

Thank you.

HIS ENCHANTRESS OF NUMBERS

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During two weeks in September, 1996, my wife Barbara and I traveled to England. The purpose of our journey was to discover more about the Babbages, my wife's maiden name. As a family genealogist once said, "Somewhere around the fourteenth century the Babbages rose out of the mists of Devon," so we made our headquarters in Exeter. Soon after settling into the hotel where Oliver Cromwell once kept his horses, we drove to a small town called Ashreigney, a short distance north of Exeter, where Barbara's family trace their lineage. We were especially interested in discovering more information about Charles Babbage, the great nineteenth-century mathematician and inventor, the "father of the computer," and Barbara's exact relation to him. On our travels through Devonshire, we stopped at the ancient town of Totnes, where Charles spent his early schooldays and where there is the Totnes Museum, with one room dedicated to the achievements of the town's most famous son.

A week later, while in London, we visited the Science Museum located in Kensington. Inside the Museum are two large rooms dedicated to Babbage's achievements. In one room is Babbage's Difference Engine no. 2, which was built at the Science Museum based on his original designs and completed by two engineers to celebrate the bicentenary of the inventor's birth in 1791. Despite his original concept and meticulous design, this is the first of his calculating engines to be completed. In an adjacent room are large-size photographs and drawings of him, in addition to numerous references to his many other inventions. In the same room there is also a portrait of a beautiful young woman with aristocratic features,

holding a fan and gazing with serene confidence toward the viewer. The title underneath the portrait read "Ada Lovelace, 1835." I was immediately entranced. Who was this woman and what was her connection with Charles Babbage?

Augusta Ada Byron was born on December 10, 1815 in London. Her mother, Annabella Milbanke, Lady Byron, and her father, George Gordon, Lord Byron, were both of the British aristocracy. Ada's parents were gifted and talented, yet very different from each other. Lord Byron, as we know, was the most popular and admired poet of his day during the Romantic period of English literature. Lady Byron, less known to us, was part of the emerging scientific age in England, and had herself a keen analytical mind.

Augusta Ada was Lord Byron's only legitimate child and by the time Ada was only a few weeks old, her parents were unable to resolve their differences. A clue to their difficulties lies in the fact that before his marriage Byron had been pursued by several passionate young women, among them Lady Caroline Lamb, who wrote of him that he was "mad, bad, and dangerous to know." He in turn described Lady Caroline as having "lava flowing through her veins." So, seeking escape from those wild young women, he had married the rather passionless and prudish Annabella Milbanke. Byron quickly realized that this marriage would, in his words, destroy him. She, on the other hand, was constantly worried over his indebtedness, which caused him to drink heavily and become violent. The union of these two radically different personalities was to last only eleven months. Annabella felt that she had no choice but to leave him, which she did in January, 1816, taking Ada with her to live temporarily with her parents. In her exact words she described Byron as having melancholy moods and a dangerous fancy, one who was depraved and evil, even insane.

Byron, after his departure, had a comment or two to make about Annabella's judgment of his sanity. From Canto 1 of Don Juan there is a thinly disguised description of Annabella in the characterization of Donna Inez, Juan's mother:

For Inez called some druggists and physicians,
 And tried to prove her loving lord was mad.
 But as he had some lucid intermissions
 She next decided he was only bad.

When Ada was two years old, her mother was determined to protect her from what she called the "poetical colourings of circumstance" and save her child from "the evils of paternal heredity." Thus, Annabella, having sole custody of Ada, saw herself as a moral guardian, shielding her daughter from anything related to Byron's scandalous and profligate life. She saw to it that Ada be exposed to a type of education focusing on mathematics. She had tried earlier, a futile attempt, no doubt, to impose what she called a rational discipline on her husband. She was now determined to impose on her daughter a discipline to, quote, "keep emotions in check" and "to train the mind." Mathematics was a discipline with which Annabella was familiar, one to which she had for some time been exposed, and one which she felt would have precisely the opposite effect on Ada from anything associated with her father.

