Now I am Become Death

Fall, 1943 CE. Sarah, a bright, young physicist and mathematician, works with Richard Feynman at the Manhattan Project lab on a desert mesa called Los Alamos near Santa Fe, New Mexico. Under Feynman's loose supervision, Sarah will design the procedures, and then test the mathematical formulations needed to measure experiments with bomb architectures, container shapes, and expansion rates of bombblast effects.

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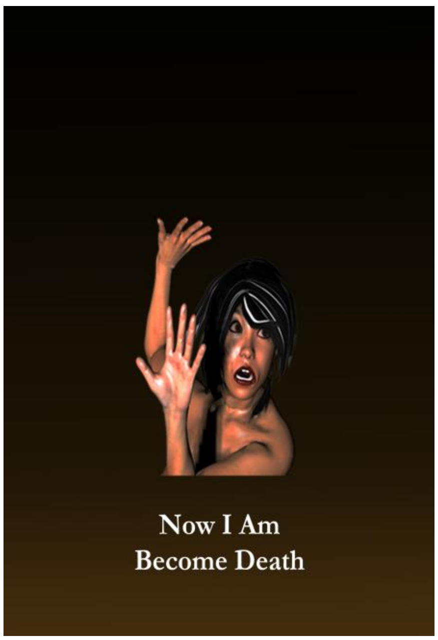

Sarah's colleague in the Theoretical Division's Diffusion Unit is named Konstanty. He is the American-born son of a Russian émigré, who arrived with his family following the events of 1917. Konstanty's family was devoutly Russian Orthodox, and there was no place for them in the new Russia.

In order to secure his citizenship, Konstanty joined the US Army as soon as he came of age. There he learned important skills in the management and use of malleable, high-intensity explosives. He apparently had not learned enough of the most important skills because his last explosive setup blew up in the process of connecting the firing changes to the triggering device. Such accidents among those trying to rapidly learn new technical skills and scientific methods were not uncommon in the mesa's intense design, development, and testing environment.

Sarah is now faced with finding a replacement for the bedridden Konstanty. Worse, she has already been dealing with the need to fill a supervisory vacancy for the computation unit. That unit is charged with running all the explosion data through a complex series of procedures, all through the use of hand-cranked calculators, to determine whether a particular experiment has produced useful data and, if useful, what it shows about the effectiveness of a particular design of the chamber within the bomb that will trigger the explosion.

Dr. Richard Feynman, the leader of the Diffusion Unit and Sarah's immediate supervisor, has not been of much help so far. Feynman is young, and his contribution to the project is a rare combination of theoretical brilliance and practical experience with mechanical gizmos, radios, electronics, and household appliances gained in his father's Bronx repair shop. Feynman is so often called away to help untangle some critical problem in some other high-priority operating unit that he has delegated almost all of the operations of the Diffusion Unit to Sarah, including, as her first assignment, the recruitment of her two primary subordinates.

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Several months ago, Konstanty had called out to me. "These calculations are fucked up, Sarah! Do them again."

This was shortly after I began working here on the mesa.

Shortly after his accident, I went to visit Konstanty while he was still in the coma. I remember swearing to myself, but softly. I was sorry to see him in the state he was in. Konstanty and I hold the same relative position in the Diffusion Unit, but he has always made it clear that he thinks himself smarter than me. Either that or maybe he thinks he has more pull with the project's senior managers. He claimed a friendship with Dr. Edward Teller, a Hungarian physicist with bushy eyebrows and a deep accent who lost out to Bethe in the competition for the job of leader of the Diffusion Unit.

I wondered why he would brag of his Teller contact because Feynman might be a little sensitive about Teller. After a while, though, it became obvious to me that Feynman paid no attention to Teller unless, of course, Teller had a technical problem that needed his serious attention and focus.

As part of my introductions to the other science managers on the project, I met with Dr. Edward Teller in his office. Teller had also been assigned to the Theoretical Division and came to the project around the same time I did. He is a gregarious man who can be charming as long as the subject isn't about his qualifications to do higher-level work or his concerns with the capability of those who now hold the positions where that work is done. He can get a little heated on these topics, as I have learned.

I changed the subject by alluding to a small stone Teller keeps in his science library, next to his lab. The stone has a deep blue color that seems almost translucent.

"I am a secret gemologist," he says, his Hungarian accents undiminished. "I appreciate the unique qualities of the stone, but the stone is rare and there is nothing in the literature available to me that speaks of this stone or its possible origins. I have never really had time to devise and run the tests necessary to determine its chemistry, nor have I been able to determine where it came from or what its value might be."

Though he has no idea where the stone came from, Teller insists that James Clerk Maxwell once owned the stone, keeping it in the library next to his lab at the Cavendish Library, which is why Teller keeps his "pretty blue stone" on the shelf next to his lab.

