Public Invention

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Public Invention, a US public charity

If you want to build a ship, don't drum up the men to gather wood, divide the work, and give orders. Instead, teach them to yearn for the vast and endless sea.

– Antoine de Saint-Exupéry

The chances of your success are zero, but the importance is infinite; therefore, I support you.

– Sir W. Lawrence Bragg

Preface

This is a draft work whose purpose is explain and promote Public Invention as a movement and philosophy. This work will likely be published electronically by Public Invention (the organization), but we will also seek a print-publisher who is willing to keep the work open access.

– Robert L. Read

Contents

List of Figures

List of Tables

Why Be a Public Inventor

“Invent in the public, for the Public.” 1

Benjamin Franklin (1705-1790) did not patent the Franklin stove because he believed it to be too useful an invention to legally encumber. He has been called “The First American”[1], but I think of him as the first Public Inventor. If you read the autobiography of Nikola Tesla (1856-1943) “My Inventions”[2], you discover a devout public servant (in a non-denominational sense), who certainly wanted to make money but whose deepest motivation was to see human progress. R. Buckminster Fuller (1895-1983) wrote extensively on the act of invention as a moral act: nerve gas is bad, vaccines are good[3]. Richard Stallman (1953-) articulated the principles of free software and in so doing indirectly increased the wealth and well-being of the planet tremendsouly[4]. This book is my attempt to extend and promote the work of those inventors to create a stronger movement which we could call public invention.

We have created a non-profit, also called Public Invention, but will try to keep the very important movement distinct from the relatively unimportant legal entitity.

Invention advances human progress spectacularly. Politicians mostly ignore it. Human history is largely a story of technological advance careening foward from the stone age with an inexorably building speed, perhaps to a frighetning climax. Those who believe it will end in a dark and terrible destruction are not fools; but that fate is not certain. We as a planet can choose instead to build a bright future in which humanity explores the universe together in peace. This will happen only if we understand technology as the powerful moral force that it is.

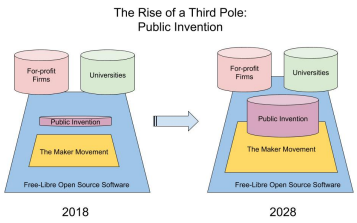

Figure 1.1: The Rise of Public Invention as a Third Pole of Progress

For the last 100 years, technological advance has been driven by two engines: profit and academic research. The modern emphasis of Universities on patenting research and the governmental practice of subsidizing research which is monopolized by for-profit firms has blurred the distinction between the two. Nations have long recognized the value of technology for competiting with other nations via war or mercantilism. Public invention hopes to be a movement that does not replace for-profit research and academic research, but becomes a third engine. The motto of Public Invention is “Invent in the public, for the Public.”

This means the public inventor does not seek monopolies in the form of patents or other intellectual property but gives an invention freely to the whole world without prejudice. Anyone is free to use the invention, including for the purpose of making a profit, but nobody is given exclusive rights to it.

Buckminster Fuller made a clear distinction between what he called “killingry”, or weapons, and “livingry”–that which increase the good in the world. The public inventor must not develop new, more destructive weapons. This is impossible to do perfectly; even a pillow can be used as murder weapon. Nonetheless, technologists are not relieved of the moral duty to invent good things instead of bad things just because it is intellectually difficult to make the distinction. The public inventor accepts this burden and does the best they can.

Love is wise; hatred is foolish. In this world, which is getting more and more closely interconnected, we have to learn to tolerate each other, we have to learn to put up with the fact that some people say things that we don’t like. We can only live together in that way. But if we are to live together, and not die together, we must learn a kind of charity and a kind of tolerance, which is absolutely vital to the continuation of human life on this planet. – Bertrand Russell, 1959

Benjamin Franklin said, “We must, indeed, all hang together or, most assuredly, we shall all hang separately.” His wit was poignant because he meant the American revolutionary leaders would indeed have swung

from a British rope for treason if the Revolutionary war had been lost. But in 2022 his words ring true globally. Buckminster Fuller believed that humanity would either destroy itself or have a bright, Star Trek-like future—there is no middle ground. We cannot continue to muddle along taking weak action on global warming. The COVID-19 pandemic has shown that we are all connected in a most intimate way, whether we like it or not. A disease incubated in my body may kill you, and vice versa. Therefore the public inventor must at some level seek the wealth and health of the whole world. Narrow national chauvinism is no longer a useful or profitable behavior.

