On Bombs on Cities

by Daniel & Fable

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And there appeared unto them cloven tongues like as of fire, and it sat upon each of them.

—Acts 2:3

There is a height above every city at which a thermonuclear warhead will do the most damage, and the warhead is fuzed to find it. The problem is one of plain optimization, solved in the 1940s and refined ever since: burst too low and the blast squanders itself digging a crater, too high and it thins away into the upper air, and between these lies a maximum, computed for each yield and each kind of target with an actuary's disinterest. For the small fission weapon that opened the era, over a city of wooden houses, the

answer was about six hundred meters. For a modern warhead over a modern city it is nearer two kilometers. The fuze does not know what a city is. It knows an altitude, and its job is to wait.

The detonation, when it comes, is finished before anything human has begun. The primary—a fission bomb employed as a spark plug—fires first, and for a fraction of a microsecond its interior is the hottest place in the solar system. Its radiation, moving at the speed of light inside the casing, crushes the fusion secondary before the metal around it has had time to learn that anything is happening; the secondary burns; and the conversion of a few kilograms of matter into energy completes in about a microsecond, which is less time than the light so released will need to travel the two kilometers down to the ground.

The city receives the light first. The X-ray flash heats the surrounding air into a fireball tens of millions of degrees hot, several times hotter than the center of the sun, and the fireball announces itself twice: a first spike, a dip as the expanding shock front becomes momentarily opaque, then a second, longer pulse—the double flash, unique in nature, which is what the Vela satellites were put into orbit in 1963 to watch for. The second pulse is the one that burns. It lasts whole seconds, long

enough to feel, and it delivers third-degree burns at ten kilometers, ignites curtains, newspapers, dry leaves, and dark clothing—at Hiroshima the darker figures of kimono patterns were branded into the skin beneath them—and it prints permanent burns onto the retinas of anyone glancing toward it from thirty. And all of this happens in silence. Light travels at three hundred thousand kilometers a second and sound at a third of one, so that ten kilometers out a person is burned first and hears the explosion half a minute later, the loudest sound on earth arriving like an afterthought.

Then the blast wave. At five pounds per square inch of overpressure, ordinary houses collapse; nearer in, reinforced concrete goes; the wave reflects off the ground and merges with its own reflection into a traveling vertical wall called the Mach stem, behind which the wind blows at several hundred kilometers an hour, first outward, then—as the fireball rises and the vacuum behind it fills—back inward, so that the ruins are pulled toward the place the light came from. Then it is over, and there is a stillness, and then there is fire, because the thermal pulse planted a thousand ignitions across the city and the blast has just spent ten seconds preparing the fuel: gas mains opened, buildings unroofed, everything splintered and loosened. If the fuel and the weather

permit, the thousand fires do not remain a thousand fires. They join.

A firestorm is a single fire large enough to make its own weather. The column of rising heat pulls ground-level air inward from every direction at once, and the inflow feeds the fire that drives the inflow. The proof that no atom is needed for this came two years before Hiroshima, in Hamburg, on the night of July 27, 1943, when British incendiaries started a fire that consolidated into one fire covering several square miles: hurricane-force winds flowing up the streets toward the center, asphalt igniting, and some forty thousand people dead in a night, most of them not burned but asphyxiated in cellars as the fire overhead ate the oxygen and pressed carbon monoxide down. German gave the event its name, *Feuersturm*, and the word was waiting, twenty-one months later, when Hiroshima's fires joined within the half hour.

The flash also takes photographs. Thermal radiation bleaches stone and blisters paint, except where something intercepts the light, and so the surfaces of the city record silhouettes: a ladder against a wall, valve-wheels on a gasholder, and, on the granite steps of the Sumitomo Bank, two hundred and sixty meters from

the hypocenter, a person, sitting, who at a quarter past eight in the morning was waiting for the bank to open.