I told Teller that I would love to look into the origins of the stone, but I never found the time to follow up with him. It was clear to me even then, before Konstanty's accident, that the time I would need to determine its origins and rarity was simply not going to be available to me, given how I needed to support the design and development work necessary to make the "gadget" work.

Following Konstanty's accident, almost all my time will be devoted to doing both my job and his in Field Services. I tried to read the brief scribbled notes that Feynman had given me on the math and physics problem he wants me to focus on as I started my work here. He had told me that my skills, experience, and graduate papers in math suggested to him that I "could make a major contribution to the work here."

I was very flattered and very pleased.

Feynman has never really sat down with me to discuss the overall purpose of his unit, nor his personal, particular, and specific interest in the work at hand. Feynman's skills, experience, and sheer brainpower are so beyond anyone in my experience that he is often called out to work on various technical emergencies on the Project. This is all the more impressive, as he is the leading physicist in the world for his twenty-four years of age and his very green, two-year-old PhD.

His work on the Manhattan Project, from its earliest days with Fermi in Chicago, has always been clear, and focused. He sees himself helping to lead the effort to untangle the theoretical issues and problems in the way of designing and building a deliverable atomic bomb. For years there have been rumors that German Chancellor Adolf Hitler has a bomb project underway that is similar to our Manhattan Project.

Finally, Feynman and the project's senior managers like Bethe, Oppenheimer, and Groves were admonished to build a deliverable bomb before Hitler could. They were to build a bomb powerful enough to break the back of the German military and, thus, end the war.

In one of my only significant face-to-face conversations with Feynman to date, he pointed to an organizational chart, to a box fairly high up on the chart labeled "Diffusion Unit."

"My official job is group leader for the Diffusion Unit," he explained. "Among other things, I am responsible for the mathematics, and the design, configuration, and testing of various ideas about the size and shape of explosive effects—how to manage the effects of bomb blasts, in other words. Your job is the mathematics. Let me know if you have any questions."

Feynman's chart showed branches to two smaller boxes below the Diffusion Unit box. One was marked "Computation," and the other was marked "Field Services." Computations is a small staff of mostly women—many of whom are the wives of project scientists and facilities staff—who work through the masses of data generated by a single bomb blast test. Field Services is a small staff of mostly men who will build the blast chambers to my own specifications. Other Field Services staffers will build and install the explosive devices, and then the firing and safety mechanisms needed to control the explosion. Finally, another group will install the sensors, telemetry, and audit procedures needed to generate accurate data on the composition of blast effects.

One of my senior staff very young, very new but very well educated, eager and ambitious asked why there were three separate elements in the work of Field Services. "The three elements really have very little to do with project security. Each of the three elements are areas of knowledge that must be developed by separate teams because no one team can develop and test all the procedures necessary to build the gadget within the project schedule. The key thing to understand," I continued, "is that the process of coordination, communication and data exchange between the three teams will be critical. That is my job, and your job as my subordinate. With respect, if you don't feel up to this you must tell me immediately."

The staffer nodded. He seemed chastened but resolved to do the job needed as he walked out of the room. I had to smile.

Once everything has been installed and tested for normative function, a lucky member of the Field Services staff touches off the explosives and creates a big boom, usually with lots of smoke. It is a great job, though dangerous. This real danger became the lesson we all had to learn; not just Konstanty.

I have no problem figuring out what Feynman wants to see from me. My job is the calculus, and I have to use and adapt Newton's 250 year old methods for measuring the relatively slow speeds of the planets around their orbits to now measure the speed of individual atoms moving, in their billions, in orbit, around the atomic nucleus, each near the speed of light.

From talk among some scientific people I have gotten to know around the project, I have gleaned some insight into exactly how the particles at the subatomic level would begin to merge once the fissile material reaches critical mass.

In one design, known as the implosion model, two pieces of highly radioactive plutonium-239 are jammed together in a precisely shaped chamber by a conventional explosion. The efficiency of that jamming together would also dictate the efficiency of the resulting nuclear fission and, therefore, the success of the bomb itself. In a second design, known as the gun model, a piece of highly radioactive enriched uranium-235 is literally shot at a second piece of highly radioactive enriched uranium-235.

I have been on my own in the development of the precision calculus and the physical testing of various bomb and container shapes. I learned early in the process that advanced calculus using multiple partial differential equations is fairly straightforward, but equations that must account for quantum factors and must use statistical mechanics in reporting the resulting output are almost infinitely more complicated.

The word "quantum" had not yet really entered the scientific vocabulary outside the physics community. In the seventeenth century Sir Isaac Newton had called the gravity that holds planets in orbit "action at a distance." In the twentieth century Albert Einstein did have the word quantum available, but he did not accept the implications of it. He called the quantum measurements that hold the atomic nucleus together with its family of electrons "spooky action at a distance."