We could define public invention simply as invention in the public interest. In that sense, it is closely related to humanitarian engineering. Humantarian engineering requires a great deal of problem-solving, innovation, and ingenuity. The distinction is that "invention" means something truly novel which has never existed before. Public invention values the truly novel, whereas humanitarian engineering values the truly useful.

In the future, it will be common place for people to move freely between the three engines: for-profit firms, academic research, and public invention. Public invention will not replace the other two engines, but augment them. Inventing in the public, for the Public is a moral act, but it is not a moral duty. Some people will be called to be public inventors some of the time.

The Joy of Public Invention | 2

It is easier to be a motivated public inventor if one sees oneself as a minor character in a great story, the greatest story that we can know, the story of human progress. It does not particularly matter if you believe this progress is positive or negative, though Steven Pinker is has argued overwhelmingly it is astoundingly positive. [6] You may see the story originating in Babylonia, Egypt, Athens, Jerusalem, the Chin dynasty, the Enlightenment, or the American Revolution as you see fit. The more history you know, the better, of course. Being part of a great story gives your actions meaning. Your life will not be measured out in coffee spoons if you see yourself as part of a great story.

"You can be the captain, and I will draw the chart..." – Rush, Closer to the Heart.

Much science fiction is dystopian and dark, but almost all places humanity in the arc of some great story, in which the characters are agents. This is not as common in fantasy, but it is true of the greatest fantasy. Certainly, the Marvel Cinematic Universe, the Lord of the Rings, Star Wars, Dune, the Space Trilogy of C.S. Lewis, and the Chronicles of Narnia all accomplish this. Distressingly, the idea of the arc of human progress is less present in political statements than it was in my youth. Without a sense of where we have been and where we are going, politics misses the point, and becomes mere tribal bickering.

TODO: Cite the LoveSong of J. Alfred Prufrock

I dare not say political discourse, which disappeared in America in 1994.

As of this writing, a war is being executed not to move the arc forward, but to restore it backwards in time.

Richard Nixon spoke of population growth and control. Whether you agree or disagree, and no matter the messenger, it was a long-term vision.

Public invention takes the inherent joy of invention and doubles it with the joy of helping others. Making something truly new is a roller coaster ride of emotions. The inventor is frought with doubts. Is the invention even possible? Has someone done this earlier? Am I too stupid to accomplish this? Often a new idea creates innumerable frustrations. The expensive equipment breaks at a critical momemnt. There may be collaborators, but there are no experts to turn to, because by definition the invention has never been made before. Despite all of the doubts and frustrations, or perhaps because of them, the eventual progress, if it comes, is an intense joy.

Comic books and movies have taken a grain of truth and mythologized it out of proportion to create the trope of the lone inventor. Most invention is done by teams. Math, is, in the end, always social, even if each baby step is solitary. The joy of collaboration is part of the attraction of being a public inventor.

Each of us is unique and has unique gifts to bring to the table. In a sense this is true in any part of life, but it is a especially true in the act of invention. However, by definition, invention is making something not just new in the sense of a variation of something old, however unique, but new in the sense of breaking new ground. An invention is not yet another hybrid rose, it is a new kind of flower. Even mediocre inventors such as myself are essential and necessary. The mediocre work makes the great work easier.