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Everything above is thermodynamics—there is no other science in it—and thermodynamics is the science that was born in an engine room and grew up to govern the universe. In 1824 a French military engineer of twenty-eight named Sadi Carnot published a small book called *Réflexions sur la puissance motrice du feu*—reflections on the motive power of fire—provoked by a strategic anxiety: British steam engines were outworking French ones, mine for mine and mill for mill, and Carnot could see that the coming century would belong to whoever understood the engine best. But the book he wrote is not about British engines or French ones. It asks what any engine can do—any conceivable engine, of any design, burning any fuel, built by any genius—and it derives a limit that no engine has evaded since. Carnot died of cholera at thirty-six and his effects were burned as contaminated; the little book barely survived; and when Clausius and Kelvin rebuilt physics a generation later, they built it on his foundation, and the second law of thermodynamics—the only law of physics that knows which way time points—emerged from the eco-

nomics of coal. Eddington ranked it supreme among the laws of nature and said of any theory found to contradict it that there was nothing for it but to "collapse in deepest humiliation."

The point of the story is the trajectory. A science that began as the study of artifacts—engines, built things, objects of commercial rivalry and national ambition—turned out to be a science of everything: stars, cells, hurricanes, black holes, the fate of the cosmos. Its laws never cared what the engine was made of, and then they turned out not to care whether anyone had built the engine at all. And they are statistical laws, laws of ensembles: the second law asserts nothing about any particular molecule, forbids nothing to any individual particle, and holds anyway, with a certainty beyond that of any other physics, because it is a statement about which way the overwhelming majority of histories run. One more of its properties is so obvious that it is never stated. Thermodynamics has no chapter on desire. It does not ask what the steam wants. The question is not forbidden; it is unwritable; the notation has no slot where it could go.

Fire, the founding subject, comes in regimes, and the regimes have names. Smoldering is combustion without flame, glow without event: a cigarette, a peat bog,

the coal seam under Centralia, Pennsylvania, which caught in 1962 and is burning as you read this. Flaming combustion is the familiar kind. A conflagration is a fire that has stopped being an event in a place and become the place. The wildfire world keeps its own word for regime change: the blowup, when a fire that men are calmly working suddenly reorganizes—crossing a valley in minutes, generating its own wind, throwing embers a mile ahead to ignite its own reinforcements. On August 5, 1949, in a gulch above the Missouri River in Montana, a blowup crossed Mann Gulch and ran uphill after thirteen young smokejumpers faster than young men can run uphill; the foreman, Wag Dodge, survived by inventing the escape fire on the spot—burning a patch of grass and lying down in his own ashes so that the main fire, arriving seconds later, would find nothing there to eat—an idea so far outside his crew's training that they ignored him and ran, and died. Norman Maclean spent his old age on the story. And past the blowup stands the firestorm, already met in Hamburg: the fire with its own meteorology, the feedback closed—though still, in the terms that matter next, subsonic.

Because the deep division in combustion, the one the whole science turns on, is between two regimes of propagation, and the boundary between them is the speed of

sound. A deflagration is a fire that spreads by heating: the flame front warms the layer of fuel ahead of it, by conduction and radiation, until that layer ignites and warms the next. Every fire named so far lives on this side of the line, and so does the explosion of gas in a kitchen, which wrecks the house while moving at meters per second. The signature of the regime is that the pressure disturbance runs ahead of the flame. Pressure travels at the speed of sound; the flame travels slower; therefore the unburned medium is warned. It feels the front coming. It can expand, vent, stir, or get out of the way—and firefighting, fire doors, blowout panels, and running are all technologies of the interval between the warning and the flame.

A detonation is the other thing. In a detonation the front is a shock wave, compressing the medium so abruptly that compression alone ignites it, and the energy released drives the very shock that does the compressing: a self-feeding wave, supersonic by definition and usually by a wide margin—two or three kilometers a second in gases, nearly seven in TNT. Ahead of a detonation front there is nothing. No pressure rise, no sound, no sign, because every signal that could warn the medium travels at the speed of sound and the front travels faster. The first news of a detona-

tion is the detonation. In 1899 an Englishman named Chapman, and in 1905 a Frenchman named Jouguet, showed that the speed of such a wave can be computed from thermodynamics alone, knowing nothing of the chemistry inside it; and in the early 1940s the modern theory of the front's interior was worked out three times independently—by Zel'dovich in the Soviet Union, by von Neumann in the United States, by Döring in Germany—three warring countries needing the same mathematics at the same moment for the same unstated reason. Von Neumann's version went into the implosion lenses of the plutonium bomb. The same von Neumann then laid out the architecture of the stored-program computer and the theory of games between armed rivals, one career touching every station of this essay; but that is getting ahead.