When I first set up my office, I left a note for Feynman asking his advice on reference materials for the latest thinking on the mathematics of quantum physics. He replied with another scribbled note: "If you don't know Maxwell's equations, start there, and write me a summary of what you learn."

I was momentarily puzzled. Surely thinking that was eighty years old, as Maxwell's was, could not be thought of as the latest thinking in the rapidly evolving science and design of a nuclear fission process driven by wartime emergency. Nevertheless, I resolved to find the paper Maxwell had written and published on the subject.

When I challenged Feynman on how old Maxwell's work was, he insisted that I constantly read about the evolution of knowledge about the structure of the atom, its nucleus, and the dynamics within its cloud of electrons. After Faraday and Maxwell. "Einstein's *Special Theory of Relativity*," he added, "is a must.

"You could also start with my notes on Fermi's work on the pile in Chicago for an overview of how I view these interactions and how they are driving the work here. My doctoral thesis might be useful in understanding my work on 'sum-over-paths.'" Then Feynman was gone, and I had no idea when I might see him again to ask questions about the things I would be reading and the knowledge I would be gaining.

Eventually I came to understand that detailed design on the prototype bomb itself would depend on the accuracy, perfection, and reliability in the results predicted by whatever calculus I will come up with.

For all his bullheadedness and badmouthing, Konstanty had helped me in my work. I hated to admit it, but he had been right about the calculations derived from the particular test configuration that got his hackles up. Shortly after that, Konstanty was seriously injured by a test explosion gone wrong. I had been devastated, but the pressure of the work was so intense that I had to put my personal feelings aside as I began a search for another assistant.

This search will be difficult. I have to find someone who has a lot of experience with applied math and the necessary social skills to help guide the human computers who do the computations by hand. They will need to understand the importance of these computations, which will eventually lead to something much more mysterious, and much more dangerous, than anything analysis alone can lead us to.

Out of the stack of possible candidates sent to me from the Army personnel office, Thomas' name and credential stuck out. Thomas has a recent master's degree in mathematics from Brown University. He has solid paper credentials for the work; has published a couple of articles on the application of statistical mechanics; and, though it is never certain, it looks like he can pass the intense security surrounding anything to do with the project.

Also, he appears to be willing to put up with the highly secretive, sometimes aggressive recruitment process that precedes any appointment to the Project. Sometimes that willingness on the part of the candidate, by itself, raises red flags among those involved with recruitment. When a flag is raised everything stops until the problem or question is resolved. The resolution of high-level security concerns often requires an extra push by Feynman; by his boss, Hans Bethe; and by the Project's science manager, Robert Oppenheimer.

Thomas's main problem, it seems to me, is that he is young and does not know anybody in the higher reaches of advanced math and physics in play on the project. After all, Enrico Fermi, formerly a professor of physics at the University of Florence, succeeded in conducting a sustained and controlled nuclear fission reaction in the basement under an unused squash court at the University of Chicago on December 2, 1942, only about 10 months ago. Before that, plutonium, along with uranium, the two materials to be tested for the most efficient bomb fuel, only existed in theory. The facilities for making the fuel do not yet exist in physical space.

Fermi himself, with his Jewish wife, Laura, is a living example of what is really at stake in our global war against the Axis Powers. No Italian scientist, especially not one as accomplished as Fermi, was allowed to leave Italy under the fascist regime of Mussolini, but Fermi's early work in nuclear physics was so fundamental and so important that he was awarded the Nobel Prize for Science in 1938. The Italian government allowed him and his wife to go to Sweden to accept the prize. After the ceremony, they never again returned to Italy.

On the day Fermi's "atomic pile" in Chicago created and sustained the world's first nuclear fission reaction using uranium-235, the coded message to President Roosevelt was: "The Italian navigator has landed in the New World."

I have read through the letters of recommendation for Thomas several times. As I look at them, again, the comments of his advisors and professors still glow with enthusiasm. They have told me that Thomas has thoroughly studied James Clerk Maxwell's primary, world-changing work on electromagnetism. Thomas has written a couple of papers extending some of Maxwell's ideas in ways that could enhance our work in the Theoretical Division. Plus, in the words of one mentor, "There is no question in anybody's mind that Thomas is the smartest guy in the room."

"Even at his young age," one of his advisors said, "Thomas has written at least two very insightful papers on Maxwell's experimental work on optics, as well as additional monographs on electricity and magnetism, and he understands the fundamentals of math in new and creative ways."

It is these heartfelt recommendations that cause me to literally ignore all the other noise associated with his somewhat offbeat upbringing and family life.

Besides, I have such an urgent need for someone who knows enough advanced math to oversee the calculation process that I have practically begged Feynman to speak for this candidate with Hans Bethe, and with Oppenheimer if it becomes necessary to ease Thomas past any security concerns.