Byron left England in 1816, never to return. He had been tormented by creditors and hounded by the scandal of the incestuous relationship with his half sister, Augusta Leigh, after whom Ada had been named. That illicit relationship was certainly another reason, if not the primary one, for Annabella's leaving him. However, Ada remained in his mind and heart until the day he died. In Childe Harold's Pilgrimage, he addresses her as "sole daughter of my house and heart." Those tender feelings were not directed toward Annabella. Byron referred to her before their marriage as "The Princess of Parallelograms", later as "the mathematical Medea." Again from Canto 1 of Don Juan he wrote of her: "Some women use their tongues – she look'd a lecture/Each eye a sermon, and her brow a homily/Her thoughts were theorems, her words a problem-
-/She was a walking calculation-in short, a prodigy."

A prodigy was exactly what Annabella wanted and expected Ada to become, that is, a mathematical prodigy, since Annabella herself was a talented student of mathematics.

During her childhood and young adulthood, under her mother's strict supervision, Ada was immersed in the discipline of mathematics. At the age of five, she showed a remarkable talent not only for mathematics but also for music. Her mathematics tutor, William Frend, had also been Annabella's. He felt that Annabella was putting too much pressure on her young daughter to learn this demanding discipline at such a break-neck speed, concerned that it would be a risk to her already fragile health.

A few years later, Annabella wrote to her friend and, by now, Ada's tutor, William King: "The greatest defect is want of order. For this mathematic science would form the best remedy." King was expected to "instill virtue" in Ada's brain and impose on her a "moral" discipline, which, according to Annabella, tended to "control the imagination." It should be noted that, in his absence, Byron was intensely concerned about his daughter's educational progress and welfare. He kept in close touch with Augusta Leigh. She provided him with necessary information concerning Ada's upbringing in addition to the status of her health.

Ada's tutors continued to guide her into "moral and mathematical maturity", using Annabella's phrase. Ada was to be free of frivolity or anything undisciplined. Others who had an influence on Ada's mathematical development were Augustus de Morgan, renowned mathematician who admired Ada's intellectual curiosity and talent, and Mary Somerville, who was highly respected, having established a reputation in mathematics. At the time, in the cultural climate of nineteenth-century England, there was the belief that women were not to be involved in intellectual pursuits, that they were not strong enough for mental exertion, and that it was inappropriate especially for a lady to be involved in scientific activity. Mary Somerville was an exception. Here was a successful woman in a male-dominated world of mathematics, who knew all the leading scientists of the day. Ada at last met this very special person, one whom she wished to emulate. It was with her and her mother, acting as chaperons, that Ada, now seventeen, was introduced to prominent English scientists and mathematicians. She became

immersed in a world to which she could relate as she attended lectures and observed current inventions.

During the year that she was presented at court, 1833, Ada and her mother attended one of Charles Babbage's soirees, to which he had invited numerous other leading scientists. Babbage had already established a reputation as a prominent inventor. He had held the prestigious Lucasian professorship of Mathematics at Cambridge and had been responsible for the formation of the British Association for the Advancement of Science. He had previously written an article titled "Reflections of the Decline of Science in England" which resulted in the formation of the Association. He was a critic of the scientific establishment, a prolific reader and writer, as well as a socialite and raconteur. He was also the inventor of a calculating machine, which he called the Difference Engine. At this time he was a forty-two-year old widower, a year older than Annabella, who was one of his acquaintances. Ada was immediately captivated by his brilliance and charm. Being in his presence undoubtedly reminded her what she imagined her father to have been: witty, original, independent, rebellious, and in her own words "lively and large-minded." Here was a socially prominent young woman, daughter of a famous poet, in the company of some of the most prominent people of the day. But it was Charles Babbage, more than anyone else, to whom she related. At the soiree to which she was invited, she felt compelled to find out more about him and his Difference Engine, which had been partially assembled in 1832. This portion represented only approximately one-seventh of the size of the full calculating machine. Those present must have been impressed by the combination of discs, gears, wheels, hundreds of parts in all.

It should be noted here that the development of the first Difference Engine was underway in 1824. Babbage had hired Joseph Clement, a skilled toolmaker and draughtsman, to build the machine, which called for an estimated 12,000 or so parts, weighing several tons. Babbage, being a perfectionist, spent much of this time and money over the years making improvements on it. Unfortunately, after years of labor, work stopped in

1833 due to a dispute with Clement, who told Babbage: "You ordered a first-rate article, and you must be content to pay for it."