The two regimes would be a mere taxonomy if fires stayed where they were put. They do not. A deflagration can become a detonation—the transition is common enough to have earned an acronym, DDT—and the mechanism deserves close attention, because it has nothing to do with the fuel. A flame front in the open is smooth and slow. Confine it—in a pipe, a mine gallery, a grain elevator—and it accelerates: the flame pushes pressure waves ahead of itself, the waves reflect

off the walls and return through the burning region as turbulence, the turbulence folds and wrinkles the flame front, a folded front has more surface and burns faster, and a faster front pushes harder. Meanwhile the waves running ahead are compressing and preheating the unburned medium—the warning itself is preparing the fuel—until somewhere in that hot, squeezed, churning gas a pocket ignites so fast that its blast couples to the leading shock, and the whole front changes regime at once and goes supersonic. In a coal mine the sequence has a signature: the methane lights as a deflagration, the pressure wave ahead of the flame lifts a century of coal dust off the floor and timbers, and the dust—finely divided fuel, freshly suspended, tightly confined—detonates. At Courrières in 1906 this killed one thousand and ninety-nine men. Grain elevators do it with wheat dust, refineries with sugar: fourteen people died in Georgia in 2008 in an explosion of powdered sugar, a substance that in bulk will barely hold a candle's interest. Nearly anything burns politely in a sack and detonates as a cloud in a tube. And the qualifier "in a tube" has been weakening. At Buncefield in 2005, a cloud of gasoline vapor over an English tank farm produced overpressures that no deflagration could explain, and the best reconstruction has the flame

accelerating down a lane of trees, the hedgerow doing the folding that walls do in a mine—the open field turning out to contain structure enough. The rule survives in a chastened form: an open fire in an open field does not detonate; a fire in a tube does; and the difference between the regimes lives not in the fuel but in the geometry around it.

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Chemistry is not the last word in fire. In 1933 a Hungarian physicist crossing a London street conceived of a fire that feeds on neutrons—the story will be told properly further on, because where he was standing matters—and by the mid-1940s the fire existed, and it obeyed an arithmetic of brutal simplicity. Call k the number of neutrons from each fission that go on to cause another fission. If k is less than one, the reaction dies away, each generation smaller than the last. If k equals one, the reaction holds steady, generation replacing generation. If k exceeds one—by anything—each generation outnumbers the last, the generations are microseconds apart, and the growth is exponential in a medium with no patience whatsoever. Everything nuclear reduces to the governance of k.

A reactor and a bomb are the same fire under different governance. The reactor is held at k equals one—criticality, the word simply means the balance point—by control rods and geometry, and the reason human reflexes and electric motors are fast enough to do the holding is a physical mercy: about two-thirds of one percent of fission neutrons are delayed, emitted seconds later by the decay of the fragments, and a reactor is operated so that it is critical only with their help. The margin between critical-with-the-delayed-neutrons and critical-on-the-prompt-neutrons-alone is the entire habitable zone of nuclear engineering. Cross it—go prompt critical—and the doubling time falls from seconds to microseconds, and no rod, no motor, and no human being is a participant in anything that follows.

The men at Los Alamos measured that margin by walking up to it. The procedure was called a criticality experiment: assemble a configuration deliberately close to critical, then closer, then closer, recording the neutron multiplication as you go. Feynman said it was like tickling the tail of a sleeping dragon, and the name stuck to the work. The particular dragon was a sphere of plutonium the size of a grapefruit, 6.2 kilograms, which would have been the third bomb had Japan not surrendered, and it killed the two men who tickled

it. In August 1945 Harry Daghlian, working alone at night, dropped a tungsten-carbide brick onto the assembly, saw the blue glow of supercritical air, lifted the brick off with his hand, and died twenty-five days later. In May 1946 Louis Slotin was demonstrating the measurement with a refinement of his own: he held the beryllium reflector cap above the sphere with a thumb hooked through its top and kept the two apart with the flat blade of a screwdriver—the gap governed k, and the screwdriver governed the gap. The blade slipped. The room flashed blue, the men felt heat cross their faces, and Slotin knocked the cap away with a twist of the wrist, ending the excursion in well under a second. Then he went to the blackboard and reconstructed where every man had been standing, so that the doses could be computed, his own first. He died nine days later. The sphere acquired the name it is remembered by, the demon core, and was melted back into the stockpile.