I learn from his file that Thomas has one other problem, interesting and largely unprecedented since Alexander Hamilton fought alongside General George Washington in the Revolutionary War. I tell Feynman that Thomas has family in Haiti. His parents now live in New York City, and one of his parents is black. He is the great-grandson of slaves.

I am on the wooden sidewalk connecting some of the Army-style living quarters as I argue my case with Feynman. Aside from his brilliant work in theories relevant to bomb design, Feynman is a very popular guy around the Project mostly because he is always available to fix some kind of machine or pick a jammed lock that is holding up progress on another scientist's urgent project.

Feynman is initially reluctant to put a word in for Thomas. From my description, he says, it sounds like he might have to use up many, many of his precious political and organizational chits in order to bring a half black, untested mathematician with a Caribbean accent onto the project. Worse, in Feynman's eyes, Thomas may not really know anything useful about the new mathematical minutiae we are using that is needed to keep the data that drives the project's fission design, testing, and developmental processes on track.

I intend to persist enough to keep the pressure on until Feynman quits fighting me.

Suddenly, though, Feynman makes a decision. "All right, Sarah. I'll include a meeting with Thomas during my next trip to the East Coast to consult with project scientists there."

I am delighted and somewhat flabbergasted with Feynman's initiative on my behalf. I excuse myself and go to my office to start making the arrangements by phone after working out the details with our designated security officer on the mesa. Thomas will come to New York to meet with my avatar, a "departmental superior" at the university I am "recruiting for."

When Thomas asks me what university that might be, I can only say, following instructions from Groves' security staff, that they are involved with a wartime project that is top secret. Thomas accepts this idea and agrees to wait for the departmental superior to show up.

I tell him that that person will simply sit down at his table at a well-known restaurant in midtown Manhattan and introduce himself as Dr. George Brown.

The "well-known restaurant" and the details of when and which table will be made known to Thomas within two days of the meeting. His travel and hotel arrangements will be taken care of. He will only need to come to the designated ticket window at the railroad station in downtown Providence, Rhode Island, and introduce himself as Thomas Brown from New Orleans. The ticket agent will then hand him his already paid-for train and hotel ticket package.

I found out later that, in the back of Thomas' mind, he could not entirely suppress the idea that this was all a huge joke. If he let his imagination flow freely, he could see someone in a plain, dark brown overcoat jumping out of the bushes at him in New York, threatening him with a handgun that popped a flag out of the barrel marked BANG! He chuckled at the notion.

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Sometimes, I get bogged down in a tangled pursuit of solutions to one of the problems typical of Feynman's requests. During my advanced courses in calculus, I had learned to recognize the point in the pursuit of a solution when I needed to stop trying to force a path to an answer and take a mental break. Everybody doing this kind of work has to know how to do this. I would get up from my worktable and walk around, or I would lie down on the couch and take a nap, or I would lean back in my chair and begin a process of woolgathering over things that I knew to be more pleasant.

I have often recalled the day—Friday, April 30, 1943—that I arrived at the train station in Lamy, New Mexico, after a three-day trip from Chicago. Lamy, a tiny town with a big railway station and a big hotel, the Ortiz, was as close as the Atchison, Topeka, and Santa Fe railroad ever got to New Mexico's state capital. The engineers who laid out the route realized that the hills around Santa Fe made it impossible to run the railway directly into the city.

A small spur line had been extended in 1896, and many new arrivals like me took this rail spur the fourteen miles from Lamy into the small station in Santa Fe. Feynman wanted me to get the best possible treatment, such as it was, on my way to the mesa with its hectic, gritty, muddy world and its barracks-style buildings known to the civilian and military inhabitants as Los Alamos.

I was approached by a civilian driver on the station platform, who greeted me by name. I did not know the driver, but I had been thoroughly briefed on the security protocols and procedures on the Project. I knew a strange man in civilian clothes would approach me, speak my first name, and take my bag to a car parked nearby. Once in the car, I was then driven to a pleasant residential compound at 109 East Palace Drive near downtown Santa Fe.

The entry to the compound was marked by a small, blue sign with red lettering that read, enigmatically, **U.S. ENG** on the top line, and then, on the bottom: **RS**. This was the only point of contact in the city for almost all civilian and military personnel, and for much of the material passing through Santa Fe on the way to Los Alamos.

Once inside the compound, I was taken to a small office in the back. There, Dorothy McKibbin greeted me warmly.

"I think you must be Sarah," Dorothy said with a smile. "Welcome to Santa Fe."

"Thank you," I responded. "Here is a copy of the orders that I think I am supposed to give you."

"Yes, thank you. You will have to fill out this form so I can give you a letter of authority to go up to Los Alamos."

I had just come out of the warm and rather carefree embrace of academia. I was not used to the possible demand that I "fill out" an official-looking—not to mention officious and scary-looking—military form.

Jokingly, I asked, "What happens if I don't fill out the form?" "Then I can't issue your pass," Dorothy responded with a smile that suddenly looked a little less warm." I'll let you think about what might happen on a top secret military base if you are caught without documented authorization for your right to be here."

