Leave a trail...

Edison is credited with many things, including the quote that invention is 1% inspiration, 99% perspiration. In my opinion, Edison was an optimist.

It was over 26 years ago that I led a small team at Hewlett Packard that was pursuing an interesting discovery at HP labs. It turned out that if you heated fluids quickly enough, you could momentarily defy the laws of boiling that we all learned in high school physics.

For a few microseconds, you could coax fluids to temperatures well above their boiling point (at 'standard pressures'). The implication was that you could super heat a small volume of the fluid, and then 'turn off' the heating element and wait for the fluid to 'realize just how hot it was'. (Technically having to do with molecular reaction times, etc). Eventually the fluid would begin to not only boil, but go through a vapor explosion of sorts.

While this phenomenon was both known and named (the super heat limit) what we had discovered is that the phenomenon could be exploited to move fluids through channels very quickly. We fashioned devices with crude thin film resistors, underneath a channel made by running a tiny saw blade across the surface of a microscope slide – and could propel drops out the end of the channel.

An interesting technology demonstration, but our 'one drop wonder' was far short of a breakthrough. Many clever ideas would be needed on the way to what has become HP's largest and most profitable business.

One of those inventions came as we struggled with how to make devices with an 'unlimited' number of nozzles, that could not only spit drops, but who's speed would not be limited by capillary refill down a long channel. On my way to work one morning, I realized if we put the nozzle directly above the heating element, we could minimize the channel fluid resistance between the 'explosion' and the subsequent ejection of liquid.

This also had the advantage of simultaneously drawing fresh fluid from all around the resistor, not just down a narrow channel. In addition, it would yield much more flexible geometries to place nozzles, including staggered patterns, etc. I spent the morning trying to figure out how to quickly demonstrate the idea and prove it feasible.

I rounded up devices with thin film resistors that we had built for other projects, and fashioned a crude spacer with very thin tape. (Clearly the low tech, high hopes model). I still needed to create a very tiny hole in a thin material to form the 'nozzle plate'.

By then it was lunchtime, and my thirst for knowledge gave way to appetite, and I went home for lunch with my wife. As I left home after lunch, I grabbed a sewing needle from my wife's collection. Back at work, I ground the tip of the needle to the finest point I could muster. I took shim stock (think of it as a thin aluminum foil), and started punching holes with the needle. Convinced by this time the contraption could never work, and too embarrassed by the crude approach to show anyone else, I decided, in true Edison style, to 'give it a try' anyway.

I put the assembled device under a microscope to look for the tiny drops being ejected. I synchronized a strobe to the firing frequency of the device, and when I looked under the microscope, the thing was actually firing drops!!

It was one of those exhilarating experiences that Edison must have enjoyed many times.

I was so fascinated with observing the device that I lost all sense of what was going on around me. Not only was it working, but the drops being ejected were HUGE compared to what we had seen previously. (Partly because of the more efficient design, partly because of the crude fabrication techniques).

All too quickly, I could no longer see any ejection of drops from the device. Eventually I looked up from the microscope to make sure the strobe was still firing and the circuit was operating.

As soon as I looked up from the microscope I became aware, not only of my surroundings, but of the root cause of my problem. The device was in fact still operating just splendidly. In fact, too splendidly. The thirsty little guy had almost completely drained the bottle of ink that fed it, and had happily coated everything in sight with a thick black film. This included the microscope optics, the lab bench, and yes – me.

To this day, there is folklore at HP about Frank's tie getting stained with ink from the experience. To set the record straight, there was no tie. (Hey, this was HP, and ties were almost non-existent in those days). However everything else was a disaster. (My wife still hasn't forgiven me for ruining my shirt, and losing her sewing needle to boot.)

That was a good day. But the hard work that followed many of those early ideas was far more than 99 times the effort to come up with the 'inspiration'.

Perhaps an even more important ratio is the relationship between the novel invention, and the ability for that invention to unleash real contributions to users and customers.

Early on, we decided that applying this technology to printers would make a lot of sense. Those were the days when serial impact dot matrix printers dominated. As we originally considered how we would use our new capabilities, we fell into the classic trap of 'incrementalism'. Dot matrix printers were 72 dpi, so we said we would set our design goals at 96. Dot matrix printers churned out 80 characters per second. We set our sights at 120. Our fundamental approach was to be better than the incumbent technology in all of the key specifications.

Eventually, we would realize that this would not yield a revolution in the contribution to our customers. There were no new applications or capabilities that we were enabling, only incremental improvements to the old ones.

At that point, someone observed that we didn't want to achieve any of 'those' objectives, instead choosing to point to the cover of a National Geographic magazine and proclaiming "we want to do that". Some looked at the page and saw scalable fonts, others looked and saw full color printing. Still others saw photo realistic images.

The inspiration in that cover would serve to completely change the way that we thought of the goal. Our ambition was to do the unthinkable (at least at that time). Create an inexpensive technology who's printed output rivaled that of machines costing thousands of dollars.

Our goal was transformed from printing memos, to printing memories (photos, posters, etc).

While it would take us years, many product iterations, and an entire ecosystem of software, displays, and computers that could take advantage of it all – the vision was compelling enough to continue to fuel our ambitions until we ultimately achieved magazine cover quality, and beyond.

The experience has caused me to re-think Edison's axiom. Cloutier's Corrollary says that:

Breakthrough is 50% aspiration, 100% dedication.

Aim high. Work hard. Don't give up.

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This book was written to encourage others to build on some of those early ideas. Its aim is to provide a shortcut through some of the perspiration, while hopefully providing seeds of inspiration.

Many will choose to use the information and devices made available here, to build traditional printing devices. While that is clearly one of the aims of the author, I would encourage you to think more like Edison. What new and novel applications are there? Others have created everything from assembly line date code printers, to machines that 'print' cellular tissue. New applications are limited only by your imagination, aspiration, and dedication.

Finally, I leave you with one of my favorite quotes:

Go not where the path may lead...
Go instead where there is no path,
and leave a trail........

Have Fun!
Frank Cloutier

Foreword