Time Voyager

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Making myself comfortable in this time period wasn't as difficult as I thought it would be. The long months of training and study had paid off handsomely indeed, and the real telltale, my insufficient acquaintance with the local facts and uses could be nicely disguised under my pretense of being a wealthy foreigner visitor. A distinguished one at that, as no one would dare to upset a guest of Sir Isaac. Such an offence would probably be taken as a personal one by the Great Man himself, and everyone knew better than that. Not that he was actually *Sir* at the time, either, but I couldn't get myself thinking about him any other way.

I knew too that Sir Isaac wasn't an easy character to deal with. Should I have tried to get to know him directly and reveal my real identity and purpose, it would have been the greatest fiasco ever, if not worse. But Fatio was quite another thing. His Swiss roots made him a much more quiet and tranquil specimen of a human being, and he was a keen mathematician too. And of course, best of all for my purpose, he was probably the one and only person intimate enough with Sir Isaac to be able to exert any kind of influence on him. Like talk to him about me. Like being able to alleviate his strong early refusal to meet me or any stranger for that matter. Like finally arranging a secret, late evening meeting for the three of us.

Convincing Fatio wasn't easy either. But after several weeks of sustained effort, I succeeded. Of course it took a lot of persuasive talking and a lot of actual, tangible proof of the kind no impostor could ever manage to produce no matter how skillful. And Fatio was smart, and fortunately for me, of quite an open-minded nature. He was ever the skeptical and would require hard proof to believe, but if given, he would obligue. I still remember the night when, cautiously, I let him have a detailed look at the machine, the very reason why I was there and then. He beheld in astonishment, doubting his own eyes for a long time, then I demonstrated. He took it in his trembling hands, and it was kind of a revelation to him. The knowledge that such things, such devices would be possible at all and furthermore, they would be easily affordable to plain men of a time just around the corner, so to speak, overwhelmed him acutely.

Once Monsieur de Duillier was on my side, we went into high gear. I didn't know exactly the extent of his influence on Newton at the time, but it must have been very considerable, because soon afterwards he told me that he had succeeded in arranging a meeting with Sir Isaac and yes, he had duly briefed him at length about the absolute marvel he was going to see, and about the strange but decidedly trustworthy gentleman

who would present it to him as a truly unique gift and his reasons for doing so. We both knew that Sir Isaac would nevertheless be taken by surprise and initially he would probably be decidedly hostile, but the shock had been largely softened by Fatio's highly persuasive efforts and enthusiasm, and we were both confident that Newton's absolute trust in him and his own longing for utmost mathematical and physical knowledge above all things would ultimately tip the scale in our favour. So the rendezvous was arranged and the succes or failure of our bold project was inminent. *Alea jacta est*. The die is cast.

Next week the three of us were standing in a spacious if somewhat spartan room at Newton's residence. He stared at me at length, suspicion in his eyes, keeping strictly within the limits of good manners but barely,. no attempt at cordiality at all, in sharp contrast to Fatio's warm if slightly uneasy attitude. Once the service left, Fatio made a short, shy introduction, but was quickly overruled by Sir Isaac. He wanted to ascertain at once whether he was losing his time or not as he wasn't the kind of person to suffer fools or tricksters gladly, and he prevented me in the gravest of terms about trying any sleight of hand on him.

He demanded proof at once, but Fatio and I had foreseen this very moment in advance and decided that producing the hard physical evidence at first would be just too much boldness on our part and likely to engender instant disbelief and total rejection. We should first convince him that no fraud was possible at all by performing feats that no contemporary state-of-the-art craftsmanship, science or knowledge could ever hope to achieve. So I told him that I would first demonstrate beyond all doubt that my device worked as stated before I would produce the device itself, and so Fatio suggested that he simply demanded at that very moment the answers to any complicated calculations involving any arithmetic operations or trascendental functions, and I, set apart but ostensibly without any means of hiding any kind of mathematical tables or even writing anything, would dictate the answers back to him with ten digit accuracy, in a matter of mere seconds.