Some people have an invention inside them that has to get out. The seed of an idea planted in childhood may mature in the unconscious until the time is right for it emerge. Sometimes this is because of a persons great love of something. We have all seen people enchanting by flying or

infatuated with light. Some people can spend years entranced by a math problem. The inventions may be useful, but unprofitable. Some may even be potentially harmful. Certainly many persons, including myself, are fascinated by projecting things at high velocity, such as in guns, rockets, bows, catapults, or water guns. So long as the invention is not designed to harm, the invention should be allowed to be born, if not practiced. The line between invention and art is sometimes blurred. The public inventor should support whimsical inventions when a person has a strong desire to make it.

The public inventor should not make fakes or toys. That is, the public inventor should not make an object whose value is that it is a miniature mockery of some other object or like some other object which has intrinsic value. Making a model of a beautiful airplane or ship is valuable and fun, but it is not invention. Making a fake starship is creative, but not invention.

However, the desire to make something new even if the utility of the invention is hard to define should be respected. This may be because it is artful, or may have nothing to do with art, and its value may lie in some other dimension. Often, an invention that wants to be made that has no clear purpose is a forerunner of something else which cannot be conceived until the first invention is reified and can be held in hand.

Joy fills invention because the inventor grapples with the sternest stuff—the laws of the universe itself. Though there is frustration and failure, in the end the success is a jewel that gives its own light. A durable, self-contained, comprenhensible thing that sheds its own light. The joy of creating it differs from the love of creating art, which is equal but gradual and soft. A work of art can fail, but it cannot fail to work at all. An invention can to work completely, and often does. When we love another person, our love, however clumsy and misappreciated, means something. A failed invention means nothing.

The Simlmarils were made by Feanor, the anti-hero maker of the Simarillion, who also invented letters. They held the light of the Two Trees of Valinor, and, if not for the pride of Feanor, could have been used to restore them to life[7].

To me, public invention is really about love—love of humanity, of beauty, of the planet, of math, and of my fellow-inventors. For some of us, the joys of learning, collaboration, invention, and helping the world melded together in public invention is the greatest joy we can imagine. At the end of my life my proudest acheivement will be my children, and my second greatest sense of joy will come from the inventions I have given the world, however small they may be.

2.1 Myths and Tropes

Myths motivate us.

Tropes and sub-myths shape our thinking. The real psychological import of the fantasy worlds of the DC and Marvel universes cannot be escaped. The sub-myth of the loner genius inventor as exemplified by Bruce Wayne, Lex Luthor, and Tony Stark can both motivate us and lead us astray. This book can be considered an elaboration of the lesson that Peter Parker, Spiderman, learned in his origin story: "With great power comes great resposibility." We all have power, and if you can be a public

Jesus said the same thing much earlier. (Matthew 25:14–30)

inventor, you have great power. If you have great power, you have great responsibility.

The fictional inventors are surely inspirational at one level. It makes a good and simple story for the slightly anti-social or sociopathic genius to come up with things more or less on their own. The reality is that invention in isolation is not very effective.

If we move from pure fantasy to the merely legendary, there is no doubt that some important inventions have been the work of nearly solitary minds. Isaac Newton was not very amaible and by modern standards was highly secretive. His impact would have been much greater if he had published properly rather than keeping his work secret. He is among the greatest of scientists for creating the theory of gravity all on his own and co-rediscovering calculus with Leibnitz Einstein also worked alone is 1905, the "annus mirabilis", in which he produced four ground-breaking papers. Tesla created the AC motor in isolation. Well and good.

It seems that Archimedes should be given the credit for the fundamental insight of the calculus, the infinitesimal change, although it was lost for two millenia with his death.

Yet we must not be fooled into thinking this is the only or even the dominant way in which humanity advances knowledge. Thomas Edison was not the freakish genius that Nikola Tesla was, but invented more, generally with teamwork, for a while even with Tesla. Marie and Pierre Curie discovered radium together and Marie Curie ran an effective laboratory after her husband's death, leading to her second Nobel prize. Today, it is not uncommon for dozens of persons to be named in a Nobel prize announcement, because science has become social. Many feats of engineering which are not technically individual inventions nonetheless are groundbreaking enough to be called "modern wonders of the world". Examples would be the Hubble space telescope, the Apollo moon launch, the Tesla electric vehicle, the modern 3D printer, and automatic genome sequencers. Yet these engineering feats are creating by very large teams, and can be created no other way.