Babbage had persuaded Parliament to underwrite a substantial amount of money for the Difference Engine. At first the government was quite supportive of his efforts, advancing him the sum of 17,000 pounds, roughly the equivalent of one million pounds today. However, as time went on, questions were raised about the practicality of this endeavor. Eventually, this much needed support was withdrawn, since patience with the project had worn thin, there being no end in sight about its completion. Confronted with skepticism, Babbage became frustrated and embittered after putting so much of his own time and money into the design and development of his machine. It was apparent that during this period of an unfavorable entrepreneurial climate few cared or really understood the importance of what he was trying to accomplish. "All this is very pretty," said one critic, "but I do not see how it can be rendered productive." Later, in 1842, Prime Minister Sir Robert Peel was more blunt: "What shall we do to get rid of Mr. Babbage and his calculating machine?"

Despite his financial woes, Lady Byron and others were so taken with Babbage's invention, they referred to it as a "thinking machine." Although several calculators had been invented, Babbage's engine was the first known automatic calculator which was designed to calculate a series of numerical values and automatically print the results. Because of inaccuracies of human calculation, Babbage saw the urgent need for the mechanization of computation to produce, he said, "error-free numerical tables of various kinds," especially for use in navigation, astronomy, and surveying. Ada was captivated by the Difference Engine. According to a close friend, Ada, young as she was, saw the beauty of the invention. She referred to it as "the gem of all mechanisms."

In 1833, the same year that Ada was introduced to him, Babbage was facing a crucial decision: whether or not to continue to work on the Difference Engine, which was considered by those close to him as "the finest

product of precision mechanical engineering to date." He had been continually modifying machine specifications and was debating whether to continue to make improvements on it, which would mean even more cost, or to begin plans on another machine, one that he visualized as being more complex with far greater capabilities than the Difference Engine.

Finally, he decided to abandon the first Difference Engine, but in 1847 he began work on the design of his Difference Engine No. 2, a simpler version of the earlier design and the one we saw in the Science Museum. The machine completed by the Science Museum engineers consists of four thousand parts, weighs over three tons, and is made of bronze, steel, and cast iron. It has seven orders of difference and is designed to calculate to thirty figures. It is able to perform long calculations without errors and it was successfully demonstrated in the summer of 1991.

In the years between Difference Engines one and two, Babbage focused his attention on his Analytical Engine, a machine capable of adding, subtracting, multiplying, and dividing and of storing a program as well as data. This was a machine of enormous capabilities, one which he envisioned would "guide the future course of science" and even "alter the ways of civilization," which, in our computer age, is a prophecy fully realized, but which in his lifetime was a dream unfulfilled. Babbage was once more confronted with government reluctance to assist him with the development of his new project. Parliament simply lacked the vision to continue to support Babbage in his efforts, failing to recognize that he was far ahead of his time. One who did understand what he was trying to accomplish and who did share his vision was Ada Byron.

Ironically, Babbage suffered many tragedies during the years he was doing his best work. He had lost his wife in 1827. Four of their seven children had died. One bright light was Ada's entering his life. Young enough to be his daughter, (whom he might have seen as such after the loss of his own daughter) Ada became a kindred spirit who shared his passion for mathematical science.

In 1835 Ada married William King (no relation to her former tutor), who in 1838 became the First Earl of Lovelace. By 1839, Ada, now Countess of Lovelace, and William had three children. Despite her duties to the court and family, Ada was encouraged by her husband to continue her studies mostly on her own, corresponding with Mrs. Somerville and Augustus De Morgan. Both recognized Ada's exceptional abilities. "Her power of thinking on these matters," stated De Morgan, "has been so utterly out of the common way for any beginner, man or woman. . . Her determination has been to try not only to reach but to get beyond the present bounds of knowledge."

During this period of her life, she discovered that what she needed was a profession. She saw in Charles Babbage just the right person to instruct her in the "new sciences", such as statistics. She hoped that he would become her mentor and teacher, friend and confidant. When she was not in his presence, she wrote to him on numerous occasions about her need to discover, with his help, more about the fascinating world of mathematical science. She told him that she would make her mind "subservient" to his purposes: "I scarcely dare," she wrote, "so to exalt myself as to hope, however humbly, that I can be intellectually worthy to attempt serving you. You must stay some days with us." She was referring to one of her homes, Ockham Park. During the years that followed Babbage was to visit both Ockham Park and her other home, Ashley Combe.