Simple as it may seem, that was a very valid proof indeed as Newton himself knew all too well. He had at leisure times indulged in numeric calculations, just for the fun of it, and had confided to his colleagues that just producing a reasonably accurate value for Pi had taken him so huge a number of hours he would be "ashamed to confess" just how many. He also had to suffer the incredibly tedious, eye- and mind-straining astronomic computations required to verify the results produced by his theories versus an overwhelming amount of empirical data, and was keenly aware of the poor accuracy and tiresome searchs and interpolations required to extract functional values from large, unwieldy tables. He also fully understood that as he was free to ask for any calculations he cared to name right then, and he would get the answers *in situ,* there was no possibility for me at all to have prepared the results beforehand or have enough time to try and compute them by any known methods.

Highly reluctant, but conceding that in all fairness, the terms of the preliminary test were valid and would constitute proof of my allegedly miraculous assertions, he acceded to Fatio's insistent plea to try me and ungainly went on to write in a sheet and then dictate a complex expression, involving an assortment of square roots and exponentials as well as other amenities, with a Pi thrown in for good measure. Consulting my recordings afterwards, this first test was: given *x* equal to *the square root of 51.338573,* to calculate

"the square root of the product of 2 times Pi times x, times x raised to the x-th power, divided by the base of natural logarithms raised to the x-th power, times the sum of one plus the reciprocal of the product of x times 12"

which I readily recognized as part of Stirling's (actually, de Moivre's) asymptotic series expansion to approximate large factorials or to compute values of the gamma function, which surely meant he was dealing with some combinatorial or probabilistic problems at the moment, though he probably used a random argument to rule out any chance of Fatio's or anyone having seen it before. As soon as he finished dictating, I turned sideways and quickly took the machine out of my pocket, out of their view. Just 30 seconds later I dictated back my ten-digit answer in a confident, assertive voice: *7042.182907*

Angry surprise was painted in Newton's face. He had just barely put down his sheet over the nearest table and that disturbing, almost insolent man was pretending to have already calculated the answer to an impossible accuracy in an impossibly short time. Fatio was exhultant, having seen the miracle in action once more. After some seconds vacillation, Newton asked Fatio to join him in verifying my answer, they would calculate the answer themselves. He didn't look at me nor did he warn me of the consequences if my answer turned out to be wrong, but I knew only too well that he would summon in his lackeys, and would probably order them to administer me a deserved corrective, as a preliminary step to have me literally thrown out of his residence. They wouldn't, of course, but that he couldn't know then.

After some preliminaries, both set up to attack the problem at hand methodically and first calculated a down and dirty answer accurate to just a couple of figures or three in order to ascertain fast whether my answer had any chance at all of being correct. Despite Fatio's valuable help, that took the best part of half an hour. Finding it in agreement, they proceeded then to recalculate the answer, this time to greater accuracy. After a further one hour and a half of furious calculation and table-searching, they had produced just four decimal places but couldn't guarantee more than five or six correct digits at most, all of them also in agreement with my ten digit result. At this point Newton foresaw that it could take them the whole night long and the best part of

the following day to achieve a result comparable to mine, and with a grunt conceded that my answer was probably correct.

At this point I thought that he would be tired, but my unexplainable feat had aroused his temper and he wouldn't leave it at that so easily. He went to a small trove, unlocked it using a golden key he produced out of some secret pocket on his vest, and extracted a little, handwritten tome, then set it open near the end and began to dictate some other complicated expression. Upon hearing it, I at once repeated my past performance and recited the computed answer very quickly. Even ten feet apart and sideways, I could see him in my mind , checking my figures against his results, uttering some suffocated curse when realizing their correctness. He then blared another, and another, and yet another. That last one brought up a gasp followed by an interjection as he announced my result to be in disagreement with his. I turned in complete calm, and asked for a manual recalculation. Before long the matter was settled: he had made some transcription error from a table while calculating a sine and his result was incorrect after the very first digit. The new value agreed with mine to the accuracy attained.

Suddenly, he stood at once and confronted me, saying that he didn't know who I was or what my intentions could be, but he couldn't deny what his very eyes had just seen and demanded that I produce at once the uncanny device I had used to perform those miraculous calculations. I knew this was it, for good or for bad this was the culmination of my boldest dream ever, so calmly but without the slightest hesitation and never taking my eyes from his, I took the calculator out of my pocket and put it squarely on the table in full view, a completely anachronic device for the 17th century, something which could not be there and then, but nevertheless against all odds there it was, the last correct result still on its display.