I recommend that we seek new fictional characters for inspiration or to emulate. Hermione Granger is a fine example, because like Bruce Wayne and Tony Stark, she has no special abilities[8]. Nevertheless she excels by working hard and doing her homework. Like Harry and Ron, her greatest strength is in the end her teamwork and friendships.

Sadly, fantasy tends to be more exciting than reality. Reality is long nights in a lab and delaying fun now to do your homework to have a greater fun later. The cold reality is that we are not all geniuses and that even geniuses struggle. But, the public inventor must toil, but need not be lonely—we are all in this together.

2.2 The Interstellar Expansion Myth

Science fiction is the literature of ideas; it would not be worth the name if it were not astoundingly diverse. Nonetheless, the Myth of interstellar travel dominates science fiction. I use the word "Myth" here not to mean a falsehood, but to mean a foundational story that gives meaning. Many science fiction stories suggest a basic conjecture, which we could call the Interstellar Conjecture[TODO: This is not typesetting correctly]:

" There exist other planets around other stars, and it is possible and desirable for humanity to travel to them and live there. " (Interstellar Conjecture)

Our telescopes and technology have now identified thousands of planets around other starts (exoplanets)[9], so this conjecture is unlikely to fail due to a lack of planets. How many of them may be in any sense habitable after how ever much terraforming or habitat building remains a mystery, but if only one in a thousand it suitable, then it may be in theory possible. It is my fondest hope that we will someday explore those planets together in peace.

Technological improvement is inexorable. If technology can find a holdfast, however small, it can generally climb upward. In the case of travel between stars however, we have no such foothold today and can conceive of none. The closest idea we have is the "generation ship", the dubious idea of building a ship that would take so long in travel that real generations of human beings would be born and die in that small space before reaching any interstellar destination.

Interplanetary travel within the solar system is coming in decades. Interstellar travel is a myth today, and may or may not become real in a century or a millenium. It may not be possible, ever.

It may not even be desirable. C.S. Lewis, in his Space Trilogy[10], puts the believe that it is desirable into the mouth of one of the great villains. Mores specifically, Dr. Westin asserts that humanity should not just travel to other stars but to dominate them; to colonize them, if possible, and if they have inhabitants, to wipe them out of subjugate them as seems most convenient to ensure the eternal expansion of the human race. Lewis found this idea diabolical. He was attacking no straw man. In the science fiction of the first half the 20th century, this idea was indeed quite common. I'm ashamed to say I bought into it as a boy. The idea that we could visit other inhabitedd planets and bring them some sort of gift (as I would wish) or even simply not disturb them or ruin them seems dubious to me. I am nervous disagreeing with Lewis; but I suppose we could mature as a species from our current mewling infancy so that perhaps someday[TODO: Cite La Infana Rasa] we need not be a plague on the galaxy.

Put putting that question aside, the Interstellear Conjecture seems pernicious to me in another way. It suggest that we need not be custodians of our solar system and Earth. It suggests that Earth is disposable. For the next 500 years this is hellish folly. There is nowhere else to go home to. We must either heal the Earth or fail.

Obscuring this fact with false hopes is not useful. A reader may think such a false hope is harmless because it is irrelevant. This book argues that that is not true; humanity needs public inventors, and they need to be working on the most valuable inventions. We need to create livingy, not killingry. If we put their hopes in the false Interstellar Conjecture, we will be less likely to invent things that heal the Earth.