In 1841, full of self confidence, she wrote to him: "I believe myself to possess a most singular combination of qualities exactly fitted to make me pre-eminently a discoverer of the hidden realities of nature. . . Mathematics would be the occupation of my lifetime. I consider it now as being my profession." In another letter she wrote to him: "Heaven has given me a mission — a peculiar intellectual moral mission — to perform. . . a striving to appear as a pure mathematician liberated from the world." With Babbage as her guide and mentor, with his assistance and encouragement, she would become what she referred to as "the patroness of a very important invention." She was referring to his Analytical Engine. At this time in

her life Ada yearned for mathematical "glory", to make her mark in the scientific world of England, as had Mary Somerville, to be able to "probe the secrets of the universe." She wrote to her friend Sophia De Morgan: "I hope, before I die, to throw light on some of the dark things of the world."

In 1840 Babbage had been invited to Turin, Italy, to explain to a prominent group of scientists plans for his Analytical Engine and to explain how it would operate. He was always prepared to promote his inventions. This conference in Turin would provide him with a unique opportunity to present his designs and to secure recognition of this particular invention. Present at the meeting was an Italian military engineer, L.F. Menabrea. He listened carefully to Babbage's presentation, which was accompanied with models, drawings, and charts, as well as notations. Menabrea was intrigued with Babbage's presentation and set out to describe the machine as well as the principles involved, to describe how the Engine would be able to act on instructions. Written in French, Menabrea's article, called a memoir and titled "Sketch of the Analytical Engine invented by Charles Babbage, Esq.," was published in a Swiss journal in 1842. When Menabrea's article appeared, Ada, having studied French since childhood, upon the advice of Babbage's close friend, physicist/inventor Charles Wheatstone, translated the article into English. Babbage was ill at the time and unaware of the translation until after it was completed. To the article Babbage suggested that she add her own notes, which she did and which turned out to be longer than the article itself. She signed the notes simply with her initials, A.A.L.

Her translation and "Notes" were published in Taylor's Scientific Memoirs. Ada took Babbage's advice and had the "Notes" published as a separate article. She was very explicit about not wanting him to interfere by marking alterations in her work. Writing her "Notes" consumed much of her energy, since she was paying such close attention to details. Metaphorically, she referred to her "Notes" as her child, which would "become a man of the first magnitude and power." Around this time, Ada had been informed by her mother not only about her father's affair with

Augusta Leigh, something she had probably expected all along, but also that Medora Leigh was their illegitimate child. In spite of the pain of the discovery of this liaison and consequences of it, which to Annabella was "a fearful sin against God," and to Ada a "most strange and dreadful history," Ada relished her work describing the wonderful capabilities of the Analytical Engine.

Ada and her husband, William, wanted to play a key role in helping Babbage gain the recognition he deserved by turning the concept of the Engine into a practical, working model, to make it become a reality. She wanted Babbage to know that he had their full support. Babbage clearly showed his respect and admiration for Ada's "Notes": "She (Ada) has entered fully into almost all the very difficult and abstract questions connected with the subject," he wrote. In letters to her he called her affectionately "my dear and much admired interpreter", "my fair interpreter", "my fair assistant", "my enchantress of numbers." He praised her "Notes" as an original paper: "The more I read your "Notes", the more surprised I am at them and regret not having earlier explored so rich a vein of the noblest metal."

In her "Notes", seven in number and labeled "A" to "G" Ada stated that the distinctive characteristic of the Analytical Engine was the introduction into it of the principle which Jacquard devised by regulation, by means of punched cards, "the most complicated patterns." Babbage had adapted the idea of punched cards earlier. It was Ada who added the comparison: "We may say that the Analytical Engine weaves algebraical patterns just as the Jacquard loom weaves flowers and leaves." She understood how those punched cards could be used to enter instructions and data, like software, as an input device. She also suggested that it would be possible for such a machine to "compose elaborate and scientific pieces of music of any degree of complexity and extent."

The main idea of Note A had to do not with the abstract and theoretical but with the practicality and usefulness of the machine, which was "adapted for tabulating the results of a particular function." She

made an important distinction between the Difference Engine and the Analytical Engine, namely that the former was strictly "arithmetical" and that the results it could arrive at lay within a clearly defined range, whereas there was no finite line of demarcation which limited the power of the Analytical Engine, which, she wrote, "transcended mere number" and only it, not the Difference Engine, could calculate the Bernoulli numbers. Ada was determined to convince those skeptics who had questioned the potential capabilities of the earlier Difference Engine of the logic and superiority of the Analytical Engine.