I was certainly luckiest in having Fatio prepare Sir Isaac for this very moment, else the consequences would have been terrible. On seeing the machine, he just could not believe that little box of metal and glass would be anything but an extremely elaborate hoax, and for a moment I feared he was on the verge of actually calling his servants in or worse still, smash it with his bare fist. But Fatio, who obviously was thinking likewise, took him reassuringly by the arm and made him sit at the nearby table. He was shaking, trembling, speechless, eyes focused wide open on the calculator. I sat too, took the machine from the table, then proceeded to demonstrate some simple arithmetic, apparently oblivious to the fact that he wouldn't talk, he would just stare intently. After the four operations, I extracted some square roots giving small integer results, then the square root of *5* to full accuracy. I could swear he jumped a little off his seat when all ten figures appeared nearly instantly. Then I computed an exponential, and some sines and cosines. He was still mute, but losing not a single word of my quiet, slow, deliberately simple explanation.

Despite the many hours we had been together by now, he was in an state of such high exaltation that he seemed full of energy. After nearly collapsing because of the intense initial shock, the man of science and mathematician genius in him had him nailed to the table, wanting to see and wanting to know. Myself, despite feeling wasted by all the recent emotions, I wouldn't dare stop then, and proceeded to explain the very basics of operating the machine, what it would do and what were its limitations. At this point I was very glad to realize that I had taken the right choice when carefully selecting this particular model and no other for our unique project.

This ancient calculator is a real gem, and extremely rare to begin with. Just a dozen or so still remain functional in the whole world, and all of them are strictly museum property. That is, save for the one my father gave me when it was my turn to become the official curator of the magnificent old calculator collection my family had been gathering for the last two centuries. It was a real stroke of good fortune that I had one of them, for it was absolutely ideal for the purpose at hand.

When I decided I would undertake this venture, I spent many months selecting the right stuff. First of all, it had to be one of the ancient models. Modern ones would be absolutely useless in the 17th century, deprived of the worldwide fast wireless broadband communications, petabyte databases and swarm of satellites. Besides, their oral interface and user-paradigm and their human-like assistant-on-screen would be taken for witchcraft and abomination on sight. What I needed was an extremely simple, non-audio, non-video, non-AI, self-contained device, which would seem as little threatening as possible. Also, it had to be very robust and extremely reliable, because any malfunction would be utterly unrepairable.

By the same token, its batteries, not being microfusion ones and solar types being absolutely unsuitable either, they would need to last as much as possible, several years at least, because once dead the machine itself would be equally dead as well, no replacements available as I needed to minimize both the number of anachronic devices left in the past and their weight. That unavoidable requirement meant no extra batteries, no slipcase, and most importantly, no manual either. Only the barebones calculator would make it, so it was essential that it was simple to use, for no manual or written instructions would be left for it at all.

On the other hand, I didn't want too simple a model. Its main and only purpose was to easy the burden of lengthy numerical computations as much as possible, and the kind of work I envisioned for it was in assisting him to test root finders, integrator procedures, and algorithms to solve differential equations. Those requisites meant it would need to be programmable, but as I would have very little time to instruct Sir Isaac to use it and without the benefit of a manual, I'd better avoid any complicated languages or operating systems, it would already be too difficult a task as it was. So it ought to use the simplest programming paradigm possible, that is, keystroke

programming, and it would not include its own preprogrammed functions to do any of those things at all, that would be highly undesirable. Why, I wanted Newton to use the machine to help him *discover* and try his *own* algorithms, not to use the ones already discovered and microcoded into the machine by a bunch of 20th century engineers.

The model I chose met all those strict requirements better than any other. It was very small, so it could be easily concealed and disguised as almost anything, thus helping to keep its existence secret. It was tough and sturdy and would stand heavy home use. Its batteries would last ten years at least. It had extremely simple programming. It included all basic math functions but no built-in solvers or integrators, as specified. And all-importantly, it was non-threatening: it didn't talk, it didn't show a helpful face in a stereographic colour display. It wouldn't even show any texts at all. It would just crunch numbers many thousands of times faster than his intended owner could.