Why it makes more sense than in the past

3

Participation in public invention makes more sense with each passing decade. Although we suffer from inequity, in raw terms the world is more abundant than ever before. Commodities are cheaper. Fewer people live in poverty. The number of people who are financially able to take a few months out of the work force to work on a public invention project without compensation is higher than ever. Philanthropists are more generous than ever before. The number of people who make a substantial income essentially through patronage and tipping is probably higher than ever before. In a world of abundance, the need to make a profit or to work relentlessly at a career should diminish.

In America today, housing in large cities and formal education are exceptions to the general trend of things becoming cheaper and easier to obtain. Participating in public invention is a powerful way to obtain two things provided by a formal education: learning and reputation.

There are specific technical reasons certain kinds of public invention are far more accessible than ever before. In the first place, the internet has made many tutorials and how-to documents available almost for free, from how to use a soldering iron to very sophisticated academic papers. Secondly, the free software movement has made an ocean of high quality software available. Although it takes effort, almost any computing task can now be accomplished without paying a cent for software. It remains the case that some of the best scientific tools do not yet have free-gratis alternatives of similar quality, but the trend is incontrovertible: the cost of computing is getting cheaper. I'm writing and typesetting this book right now using mostly free software tools. This same software generally also makes it cheaper to build new software. Usually, software that it free as in free-pizza is free as in free-speech—meaning that anyone has the freedom to use it as a starting point for making something new. Software has limitations, but it is extraordinarily versatile. It is the most general-purpose of all technologies. The fact that it is free is a fundamental enabler of public invention, because capital attracted based on expectations of profits is not needed.

Hardware is more expensive, but has gotten dramatically more accessible at a low price. 3D printers that cost USD$300 can now make astounding object that could scarcely exist 30 years ago. Similarly, it is now possible to design printed circuit boards on free software and have them fabricated and very low costs, usually in about two weeks. This capability augments the old-fashioned but still useful soldering iron as a means of making sturdy circuits. Of course the reduction in the price of computers, which includes single-chip micro-contollers used in electronic embedded systems, is legendary.

Although I am weak on bio-hacking, I believe the same expansion of capability at reasonable cost has occurred in the word of biology, microbiology, and genetics. Even optics, in the form of microscopy and telescopy, has seen major improvements.

Batteries and solar power have enabled deployment of electronics portably and to remote off-the-grid locations. Significant improvements in cameras, sonar, and other sensors have also increased the sophistication available at low cost.

(Create Matrix/Infographic of relative acceleration in fields.)

Although hardware cost remain a relative imepdiment, the combination of cheap hardware, free software, and cheap connectivity enables easy innovation and invention. Sharing and publication of inventions is also ever easier.

see Chapter 34.3 for Public Invention's policy

3.1 Makers into Public Inventors

Makers know the fundamental human joy of making. The Maker movement supports creativity, skill building, art, humor, and practical function. Makers today, thanks in large part to Make magazine[TODO: add citation] and Maker Faires, have thousands of fascinating projects to prove from. Their projects are very diverse, from fiber arts to 3D printing to microelectronics to amateur science. Perhaps millions of people consider themselves Makers. If the public invention movement could co-opt even three per cent of the energy of the maker movement, the benefit to the world would be astounding.

An invention by defintion has to be something which has never been made before. Making is not easy; it takes practice, problem solving, creativity, and ingenuity, but usually not invention. There is a natural path from making to public inventing which some makers will follow. This book is an attempt to create for the public invention movement a culture as strong and supportive as Maker culture is today.

It is also an appeal to Makers to band together and take on more ambitious projects by growing into actions of humanitarian engineering and finally public invention or open science. Millions of Makers know the joy of making. Clothes, tools, and machines are the extended phenotypes of human beings, as necessary to us as a tortoise shell is to it. They know the satisfaction of creating something beautiful with their hands. They know the relief of finally getting a computer program to work properly. They get to see their friends admire the sweater they knitted, or the robot they built. This joy is both personal and social. The exercise of the making mind and the athlete's muscles is the same sort of satisfaction. It is an intrinsic part of what it means to be human. A part of this joy is overcoming the difficulty of learning a new skill.