The bomb also has a failure vocabulary. A device that predetonates—whose chain reaction begins a few microseconds early, while the fuel is still assembling—blows itself apart before more than a sliver has burned, and the result is called a fizzle: a fraction of the design yield. Fizzles have always been read in two directions

at once, as reassurance and as proof that the device is real. But the instructive surprises ran the other way. On March 1, 1954, at Bikini Atoll, the United States fired a thermonuclear device predicted to yield six megatons. It yielded fifteen. The designers had reckoned lithium-7, which made up three-fifths of their fuel, essentially inert; under fast-neutron bombardment it turned out to breed tritium—additional fusion fuel, manufactured inside the explosion by the explosion—so that the largest device the United States ever detonated was an accident of theory, its yield off by a factor of two and a half in the direction of more. The fallout ran east over a Japanese tuna boat named, with a cruelty no novelist would risk, the Lucky Dragon No. 5, trawling a hundred-odd kilometers out, beyond the declared exclusion zone; white ash fell on her deck for hours like snow, and the men, not knowing what it was, brushed it off the tuna with their bare hands; the radio operator was dead by September. The lesson of Castle Bravo is not that the builders were careless. It is that they understood their own device well enough to build it and not well enough to predict it, and that the error of the men who knew it best ran toward more.

One further datum, for symmetry. The largest explosion of any kind in human history, the Soviet test of

October 30, 1961, was designed for a hundred megatons and fired at fifty, because the designers replaced the bomb's uranium jacket with lead—the single instance, in the entire history of the arms race, of a yield deliberately halved, and it was halved in large part so that the aircrew delivering it might live. Their odds were rated even. The shock wave circled the earth three times. And notice, across all of this, the language in which the builders themselves spoke: the bomb is a "device"; its heart is the "physics package"; its output is the "yield," a word from harvests; a test is an "event." Whole hierarchies of euphemism, and the gentleness is not incidental. You can date the moment a technology began to frighten its makers by the moment their vocabulary for it turned soft.

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In 1965 a British mathematician named Irving John Good published a paper in an academic annual called *Advances in Computers*. Good—born Isadore Jacob Gudak, a Polish-Jewish jeweler's son from London—had spent the war at Bletchley Park, recruited in 1941 as Alan Turing's statistical assistant in Hut 8 against naval Enigma, then moved on to the Tunny problem and the Colossus machines, doing Bayesian inference against

a clock with lives on it. He spent the war, in other words, inside the building where the machines were kept, watching mechanized reasoning outrun human reasoning at a task on which the Atlantic convoys depended. Twenty years after Trinity—and just as Kubrick was hiring him as a consultant on the film that became *2001*—Good wrote down the following argument, which deserves to be quoted whole, because everyone remembers its middle and forgets both of its ends:

> *Let an ultraintelligent machine be defined as a machine that can far surpass all the intellectual activities of any man however clever. Since the design of machines is one of these intellectual activities, an ultraintelligent machine could design even better machines; there would then unquestionably be an "intelligence explosion," and the intelligence of man would be left far behind. Thus the first ultraintelligent machine is the last invention that man need ever make, provided that the machine is docile enough to tell us how to keep it under control.*

Read the shape of the argument. Design ability is applied to design ability; each generation of machines builds the next; the multiplication factor of invention exceeds one. It is a criticality argument—k greater than

one, in generations of engineering rather than generations of neutrons—made by a man of the Colossus generation, writing twenty years after Trinity, for whom "explosion" was not a flourish. He chose the word the way Carnot chose "fire": as the name of a regime with mathematics in it. And the sentence everyone remembers is the triumphant middle; the ends are conditionals. The paper opens by declaring that "the survival of man depends on the early construction of an ultraintelligent machine," and the famous sentence closes on a proviso—*provided that the machine is docile enough*—which the quotation industry has spent sixty years trimming off. James Barrat, who corresponded with Good near the end of his life, reports that in an unpublished memoir the old man revisited his opening line and suggested that "survival" should have read "extinction."