I felt admonished. I took the form, looked Dorothy in the eye, and apologized for my devil-may-care attitude. I took my time so that I could carefully fill it out.

As I turned to go back outside to find my driver and my ride up to the mesa, Dorothy left me with this parting comment: "I think you will do fine. Be glad that you had a more or less friendly introduction to project security. Up on the mesa there are some people in uniform with guns, and they can sometimes get very excited when they think there is a security problem standing in front of them. Be careful and good luck."

I waved and thanked Dorothy. Obviously, she carried a lot of weight on the project. I expected that I would see her again. When that happens, I will know better than to ask a dumb question.

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By late summer, processing the huge quantities of data emerging from testing designs and configurations has become the single biggest bottleneck in the work of the Theoretical Division. Each configuration test run against protocol produces hundreds of thousands of data points; all have to be processed by hundreds of people called computers or calculators using mechanical calculating machines sometimes called "comptometers." These are made by Marchant and are powered by manual hand cranks, which gets tiresome after a while. Machine operators had to take frequent breaks to rest their tired arms, shoulders and hands.

Processing the data on the manual Marchant machines requires a series of steps in complicated but rigorous sequences. A single dataset often has to be entered into one of the machines, processed to a result, and then tested to make sure the data is "normative." If it is, then the data in the result can be entered into a different machine with a different set of steps and a different set of normative parameters.

These complicated sequences are prone to a lot of errors, which is a source of tooth-grinding frustration for me. Results have to be constantly checked and rechecked. The constant pressure to do careful, detailed work and to produce accurate, verifiable results is intense. We limit our computers' work shifts to four hours. Otherwise they will wear out too fast, making the error counts escalate and the process downtime accumulate to unacceptable levels. Some of the staff have already started asking for transfers to any other unit of the project.

Feynman's talent for fixing broken machinery is constantly on call by the computers. He responds quickly because the results they produce are critical to the overall performance of the Diffusion Unit. He knows he can't allow this backlog situation to continue, if for no other reason than that Bethe feels the machine maintenance is taking away too much of Feynman's time, which is needed for work on the theory, design, and development of the bomb itself.

Eventually, I was told that Bethe, for that very reason, has told Feynman to stop doing machine maintenance. His valuable time and talent are needed on theory, not mechanism. In a way Bethe's concern mirrors the general concern across physics since Newton, Faraday, Maxwell, and Einstein: "Is there such a thing as a 'real' object, with mass, dimensions, and boundaries that can be measured by numbers that can be added, subtracted, and in other ways 'calculated,' or not?"

Making progress in finding an answer to that profound and persistent post-Einsteinian question is very much within the mandate of the Theoretical Division and, therefore, very much within the direct and explicit responsibilities of Bethe and Feynman. And they look at me with the expectation that I know how to set up the math. I hope every day that I will not prove them wrong.

As the supervisor of the computation unit I have to think about all these things and try to follow Feynman's casual and seemingly off-the-wall comments on what I should be looking for in a subordinate. One of his comments, for example, had to do with George Babbage and Ada Lovelace. I had read about Babbage in school and some poetry by Lord Byron. I had not learned, however, that Byron's daughter Ada was something of a math whiz.

Feynman had said: "When you are thinking up questions for your prospective computation supervisor, why don't you ask them what they know about Babbage and Lovelace? If they say, 'Who?' My advice to you would be to thank them for their time and send them home."

In order to avoid embarrassment and a possible firing of my own, I quietly looked up Babbage and Lovelace in the compound's library. Early in the nineteenth century, George Babbage and his eventual protégé, Ada Lovelace, had set out to build a machine that could do arithmetic functions with speed and accuracy. With extensive financial support by the British government under Queen Victoria and her husband, science enthusiast Prince Albert, Babbage and Lovelace made great strides in developing the actual machinery and programming techniques for scientific calculations.

These were to be working machines driven by steam. Unfortunately, Babbage was only able to build a small working prototype before the escalating costs of development approached that of a major warship for the British Navy in that day. The main problem seemed to be not with Babbage, but with the lack of well-developed standards of manufacturing for metal. In particular the irregular quality of brass used by Babbage caused errors that accumulated as the mechanism in the Babbage machine progressed toward a solution.

The accumulated errors too often stopped a complicated calculation procedure before it could produce a meaningful result. Babbage's inability to move his machine past the prototype stage caused the British government to terminate the development funding. Nobody stepped forward to take over the ideas in the prototype established by Babbage. Lovelace, though she was willing to continue the work toward an analytical engine, began to sicken with a gastrointestinal disease. She died in 1852 at the age of thirty-seven.

In reading up on them I discovered that Ada Lovelace was much more than a simple math whiz. Working with Babbage on what Babbage called his "difference engine," Lovelace had begun designing what was eventually called an "analytical engine" to be built following their expected success with the difference engine.