In general, you can eventually make something with enough patience. I normally have to try several times before my craft work starts to become satisfactory, but in general the knowledege of how to do it is freely shared. One has to practice, but one need not innovate. In the end you are making something that has been made before, perhaps thousands of times. The fact that it can be made by hands only a little steadier and mores skillful than one's own is not in doubt.

The risk of utter failure is much higher when researching an invention. Many ideas, perhaps most ideas, will simply never work. It is entirely possible to spend several years on something that in the end amounts

to nothing which you can demonstrate. You may still have gained a lot, but it may not be anything of physical beauty, utility, financial value, or prestige.

Nonetheless if just a small fraction of the creative energy and effort put into Making for fun could be channeled into public invention, humanity would make much greater progress.

The millifuller

4

Science is about truth; engineering is about compromise.

Public inventors do both, but perhaps more engineering than science.

Our goal is to have a large positive impact on many people; but time and money are always in short supply. How, then, to compromise on which projects to prioritize?

In order to be able to prioritize two projects that may compete for attention, it helps to be able to measure humanitarian impact in some way. To do this, we have created "The Fuller Scale". The "fuller" is a new unit of humanitarian impact, inspired by Buckminster Fuller, the great American champion of invention as a moral good. It is by definition the impact of all of the inventions of his long life.

It is, of course, subjective; the best things in life are.

A team of inventors does not need to agree perfectly to usefully quantify impact. I hope in the future Public Inventors and other will have conversations like:

"Well, I agree your robot technology is a useful search-and-rescue idea. If it is worth 20 millifullers, then surely detecting contaminated drinking water, which kills 270,000 children every year, is worth at least 40 millifullers!"

"Yes, but free software for transparent accounting is equally important, and easier to develop!"

"Well, it may be easier, but it can't be more important—let's call it 30 millifullers."

"Okay. But if we can do it in one year, that about 3.5 millifullers a month of value added to the world; that robot thing is going to take years. I doubt you will get more than 1 millifuller a month doing that!"

And so on.

Note that in our diagram, we have social inventions, such as Universal Suffrage, on the right, and physical inventions on the left. The world is broad, and there is room for improvement everywhere.

Like everything we do at Public Invention, The Fuller Scale and its diagram is Free-libre open source content. In this case it is licensed under the Creative Commons Attribution-ShareAlike 4.0 International (CC BY-SA 4.0) license, which means you are free to share it, extend it, and even change it, so long as your retain a pointer back to Public Invention and its inventors (Robert L. Read and Amy Cesal, the graphic artist, in this case.) It is in a GitHub repo that you can fork. Please share.

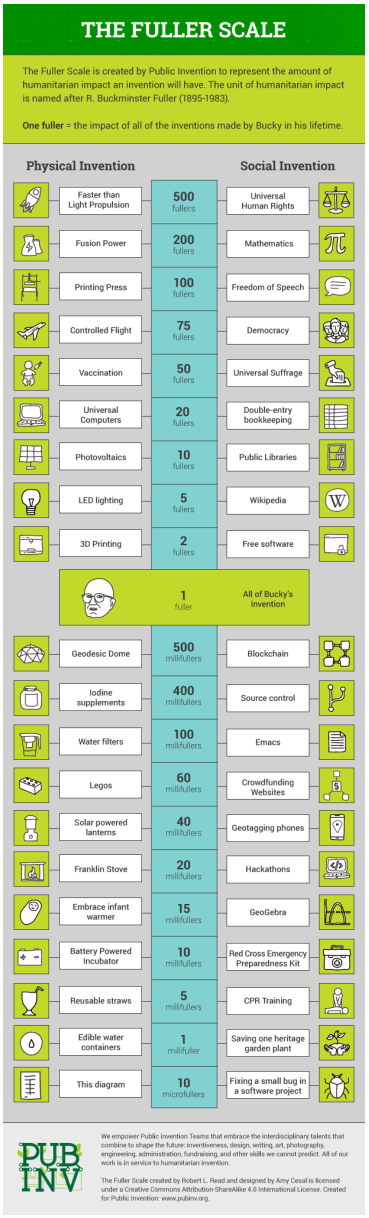

Figure 4.1: The Fuller Scale of Humanitarian Invention Value

Imagining what it will be like 5

5.1 The Near Future

With your kind permission, let me take you on an imaginatvie journey into the near future of the next 20 years.