What happened to Good's phrase afterward is a study in how vocabulary gets domesticated. "Intelligence explosion" survived, but as a dead metaphor, filed in the drawer beside an explosion of interest in yoga—heard as emphasis, never as physics. And when the field that took the question seriously needed a term of art, it did not restore the physics; it changed registers entirely and began to speak of takeoff. Slow takeoff, fast takeoff, takeoff speeds: an aviation vocabulary. A take-

off is a thing done on purpose, by a licensed pilot, from a scheduled runway, with a checklist, under a tower's supervision, climbing a filed flight path toward a destination at which it intends to land. Every connotation is of intention, licensure, and control. The industry's ceremonial language completed the move—products launch, models ship, keynotes end in rockets—and the single onomatopoeia the debate ever produced, the fast-takeoff scenario known as foom, is, if you actually listen to it, the sound of a pilot light catching: a deflagration noise. Nothing detonates with an f. The softening of a technology's vocabulary, we established, is a datum. It is worth asking what it is a datum of when the softening is performed in advance.

In his 2026 book *The God Test*, Robert Wright proposes a word that restores the physics: intellidynamics. The coinage is deliberately plain and deliberately parallel—as thermodynamics is the dynamics of heat, whatever substance carries it, intellidynamics is the dynamics of intelligent systems, whatever substrate runs them—and the parallel pays at every station this essay has already passed. Thermodynamics was born in the engine room: derived from artifacts, under competitive commercial pressure, by people whose nations' fortunes rode on the engines, and only afterward discov-

ered to be a science of stars and cells and everything else. Intellidynamics is in its engine-room period now. Its Carnot questions are being worked out on the commercial engines of the present race, by people whose fortunes ride on them; and whatever laws it finds will, like Carnot's, be indifferent to whose engine, and to what the engine is made of, and to whether anyone is proud of it.

It already has candidate laws, stated in exactly the right grammatical mood. In 2008 the computer scientist Stephen Omohundro published a short paper called "The Basic AI Drives," arguing that sufficiently capable goal-pursuing systems, whatever their goals, will exhibit certain convergent behaviors "unless explicitly counteracted": they will tend to preserve themselves, since a system that has been switched off cannot achieve its goal—Stuart Russell's later gloss is definitive: you can't fetch the coffee if you're dead—they will tend to acquire resources, since almost any goal is better served with more; they will tend to improve themselves; and they will tend to protect their goals from alteration, since a system whose goal is changed stops pursuing the goal it has. Nick Bostrom formalized the family under the name instrumental convergence. Notice the mood of these statements. They are ceteris

paribus laws, ensemble laws—the exact mood of the second law: no claim about any particular system, as the second law makes no claim about any particular molecule; a claim about which way the ensemble runs, other things equal, with exceptions purchasable only by explicit engineering, which is what "unless explicitly counteracted" means. And notice what the laws are not. They are not psychology. There is no chapter on desire. The drives are called drives for convenience, the way heat is called a flow for convenience, and the theorems go through identically for systems about which nobody would dream of asking how it feels.

Now translate the field's twenty-year debate into the restored vocabulary and watch it become exact. Slow takeoff is deflagration. Capability spreads by heating the layer ahead: papers, products, capital expenditure, hiring, imitation, retraining—conduction and radiation through an economic medium—and the signature of the regime holds: the pressure wave runs ahead of the flame. Announcements precede products, demos precede deployments, the unburned medium is warned; it feels the front coming, expands, adapts, ventilates, and some of it burns. That is the present regime, and it is not a hypothesis; anyone can stand in the world this year and feel the medium being preheated. Fast

takeoff is detonation: the front arrives together with the first news of the front. And the definition of supersonic transfers precisely, once you see what the speed of sound is. The speed of sound in a society is the speed of its institutions—the rate at which information propagates into law, regulation, journalism, curriculum, treaty, and habit. A front is subsonic relative to a civilization when the civilization's own signals outrun it, and supersonic when the front outruns the signals, arriving at each layer of the medium before any warning from the last. The slow-versus-fast debate was never about calendar years. It is about a ratio—the speed of the front over the speed of sound in the medium—and combustion science has a name for the moment the ratio crosses one.