In those days weavers could weave their spun yarns into customized designs by use of a Jacquard loom. Lovelace developed a system of programming based on the Jacquard loom, which would make it possible to analyze any data on any subject using the computation capability of Babbage's difference engine.

With the story of Babbage and Lovelace in mind, our project managers reason that, as the largest and most well-known provider of commercial data processing services, International Business Machines should be able to help us with our growing calculation problem. Unfortunately, the problem in the way of finding answers to the technical and mathematical questions arising out of studies of nuclear fission is not only about the money. It is also about the application of mathematics in ways that go far beyond anything that has ever been tried before. The calculus developed by Newton in the seventeenth century can provide rigorous approaches to many of the known nuclear forces that need measurement, but there are so many unknown aspects that can only be understood by brute calculations of billions of nuclear particles moving among each other, with all their accumulated and explosively expanding masses, at speeds approaching the speed of light.

In the explosion contemplated for the bomb, the time between achieving critical mass and the maximum explosive yield is a matter of a few billionths of a second. A few billionths too early and the fission will stop without exploding; a few billions too late and the effects will be unpredictable, possibly catastrophic to an unknowable extent.

The factors affecting the length of the time between a failed reaction and a possibly catastrophic one include the mass and shape of each of the two chunks of plutonium to be merged; the shape of the merged chunks at critical mass; the shape of the container containing the merged chunks; and the purity of each of the materials in the explosion chamber.

This thinking leaves aside the question of bomb delivery. Can the device be shrunk enough, and can an airplane be built big enough to carry the bomb to its target?

As acting supervisor of the computation unit I felt it was my duty to see for myself how this process of taking raw explosion data and running it through a series of independent data processing and validation procedures worked to produce information that we could use in bomb configuration design.

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Unfortunately for the managers of the Manhattan Project, the technology needed to extend the Babbage-Lovelace prototype into a production-capable calculation system has never been built. Whatever happened when Babbage and Lovelace demonstrated their prototype to Queen Victoria, no further development money would ever come to Babbage-Lovelace from the British government.

The Project's military and scientific managers had no real choice but to create a formal Diffusion Unit with Feynman in charge to try and figure out a solution. Among the Diffusion Unit staff we feel there is no one more qualified to build a diffusion process than Feynman.

Having seen his skills up close it has become clear to me that Feynman is the guy who will try anything, including the dumbest and nuttiest-sounding ideas, even when the opposition is hostile, in his attempt to try to make something work. The result of his wildly creative but often scattershot approach to problem solving often succeeds when others have given up long before.

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At a party on the mesa after Feynman returned from New York, he gave us a summary of his first meeting with Thomas.

Feynman met with Thomas at a small restaurant called Julio's Bistro on the corner of Fiftieth and Seventh Avenue. He recognized Thomas from the pictures I had shown him. He told me that he walked up to the man, sat down, and said, "Hello Thomas. My name is Fred Brown."

Thomas later noted that "Fred Brown" wasn't much older than he was. In fact it looked like he might be younger. "Should I shake hands with you?" Thomas asked.

Feynman's finely tuned ear could not help but notice Thomas' careful but not quite successful attempts to control his Caribbean accent. "Of course." Feynman stuck out his hand. "We're pretty secure here, but I can't tell you exactly how secure. If you come to work for us you will begin to understand the full extent of it. I understand you are from the Caribbean, and you know something about math. Is that right?"

"My father was born and raised on Haiti. His parents, my grandparents, were both black at least for a few generations back. Few people in the Caribbean will hazard a guess about bloodlines if their lineage has origins among slaves working the plantations. Whatever the bloodlines, my father became an accountant, and he was successful enough to be recruited by a major US firm, then relocated to New York, where he met and married my mom.

"My mom was a math teacher, and she and my father both spent a lot of time with me on my homework. Now, I like to think that I know quite a lot about mathematics, especially the application of some math in the area of statistics that has never been attempted before. I don't know what you can tell me, but whatever you can tell me about your current problems in computation, I can certainly tell you what I know and have experience with."

Feynman paused. "I've read your papers on Maxwell's work in optics and electromagnetism. We are finding that some of the mysteries he and Faraday exposed at the molecular level are still mysteries today, but they are mysteries now more at the level of the atomic nucleus and surrounding cloud of atoms."

"I agree with what you say about Maxwell and Faraday," Thomas said, "but what can you tell me about the math and computation problems you are having at the subatomic level?"

Feynman stared at Thomas for several moments. Thomas was calm under this close scrutiny. "Do you know any magic tricks?" Feynman asked.

Now it was Thomas' turn to stare. "Is this a question about whether or not I believe in black magic; whether or not I believe in the scientific method; or whether or not I might prefer to believe in voodoo over mathematics?" He frowned as though he had been profoundly offended. Then he looked up at Feynman to see if he could read his intent.