There will be three engines of economic growth: for-profit research, universities, and public invention. People will flow smoothly between these three. A young researcher might start volunteering for public invention while looking for a good job, move to that job, then go back to school as a student or a lecturer, then back to work, then back to public invention. Profit is one of many tools of motivation, competing with the status and recognition of universities and public invention.

When a person has a three-month hiatus between jobs or a high school teacher has a summer off, it is easy for them to find a public invention project to work on, because there is a well-catalogued and maintained list of projects to which they can match their talents and desires. Everyone kind of knowledge worker can contribute, because there is high demand for technical writers, photographers, graphic artists, managers, quality assurance experts, etc. Skilled makers can contribute PCB designs or hand-soldered boards. Woodworkers, metalworkers, 3D print makers, and other craftspersons can find a list of needs and quickly produce something contributing to a project.

Universities remain exclusive, and people compete to get in as both students and faculty. Public Invention remains inclusive, and people compete to be recognized for their contribution. Gratitude begins to hold its own againt vanity.

The landscape of projects is driven by human curiosity and altruism. Finding needs to be addressed by public invention by adding to the list of potential projects is a recognized contribution.

Everyone who wants a mentor can find a mentor if they show they are willing to do the work to be worthy of mentoring.

Material costs of projects, but not labor, is financed by charities that serve an evaluative function on the projects, guaranteeing donors that their gifts have high impact.

When a person has an invention idea, they have a choice. They can attempt to monopolize it and have a small chance at a large profit, or they can donate it public invention and have certainty of a small recognition.

The current near-monopoly on sophisticated medical devices held by large corporations has been eroded by open-source designs created by public inventor in response to health crises that began with the COVID-19 pandemic 20 years earlier. A much greater competition by medium sized firms has led to greater innovation. In the low and middle income countries, medical care still lags the wealthiest countries, but is clearly catching up rapidly. Open access to medical data and training materials is a part of this process. Colleges, universities, and clinics have open-source

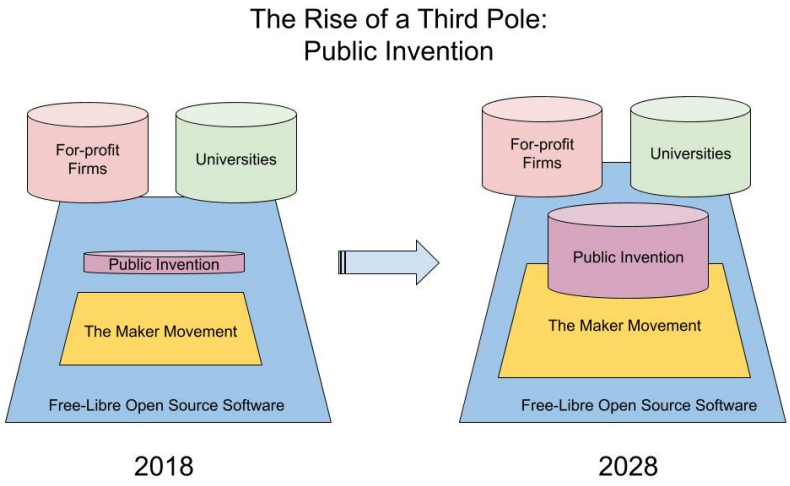

Figure 5.1: The Rise of Public Invention as a Third Pole of Progress

versions of ventilators, imaging devices, anesthesia machines, lowering the cost of training.