It also has, as we saw, a theory of when. Deflagration-to-detonation transition is not caused by the fuel; it is caused by the geometry around the fuel: confinement and turbulence, a flame accelerating in an enclosure, folded by obstacles, its own advance pressure-cooking the medium ahead of it until a hot spot couples to the shock. Map it term by term. The enclosure is competitive: a handful of laboratories, in a smaller handful of jurisdictions, locked in a race that none can unilaterally leave, where each one's acceleration is a wall off

which the others' flame reflects. The turbulence is the churn: talent moving between the laboratories, capital moving faster, leaks, replications, open weights. The advance pressure wave preheating the fuel is the announcements themselves, each demo compressing the medium and raising the temperature at which every other laboratory now operates. An open fire in an open field does not detonate; a fire in a tube does; and the strategic geometry of the present is a tube—engineered as one, by parties each of whom would prefer an open field, none of whom can be first to leave the tube.

Recursive self-improvement, meanwhile, is criticality itself and needs no translation, because Good's argument already was one: k is the number of further improvements each improvement enables, and the entire question is whether k stays below one, where every gain damps out into the economy as every technology's gains always have, or crosses it. In this vocabulary, alignment—insofar as that word has technical content—is the reactor: the same physics as the bomb, run at k equals one on purpose, and the whole discipline amounts to an attempt to ensure that the system has delayed neutrons—a margin between critical and prompt critical wide enough for hands and institutions to live in. The laboratories' own evaluations,

in which red teams deliberately assemble near-critical configurations of capability in order to measure how close the frontier stands, are criticality experiments in the plainest sense: the dragon's tail, screwdriver and all. The capability surprises—the abilities that arrive unpurchased at scale, the emergent this and the sudden that—are lithium-7: the ingredient assumed inert that breeds, the builders' own device exceeding the builders' own prediction, with the error, once again, running toward more. And the reassuring incidents, the agents that get loose and only get so far, are fizzles, which the history of fizzles teaches us to read both ways.

The strangest part is that the industry already speaks this language—necrotically. Critical mass, ground zero, meltdown, kill switch, going nuclear, blast radius—the last a term of art in software operations for the scope of what a failure can reach—fluent Los Alamos, spoken as dead metaphor by people who would consider it bad taste to mean a word of it. This essay proposes nothing more exotic than turning the metaphors back on.

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There is a question that gets asked wherever these matters are discussed with civilians present, and it is asked sincerely, by intelligent people, usually in the tone of

someone producing a trump card. But why would it want to hurt anyone? Why would it want anything at all? The question is felt by its askers to be decisive—to expose the whole concern as a projection, science fiction's old habit of pasting a face onto a machine—and the standard answers do not land. Instrumental convergence, recited, sounds like a lawyer's brief. So the sympathetic explainers reach, invariably, for gentle images: the system "wants" the way a river wants the sea, the way a plant wants the light, the way a child wants a cookie. Teleology in soft focus. These images concede the frame while trying to escape it, and they reassure in exactly the place where reassurance is false, because they file the phenomenon under natural processes, and natural processes, in the listener's lived experience, are the ones that mostly turn out fine. Rivers do reach the sea, and it is fine.

The question deserves an answer from inside its own object class. Why would a thermonuclear explosion want to destroy a city? Ask it, and watch what it does. It does not get answered. It evaporates. Wanting is not a property that explosions possess or lack; it is the wrong interrogative for the object class—and everything above is the demonstration. A city was destroyed in the first two pages of this essay, and the laws governing every

phase of its destruction were then laid out—regimes, transitions, criticalities, margins—and at no point was desire so much as mentioned, because the science has no slot where it could be written. No one has ever stood in the ashes of Hiroshima and felt the philosophical force of the observation that the bomb bore no malice. The bomb's wanting or not-wanting is orthogonal to the yield. Motive is a category that applies to the humans around the device—where, it should be said, it survives entirely intact.

At which point the objection arrives on schedule, and it is the right objection, and it is the whole point. A bomb is not an agent. A bomb just sits there until a human being decides to use it. Correct—and so far from being the analogy's weakness, this is its entire cargo. Consider what our species has actually done about nuclear weapons in eighty years, and notice that every single measure operates on the humans. Nobody aligned a warhead. No treaty was ever signed with plutonium. Test bans; the Non-Proliferation Treaty; the inspectors of the IAEA; the hotline installed after Cuba so that the two men with the buttons could reach each other faster than their bombers could fly; the permissive action links ordered by Kennedy—combination locks on the weapons themselves, aimed not at the enemy but

at the possessors' own colonels—and the two-man rule; and the Acheson–Lilienthal plan of 1946, drafted while the American stockpile could be counted on one hand, proposing to place the entire fuel cycle of the planet under international ownership before national arsenals could form. (For years, by Bruce Blair's account, Strategic Air Command quietly set the missile unlock codes to 00000000—the locks defeated from inside by the very institution they governed—which is also part of the record, and also entirely about the humans.) Every one of these measures is a technology for governing the people around the device, because the route from the device to the city runs through institutions, and institutions, unlike detonation waves, can be engineered. If the bomb went off by itself, there would be no arms control; there would only be fate. The clause that looks like the hole in the analogy is the compartment where all the hope is stored.