Several hours later, the sun nearly rising, the worst was over. With the full consent of a tired, but by then mesmerized Newton, Fatio had ordered the servants to attend the three of us to our chambers (one having been reserved for me as an special guest, a most rare occurrence in the house) for sleep and restoration, with strict orders not to disturb us till noon, no matter what. I was almost fainting by then, but before abandoning myself to golden slumbers, I cherised the thought of what I had been able to achieve: Sir Isaac taking the machine in his hands, and pressing the keys under my instructions, extremely reluctant at first, fearsome bright eyes when he got his first results. Only Fatio's insistence that he should rest and have some sleep and his feeling extremely tired could make him stop and let Fatio call the servants. But not before he put the machine in the little trove, locked it, and took it with him to his chamber.

Next day, Sir Isaac spoke to me in no ambiguous terms, and demanded to know why. That's it, simply why. Having nothing to hide, I told him at length. He asked a lot of pertinent questions and I gave him all the honest answers. After several hours, my seemingly preposterous claims never contradicting what Fatio had already told him, he was still on guard but for the time being, somewhat convinced. Just for the record, I made it plain clear that I would not give him any information whatsoever about anything, but I would limit myself strictly to teaching him how to use the machine to the extent he would need it.

I also made it absolutely clear that it was exactly that, a mere machine, incredibly advanced for his time, certainly, but just a simple commodity in its own time that any sufficiently wealthy person could buy at the local store, just as he could buy a good slide rule. That’s all it was, an incredibly advanced slide rule, nothing magic in it. Finally, I reassured him I wanted nothing from him for it, at all. He didn't have to sell his soul to me, he didn't have to sign any contract with his own blood or have to pay for it in any way. It was a very special, unique present for an exceptional genius like him, though he would be expected to keep some commonsense security measures. I also

told him extensively about our reasons and goals. Finally, I demonstrated ostensibly that neither he nor anyone else could either harm me or restrict my freedom of movement or prevent my returning to my own time period. You see, the calculator was *not* the only technologically advanced piece of hardware I had brought with me.

Regrettably, for a number of extremely complex reasons I wouldn't explain to him, my stay would last only four more days, and I would afterwards leave his company forever. So we should hurry up and begin his training on using the machine as soon as possible. He agreed, and gave orders to the servants to the effect that no one be allowed to disturb us till he ordered otherwise, everyone asking being told that he was out of the town for a week, taking baths at some remote well-known spa.

After a couple of days I had succeeded in teaching him all the fundamentals on how to use basic instructions and functions manually. I was very pleasantly surprised that he understood everything at once and participated intensely, always asking the right questions, and always suggesting we tried some additional examples from his own manual calculations, almost cheering when the nearly instant results would confirm his own, painfully arrived at.

Then, I undertook the no mean feat of teaching him how to program the machine. Thanks to my election of keystroke programmability, the task was made so much simpler. He understood the concept of loops inmediately, for he had always thought that iterative algorithms were the key to most advanced computations. As for logical tests, that a calculation procedure must require some decisions was also plain to him, as was the necessity for the machine to have a mode in which to learn instructions and another in which to execute them. And thanks to the simple programmable calculator I had selected, that's all there was to programmability. No need to teach him about flags, subroutines, parameter passing, objects, hyper-structures, meta-threads, quantum-parallel methods or AI-driven assistants. So I proceeded to set up some didactic examples for him.

The first one was an extremely simple, non-optimal but quite didactic program to compute a factorial I found among my father's collected papers. It read like this:

*STO 0, STO / 0, STO*0, 1, - , X=0?, GTO 09, GTO 03, RCL 0, GTO 00*

and in its 10 instructions it demonstrated a lot of essential features of the machine, such as using storage registers, performing arithmetic directly on them, use of the stack to hold intermediate results, testing for a condition, branching and iterative looping. What more could you ask from such a short program ? I told Sir Isaac how to teach the instructions to the calculator, which he did himself, then executed them one at a time, using *5* as input, for he to grasp how it all worked. When the result *120* appeared in the display, he was giggling like a child. Then I asked him to dare and try an

example of his own. He did, using *13* as input, then pressing the *R/S* key, as told. When all ten digits of *13!* appeared on the display, he was almost on the verge of crying out of pure joy. So was I.

The next day Sir Isaac, who already trusted me completely and was becoming extremely accustomed to me, told me about some algorithm he had in mind for quickly solving arbitrary equations. Though I wouldn't tell him, I knew he was just in the initial steps of developing the algorithm that would later be known as "Newton's Method" (what else!), one of the simplest and fastest methods available for finding roots of equations. I knew all about it from my research of his work, but was curious to see him explain it firsthand.

