The volunteers, ten or so, stand in a row in the parking lot outside their barracks. A car backs out of a parking slot behind them. The soldiers take three steps forward, in formation, and one step up, onto the kerb. When the car pulls away, they step backward and down. Anytime they walk someplace in a group of four or more, Accetta says, they have to be in formation. Like geese flying south.