"It's a simple question," Feynman said. "Give me your honest answer so we can move on."

Thomas thought for a moment, then raised both his hands in front of his face and waggled his fingers at Feynman. "Booga-booga."

Feynman's bursts of raucous laughter could be heard across the room. At Julio's Feynman learned that Thomas also played music, the trumpet. He suggested an uptown jaunt to the Braddock Hotel, where they could listen to the house band play its signature Caribbean music.

They never made it to the Braddock, Feynman told us, and a shadow came over his face. The day was Monday, August 2. On Sunday, the day before, a black GI had seen a white police officer trying to arrest a black woman for disorderly conduct. The GI sought to intervene. A scuffle ensued, and the policeman apparently shot the GI. A riot began that lasted for two days.

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"Focus on the question at hand," Feynman would say. "Ignore all of the issues and history that brought us to this particular problem in the first place."

This was Feynman's entire life and his entire attitude toward the problem's others had long since given up on. His doctoral thesis merely reflected his most fundamental attitudes. Paraphrasing again: "When confronting a problem, ignore everything that has nothing to do with it, and be alert to all the possibilities for fixing and repurposing. Don't hesitate to try off-the-wall fixes that might sound stupid at the time.

"Most important of all," Feynman instructed us, "try not to make a mess."

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A month after the incident at the Braddock Hotel in Harlem, Feynman calls me, Thomas, and Konstanty to a short meeting in one of the labs used by the Theoretical Division. Though still somewhat shaky on his feet, Konstanty is back at work and trying his best to reconnect with the other members of his field team and his other collaborators on the Diffusion Unit team.

"I assume you've met Thomas, Sarah?" Feynman asks.

"Yes. Of course." I turn to Thomas. "I have been showing him around and introducing him to the human computers while we wait for our new computing machines to show up. Maybe he has some thoughts he would like to share with us about what he has seen so far?"

Thomas clears his throat. "Yeah, thanks to you both, very much, for bringing me on to this project. I have been getting the whole story from the women who are working the Marchant machines about the kind of data you are processing, and the steps you have set up to handle the calculations. My compliments on your process arrangements for handling the data. It should all go quickly from paper onto the punch cards. If we can get those machines set up quickly, we should be able to start processing real cycles of digital data within a couple of months.

"I think I do have a few mathematical tricks I can contribute to the solution of the main problem you are dealing with now, the shape of the blast effects. You will have to merge the partial differential equations of Maxwell with the statistical mechanics that can deal with the fuzzy positions of nuclear particles. Have I got that right, more or less?"

"My compliments to you, Thomas," I say. "You have picked up a lot in a few days."

Feynman agrees "I'm looking forward to seeing your work once you get your teeth into some of the real problems we're dealing with here. One more thing I want you to take a look at before you start locking yourself into approaches and methods that you think will work: read my doctoral thesis, and work through enough of the math to get an understanding of how I think we need to work out the identification and analysis of forces when particles collide in a condition of critical mass."

"I'll get right on it," Thomas says.

Konstanty chooses that moment to jump into the discussion, glaring at Thomas. "Wait a minute. With all due respect, who the fuck are you? I don't remember seeing your name on any paperwork." He looks toward Feynman and me. "Did you guys forget that I work here? What the fuck is going on? Are you guys just hiring off the streets now? What is his security clearance?"

I do my best to hide my frustration. "I had to make a lot of decisions in your absence, Konstanty, including the recruitment and hiring of Thomas. There was no way to know your real condition, nor could we know if you would be back on the job in the foreseeable future. Dr. Feynman and I consider Thomas to be a capable addition to our group. We both expect him to do very important work in the integration of our manual data processing with the IBM systems that are being installed and tested as we speak."

I cross my arms. "Frankly, Konstanty, I am a little concerned about your attitude toward Thomas. I assume you have never met him, so I am wondering if you have ever had to work with a black man before?"

"No. And I don't particularly want to start now."

"If that is what you want, we can arrange that," I say. "You need to understand that I am not going to let Thomas go without a fight, let alone on your say so. I need his skills on my team. Besides, after the fights I have had with some of my sisters and faculty members in college, I don't think you are going to be much of a problem."

There is now a pause in the discussion. Konstanty is looking down at the floor. Thomas looks like he is about to say something. I scowl at Konstanty. At this moment, in my mind, he has no right to free speech.

Feynman speaks up. "You need to say something, Konstanty. Right now, I am wondering if we have a team that is capable of the kind of collaboration I need to help me get through the work in front of me. So, answer the question: do I have a team or not?"

"You have a team, Dr. Feynman," Konstanty says, "but I am not sure I should continue to be a member of it. My parents are typical Russian peasants; they suspect everybody who does not swear to the Russian Orthodox faith, and their obeisance to the practice of that faith has not mellowed during their time in America."