In 1843 Ada wrote Babbage that she was in "good spirits" and that another year would make her "really something of analyst." "The more I study," she said, "the more irresistible do I feel my genius for it to be. I do not believe that my father was, or even could have been, such a poet as I shall be an analyst and metaphysician." Ada at this time was developing an understanding of what she called the "metaphysical" concept of the Analytical Engine, that is going beyond the technical aspects of the machine, visualizing its potential in a much broader light. She used her imagination to speculate on how the machine might be what she called "a path to a higher truth."

Despite her joie de vivre, ambition, and joy in her work, Ada's health was a lifetime concern. When younger, she experienced various physical problems, such as severe headaches which affected her eyesight. When she was thirteen, she had measles and a partial paralysis which made it difficult for her to walk. Her health and general well-being had always been a concern to her absent father and to Annabella, who kept Ada on a strict dietary and medical regimen. In 1843, at the height of her creativity, she contracted cancer. The remedy at first was bleeding. Then she was given laudanum, a drug used for a variety of illnesses at the time which caused drowsiness, a condition counteracted by brandy, a stimulant. However, this combination had a devastating effect on her, causing her to float in and out of reality. Given her already fertile imagination, these drugs at times stimulated her to enter another world on a "kind of maniac transport, a world of wider and wilder horizons." (Moore).

Annabella was not opposed to the laudanum prescription, but she was to the brandy stimulant, which must have reminded her of her husband's frequent state of intoxication, the cause of his violent behavior. Annabella suggested mesmerism which was in vogue at the time and which, she claimed, relieved her of the need for opiates and stimulants. Ada, however, elected to remain on laudanum, which she felt would be more effective in relieving what she called her real pains.

From 1844 on, Ada's physical decline continued, complicated by back pains, swellings, and gastritis. In spite of extreme discomfort, she had periods of good health and was able to get up and about. She was determined not to be bedridden and once journeyed to the north, two years before she died, to Nottinghamshire to the Byron ancestral home. While there, she went to the burial site of her father and knew right away that she wanted to be buried next to him, to the father she had never known. Ada expressed her feelings about her visit there: "Altogether, it is an epoch in my life, my visit there. . . I do love the venerable old place and all my wicked forefathers." Active as she had always been in her adult years both mentally and physically, Ada yearned for excitement and escape not only from her present discomfort but from the sheltered life with her family. She was satisfied with her marriage of eleven years to William. He was kind and understanding, yet conventional and proper. Ada could not, in her words, "feel him to my mind." Like her father, she wanted to live every day to the fullest. She wanted to "seize the day" before it was too late.

It was then that another man entered her life. John Crosse, son of Andrew Crosse, an inventor and part of the wide circle of prominent people Babbage knew and one with whom Ada had corresponded on scientific matters. John Crosse appealed to Ada because of his energetic and extroverted personality and his shared interest with her in horseback riding, an activity she had loved since childhood. Unfortunately, this shared interest led to an addiction of another sort, betting on the Sport of Kings. Ada enjoyed Crosse's company, and in a short time, became his mistress, unknown to Lord Lovelace, her dutiful husband. Crosse was a

married man with children and Ada's risky affair with him led her down the wrong path and accelerated her tragic decline.

By 1851, Ada was heavily in debt. In her desperation, she reached out to her mother and to Charles Babbage. By this time she was terminally ill with cancer of the womb. Faced with huge gambling debts, she gave Crosse a family diamond to be pawned, one of the items recovered by Annabella, who was faced with having to pay off Ada's debts. During Crosse's visits to her home, Ada trusted him with making secret payments, including those on an insurance policy on her life, a policy on which she borrowed to help pay off her indebtedness. She now felt the need to handle her own financial obligations.

Becoming more eccentric and neurotic as she became older, Annabella turned against John Crosse, who she thought was attempting to blackmail Ada. She also turned against William, her son-in-law, who she thought was responsible for Ada's moral decline and for adversely affecting the once close relationship between herself and Ada. She also believed that Babbage implicated Ada in a supposedly infallible betting system. Drugged and helpless, Ada entrusted Babbage, whom she appointed her executor, with a letter containing instructions in the event of her death. Babbage, realizing that the letter was not legally valid, implored Ada to make out a will, which was never done. Ada was under the false assumption that her mother would provide the sums of money as specified in her letter for Babbage to distribute.