He told me the basics behind his method, which simply consisted in using tangents to the curve defining the equation, in an iterative fashion, to help refine an initial guess until the root was found to some prescribed accuracy. He had all steps of the algorithm already worked out, but the sheer amount of lengthy and tedious numerical calculations needed to test it kept him from doing it. That is, till now. And though he knew that he could use the machine manually to easily calculate every individual step, he was eager to try and see if *his* machine could do all steps unassisted using that learning feature I had shown him lately. He then told me the specifics of his algorithm, as yet unpublished. In modern notation, it simply was:

"Given the equation f(x) = 0 whose root x we want to find, and an initial guess x0 to the root, we can obtain a better guess by performing this computation iteratively:

$$x(i+1) = x(i) - f(x(i))/g(x(i))$$

where *g(x)* is the derivative of *f(x)*. Of course, Sir Isaac didn't call it like that, he would refer to it as a "*fluxion*", which was one of the basic fundamentals of his ultimate mathematical achievement, Calculus. I listened with utmost attention as if the concepts were all new to me, then pointed out to him the fact that he could easily give the initial guess as an input and teach the machine how to calculate *f(x)* for any given *x*, but there was no way it could symbolically produce the *fluxion* by itself, being just capable of numeric results.

He said there would be no problem, for he knew how to calculate an approximation to the numerical value of the *fluxion*, like this:

$$g(x) = \lim (f(x+epsilon)-f(x)/epsilon, \text{ for } epsilon \to 0)$$

and thus he assured me that using a suitably small value for *epsilon* he would get a sufficiently accurate estimate for the *fluxion*, subject to empirical tests using diverse

small values of *epsilon* in order to find the optimal one. Once an adequate value for *epsilon* was found, he would compute the *fluxion g(x)*, then use it to compute the refined guess, and so on proceeding iteratively till reaching the desired accuracy.

I agreed, expressed my sincere admiration for his original method, then we spent the rest of the afternoon discussing how to teach the machine his method using the available features. It was obvious that the very simplicity of the machine and thus its limited memory for learning the instructions would make it necessary to use some ingenuity in fitting it all together. I pointed some problematic areas to Sir Isaac (such as the fact that computing *f(x)* more than once per loop would require some clever tactic), as well as the necessity of keeping storage usage to a minimum, so maximizing the space left to define the function. When we agreed to call it a day, a very sketchy preliminary procedure had been concocted, but still no workable implementation. After supper, we both went to our respective chambers, me still thinking about the algorithm while trying unsuccessfully to fall asleep.

Next morning, Sir Isaac in person stormed my room and began to excitedly tell me all about something wonderful he had done, before I was fully awake. Soon after, I began to understand: he had spent most of the night racking his brains to write down the instructions that would fit into the machine and allow it to execute his root-finder algorithm, and he had just succeeded !! Of course, he had already keyed it in and tried it and he wanted me to see it working inmediately, he just couldn't wait.

Still he *would* have to wait, as there were some physical necessities I had to address first, but after that I was all his, and began to scrutinize the sheet he was putting before my eyes. His short list of machine instructions read thus:

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01 STO 0     10 GTO 27     19 STO 0      28 STO 1
02 CLX       11  /         20 PSE        29 RCL 0
03 STO 1     12  1         21  -         30 EEX
04 RCL 0     13  -         22 X=0?       31  5
05 GTO 35    14 STO/2      23 GTO 25     32 CHS
06 X=0?      15 RCL 0      24 GTO 02     33 STO 2
07 GTO 25    16 RCL 0      25 RCL 0      34  +
08 RCL 1     17 RCL 2      26 GTO 00     35 f(x)
09 X=0?      18  -         27 X<>Y       nn GTO 06
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I knew all too well that this man was a true genius, one of the very few the human race has been blessed with in the long millennia, but how on earth did he manage to come up with that listing in so short a time after such cursory lessons is beyond my comprehension. Not that I could rest my eyes on it for long, for he instantly pulled my arm and produced the calculator from one of its pockets. He wanted me to see his instructions in action, solving this particular cubic equation:

*f(x) = x^3 - 2*x - 5 = 0*

which he had already defined into the machine like this, beginning at instruction 35:

*ENTER, ENTER, ENTER, * , 2 , - , * , 5 , - , GTO 06*

Anxiously, he set the instruction counter at the beginning of the list, and told me he would use the number *2* as the initial guess. Then he pressed the *R/S* key, and the refined guesses were displayed one by one, till the machine halted with the computed root in the display, *2.094551481*. He remarked joyfully that he had already verified the result and it was absolutely correct, and so its new tangent method was useable and fast, as it took just five iterations to find the root at that accuracy. He had made his point, his brand new algorithm worked perfectly, and it would converge to a root faster than any other algorithms known to him at the time.