Konstanty walks over to Thomas with his right hand extended. "I'm sorry for my bad behavior," he says. "I am sure you are a good man, and I'm sure you are well qualified to do the work Dr. Feynman and Sarah have in mind for you. My parents have given me a load of bad impressions to carry with me in life about the evil done by people who do not live by The Book.

"I have only recently begun to realize that almost every one of those evil people my parents talk about is of a different race than are the white European 'true believers' in the Russian Orthodox Church. I am sorry."

Thomas clasps Konstanty's hand in his. "You don't need to apologize to me, but I have to admit that I have had warmer receptions on meeting someone new. On the other hand, I have had much worse receptions, but none of those perpetrators has ever stepped forward to shake my hand afterwards. I hope you will stay on with us because I look forward to working with you."

"Sarah, I think this is a good time for you to take Thomas and Konstanty down to the explosives shack and introduce everybody around to the sapper crew down there. Once you're done, I'd like to have Thomas give me his thoughts on what we need to do to speed up the turnaround on explosion data once we get our computers set up," Feynman says.

I nod. "I'll call up a jeep. Konstanty, are you up to reintroducing yourself to your crew?"

"Yes, I am. But I want you and Dr. Feynman, and Thomas, to know that I still need to assess what I am now seeing as my new life since the accident and the coma. I still need to decide if I am in the place I need to be and want to be."

Feynman spoke up. "While you consider your options, Konstanty, I have some news you might all find interesting. Some of part of the scientific staff here have been working to resolve the technical problems of manufacturing Plutonium in the quantities we need to even run an initial test of our designs for the implosion model of the bomb chamber. We were told that the process designers for the making of plutonium might be able to produce a few grains as samples last spring. However, that proved to be way too optimistic."

Feynman continued. "In fact, they have only this past week managed to produce a couple of tiny specs of U-239. As part of my job to keep track of the manufacturing process I was able to get one of the techs involved with the process prototype at Hanford to send me these.

Feynman pulled a small box out of his pocket. It looked like a box for an engagement ring and perhaps it had been that exact thing once perhaps in making a proposal of marriage to his wife, Arline, now bedridden in Albuquerque with tuberculosis. By one barely legal subterfuge or another Feynman has managed to escape the mesa almost every weekend in order to visit his dying wife.

He flipped the lid up and with a pair of tweezers he lifted aside one corner of a piece of black cloth.

Inside, laying on the black backing lay two tiny, barely perceptible dots of something that looked like they might have been carefully scraped off a piece of light grey metal. Perhaps they had.

"Behold. Plutonium," Feynman said. "Don't touch."

I got closer. I had to take my glasses off and move them toward and away from the two particles in order to bring them into some kind of minimal focus. Suddenly my flesh grew cold and I could not stop shaking. My mind became flooded with the horrible images my family pass along to me almost every week from what they hear of persecutions of our close relatives in Europe; about Kristallnacht, and about neighbors and friends being stripped of their possessions then taken away to work camps. In 1937 my parents arranged a trip to Paris with some school friends to celebrate my good grades. My mind now flies to Pablo Picasso's Guernica hanging in the pavilion at the Paris International Exhibition.

Shortly before, Picasso had the painting taken away to the United States to keep it away from Spain's Fascist dictator Francisco Franco.

Even so my vision of the painting and of the people and animals being torn apart and the awful screaming of the children as Hitler's bombs exploded gripped me in the terrible embrace that Picasso's work had created and held inviolate in my suddenly disordered mind. At Franco's invitation German Chancellor Hitler had done his bombing of Guernica, a small Basque farming community in northwest Spain, just to give his pilots and bombardiers and new bomb-carrying aircraft some practice dropping high explosives on helpless civilians. No warning had been given.

I backed away. I was overwhelmed with emotion. Tears came to my eyes. It was our job to take these tiny specs, these two tiny particles, and apply sciences to them that we barely understand in order to create a destructive device that we can barely imagine to burn and destroy an enemy and the men and women in their armies and navies that we have never met.

"And what of the children?" I thought to myself. "What of all of the little children?" My tears now flowed more freely. I excused myself and stepped from the room.

The last thing in my mind before I ran into the bright sunshine outside the building were the words of Alexander Graham Bell on the first successful test of a device that would become a telephone in every American home: "What hath God wrought."

It has become so easy to ignore what we're doing, holed up in our offices, distracted by the day-to-day minutiae of finding computers and hiring staff. I am ashamed that I have lost track of the gravity of our situation. We are doing something that will change the twentieth century beyond recognition. The dark spaces between atoms will strike like flint, become weaponized. They will mushroom, and light the air afire. They will rain down on children. They will enforce pain and suffering. They will support the war machine. They will enforce peace.

I look around from face to face. There is grim hope, there is fearful expectation. There is a fevered sense of discovery.

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