Ada was trying to postpone the inevitability of Annabella's taking control of the house. She wrote to her mother: "I begin to understand Death. . .I will send for you at any minute, but we still have a little time before us." Annabella chose not to wait. Ada now had no control either over the house or over her life. She was coerced by Annabella to amend the bequests in her letter. She went so far as to deny either Crosse or Babbage admittance into the house. Babbage was never to see Ada again. William, already distressed over his wife's suffering, was devastated when he had found out about Ada's affair with Crosse, in addition

to the magnitude of her gambling losses. Annabella, overcome with religious fervor and moral indignation, was determined that her daughter "repent of her errors and confess her sins." She had Ada taken off drugs, which had failed to relieve her of pain at this stage of her illness, believing that her suffering would be "a path to paradise."

Before she died, Ada made William, whom she had never thought of leaving, promise that she be buried next to her father in the burial site in Hucknall Torkard near Newstead Abbey, site of the Byron family seat. Her remains were to be placed in the family vault. William, at last showing courage in standing up to and not being controlled by the formidable Lady Byron, fulfilled Ada's wishes. In the end, Ada also stood up to her dominating mother, to whom she had written hundreds of loving and intimate letters. How does one account for Annabella's bitter feeling toward her only child? She had been so instrumental in Ada's development, encouraging her to excel, providing her with every opportunity to become the mathematical prodigy she wanted her child to be. Undoubtedly, it was Ada's affair with Crosse that reminded her of her husband's illicit affair with Augusta. Both husband and daughter, she felt, had "sinned against God" and deserved punishment.

On November 27, 1852, Ada's death notice appeared in the London Times. It read: "Augusta Ada, wife of William, Earl of Lovelace, and only daughter of George Gordon Noel, Lord Byron, died after a long and painful illness borne with utmost patience and fortitude. She left behind two sons and a daughter." That was all. No mention of her work in mathematics or her association with Babbage. Some time after she died, Babbage wrote to her elder son: "In the memoir of Mr. Menabrea and still more in the excellent Notes appended by your mother you will find the only comprehensive view of the powers of the Analytical Engine which the mathematicians of the world have yet expressed. . .I have only the highest respect for your mother." Earlier, in one of his letters to Ada, he wrote: "Forget the world and all its troubles and, if possible, its multitudinous charlatans, everything in short but the Enchantress of Numbers."

Ada Byron Lovelace was an extraordinarily gifted, creative, and visionary woman, who, had she lived longer, would undoubtedly have made significant contributions to mathematical science. We are fortunate, however, to have her "Notes" and especially the hundreds of letters she wrote over the years to her mother, to Babbage, and others, letters which revealed her varied and complex personality. She remained forgotten for over a century until the U.S. Department of Defense in 1974 developed a software language named in her honor. In a small but significant way Ada helped in the development of computer technology, visualizing its future use. Thanks to Charles Babbage, she has been called the world's first computer programmer. Ada combined the attributes of both her mother and father. She maintained a balance during her life between science and poetry, analysis and metaphysics.

In closing, I would like to quote from Byron's Childe Harold's Pilgrimage, when he addresses Ada in absentia: (Italics mine.)

The child of Love! though born in bitterness,
 And nurtured in Convulsion! Of thy sire
 These were the elements, -and thine no less.
 As yet such are around thee, -but thy fire
 Shall be more tempered, and thy hope far higher!

The following is an excerpt from a sonnet written by Ada which she asked to be inscribed on her tombstone:

The hope, the faith, that Pow'r divine endures
 With latent good the woes by which we're torn.
 'Tis like a sweet repentance of the skies,
 To beckon all but the sense of sin opprest,
 Revealing harmony from tears and sighs;
 A pledge, that deep implanted in the breast,
 A hidden light may burn that never dies,
 But burst thro' storms in purest hues exprest. . .

In her relatively brief life Ada Lovelace possessed the Byronic fire of imagination in speculating how the Analytical Engine, the distinguished ancestor of the modern computer, might be

a "path to a higher truth." She had that necessary creative energy along with hope and faith in the future of mathematical science. Against many odds, she was able to cast her particular light, small but penetrating, on what she called "the dark things of the world," and to attempt, to the best of her ability, to "discover the hidden realities of nature", "to try not only to reach but to get beyond the present bounds of knowledge," and "to probe the secrets of the universe."

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