After this triumphant demonstration, he would spend the afternoon trying other equations, testing difficult cases of non-convergence, discovering empirically when a guess would converge to some particular root instead of another. As for me, I was quite happy to leave him to his own devices. His crafty implementation of his tangent algorithm made it clear to me that there was little else I could teach him, and in just over a day I would be gone.

That very night, Sir Isaac left the machine rest for a while and somewhat uneasily confided that he wanted me to know that with my miraculous present I had really injected new energies and new goals in his life and made him feel an enthusiasm like he never felt before, not even when the preliminary predictions from his new revolutionary theory of gravitation agreed reasonably well with Flamsteed's extremely accurate empirical data.

He was now full of ideas for new algorithms he had had in mind for a while but never dared to develop and try for the sheer boredom of the lengthy calculations. He then mentioned a few, such as several to deal with some *fluxion* expressions (i.e: differential equations) he needed to solve in order to further test his new theory of Universal Gravitation by predicting the orbits of major astronomic bodies and comparing his results against new data, as well as some interpolating techniques he had devised to approximate arbitrary functions or sets of discrete values using just polynomials. And he also needed to test some formulae in the field of optics, namely calculating the physical parameters of a mirror for a revolutionary design of his, an aberration-free *mirror telescope* which he expected would work fine after many months of painful labouring, and he was also interested in computing numerically some difficult integrals nobody had been able to express in terms of known functions,

and ... the list went on and on and on. I smiled all the way as I went to bed for my last night there.

Next morning, my goal accomplished, I had to go back. He had already agreed to hide the machine's existence from everyone at all save Fatio, of course, and never, under any circumstances, leave written documents mentioning it or featuring keystroke procedures or programs for it, or anything related to it in general but the anonymous numerical results themselves. The importance of those measures he understood perfectly. But now I had to ask another sacrifice from him. Once the machine ceased to be useful to him, be it dead batteries or be it himself not been able or not wanting to use it again for whatever reason, he should destroy the machine completely, shattering it to pieces, then burning all of them till their total annihilation. I knew the batteries would be long dead before Newton himself would, but I wouldn't tell, of course. Though he felt it would be quite hard for him to do as I asked, to destroy such marvel and remove it from his sight forever, he duly agreed to obligue. I didn't want my departure to be longer or sadder than necessary, so it wasn't long before I was back to normality, if our crazily technological modern life can be called normal.

Needless to say, there were no discernable consequences of our actions, nor could there be at all. Of course Newton had used the machine extensively. But as I knew long before I gave it to him, all his known works and results already reflected the fact, as they inevitably had to. Just have a look at his computation of *ln(1,1)* to no less than *57 decimals* ! I saw him attacking that one just before I left. Or his treaty on 72 different types of cubic equations, which *includes* the one he solved right before my eyes using his triumphantly programmed new method.Once you know about it, you can feel the machine’s shadow everywhere in his results.

As was also to be expected, the Great Man did fulfill his solemn promise, and no remnants of the calculator have survived at all, nor any mention of it anywhere, nor any telltale sign of his using it has ever been found to date on any of his many papers, manuscripts and legacy in general. Not a single X<>Y on some obscure margin. That wonderful machine has completely vanished from history without a trace. Or so I thought.

But if you ever go visiting the magnificent Sir Isaac Newton's National Museum, Cambridge, take a look at that small trove featuring in the second alcove to the left of the stairs, up on the second floor, the one with the small golden key inserted in the lock. If you were to open it, you'd find some handwritten notes, a shattered pen, several old yellowish lenses and prisms, and right below them, among a number of metallic buttons and ceramic beads, a very small bit of material so worn and oxydized that only the keenest observer would ever recognize that rusty little square as a once silvery and shiny HP-10C logo.