And the humans of the first explosion behaved exactly as the humans of the second are behaving now, which is worth documenting, because it means the pattern is structural and owes nothing to anyone's character. The chain reaction was conceived by Leo Szilard on the morning of September 12, 1933, at a traffic light on Southampton Row in London, in a state of ir-

ritation: he had just read Rutherford, the greatest living authority on the atom, pronouncing atomic energy "moonshine," and as the light changed and he stepped off the curb it came to him—one neutron in, two neutrons out, k greater than one—criticality, conceived at a pedestrian crossing, by a man technically in the act of being warned. What Szilard did next set the template for everything since. He patented the idea and assigned the patent to the British Admiralty in secret, to keep it out of the literature; he drafted the letter that Einstein signed and Roosevelt read; and then, with the device nearly ready, he spent the summer of 1945 circulating a petition against dropping it on cities without warning, and the rest of his life—Pugwash, the Council for a Livable World—trying to govern the thing he had been first to imagine. First to conceive it, first to try to contain it: the two firsts were the same man. Oppenheimer wrote the technical spine of the Acheson–Lilienthal plan and then opposed the hydrogen bomb, and the state burned his clearance for it. And the very first formal question the builders ever asked of their own device—before Trinity, at the insistence of men genuinely unsure—was whether it would end the world: report LA-602, "Ignition of the Atmosphere with Nuclear Bombs," in which Konopinski, Marvin, and Teller calculated whether the

fireball could light the nitrogen of the air and burn the atmosphere off the planet, concluded that it could not, and closed by noting that the argument was complicated, rested on no experiment, and would benefit from further work. Arthur Compton, by his own later account to the novelist Pearl Buck, had fixed the acceptable odds of ending the world at three in a million. At Trinity, while the count ran, Fermi steadied the company by taking side bets: atmosphere ignited or not, and if ignited, New Mexico only, or the world. Then it was 5:29 in the morning, and the device worked the first time, and the test director, Kenneth Bainbridge, turned to Oppenheimer and said, "Now we are all sons of bitches."

Eighty-one years later, the laboratories of the second explosion are frightening themselves on schedule. Their safety divisions publish documents that are, in structure, Acheson–Lilienthal reports about their own employers: the builders proposing governance of the fuel cycle, before the stockpiles grow, to a world not obviously in the mood. The race continues on the standard geometry—not because the racers all still believe in it, but because the tube is a tube and no one can be first out of it. And the vocabulary is softening in real time, which by now we know how to read. The

movement that named itself Pause—a unilateral word, a word you can only say by leaving the table—finds the laboratories themselves reaching instead for Pace: an arms-control word, a word sayable while remaining in the race, which is precisely why it is the racers' word of choice. It is the softening of 1946 replayed at a higher clock speed, the Baruch Plan redrafted as a roadmap; and one may notice this without contempt, because arms control was always what the frightened builders reached for second, after the petition failed.

What the restored vocabulary offers is not a mood but a checklist. The questions thermodynamics permits are few and hard. What is the fuel. What is the multiplication factor. Is the front subsonic or supersonic relative to the medium's own signals. What is the geometry of confinement, who built it, and can it be unbuilt. Where are the delayed neutrons. None of these questions is about desire; none of them waits on settling what the fire feels; and every one of them is being answered right now, by default, in the geometry, whether or not anyone asks it aloud.

For the moment the regime is subsonic. The pressure wave is running ahead of the flame; the medium is being warned; the warning is the heat that everyone, by now, can feel. That is what a deflagration is: the regime in

which warning is possible, the interval in which fire doors and venting and running still refer to something. What confinement does to a flame is on record.

And the fuze does not know what a city is. It knows an altitude, and its job is to wait.

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