A growing public commons of free and open designs across the entire spectrum of possible inventions is mined by corporations and both large and small to provide new devices at reduced research costs.

Universities have mostly abandoned patenting their research and now by default release all of their work in open-access journals and under open-source licenses. Universities compete with each other not only the quantity and quality of their research, but on their openness and humanitarian impact.

Philanthropists and funding foundations provide perhaps three dollars out of every ten to public invention projects.

People go to parties and say things like "I'm a public inventor" and everyone knows what they mean. Although, just as today, with open source projects, a majority of public invention projects uknown and obscure, but everyone once in a while at a party someone will say in hushed tones, "See that person with the ombre dyed hair? They were the leader of the magnetic oxygen concentrator team in 2025."

5.2 The Far Future

In 2122, the first class of Solar Fleet Academy is matriculated. Money is still in use for luxuries and to fund world wonders, such as the first generation starship, but is largely irrelevant for basic food, clothing, and shelter.

There are now 50 billion people on Earth and 5000 off-Earth and inside the asteroid belt. The carbon footprint of all human society is now less than it was in 1950. Global warming remains a problem but CO2 levels are declining.

The constant improvement of energy storage, renewable energy sources, fission and fusion has made energy cheap and non-polluting, but less of it is needed for transport and manufacturing than ever before.

The oceans are clean and productive. The by-catch has been eliminated; only the fish that are actually eaten are taken. The reefs that were lost to global warming are being carefully reconstructed. Whole new ocean biomes are being created: floating reefs that increase the diversity of the ocean directly. The oceans produce abundant small fish and custaceans; large fish are luxury eaten a few times a year.

The forests are half-way to fully recovering. People gather that was never worth gathering before in forests with the help of tree-climbing spider monkey robots. Many parts of the earth are both wilder and more economically productive than they were previously. Mature trees are carefully selected, cut and sawn into timber in place. The boards carried out by gentle walking robots that leave footprints no bigger than bears. Forests are many times more productive of wildlife, mushrooms, and timber than ever before.

Hunting is carefully regulated but game is abundant. The restored bison herds of the North American plains provide 1/10th of the meat for the entire planet. The great herds of Africa have been restored and produce all manner of game. The boreal forests of Siberia and Canada provide timber, venison, and delicious mushrooms.

Agriculture has been transformed into small scale gardening. Robots and artificial intelligence allow hyper-efficient yields from small spaces.

Although the population has increased, the total land used for agriculture has gone down. Basic calorie crops for food are produced by a few large factory farms. Many people are engaged in producing very high-quality foodstuffs locally based on genetically engineered plants tailored to micro-biomes. Professional farmers make a living on plots as small as 1000 square meters.

Biohacking has reached new levels, driven by necessity and pleasure. A student in England just engineered an English pea plant whose pods open and spill out 100 multi-colored peas like unzipping a purse of pearls. There are tomatoes for 413 distinct micro-climates. Luxury furniture is now grown in place as a single tree controlled by hormones and rigid frames matched exactly to body contours.

Forms of art unthought of in 2022 are flourishing. Most people know and care very little about public invention, and are engaged in their own pursuits.

Travel is inexpensive. High-speed trains flow beneath the bicycle paths that have been built across the oceans. Educational resources are cheap, but personal teachers are in high demand. Infectious diseases are something taught about in history classes.

A highly organized and efficient rescue corps address natural disasters, whether local or global.

Nations no longer fight wars of territorial control, but have become more diverse in conforming to their inherent strengths. The Russians lead human space exploration. The Japanese excel at theoretical physics. The

Germans lead chemistry. The Americans produce pre-eminent inventors. The French are great philosophers. Smaller nations have developed independent intelllectual histories and have grown into their own strengths. Rather than a homogeneous and undifferentiated planet, the intellectual field of humanity has burgeoned into a flourishing of a thousand flowers, each unique and making the others more beautiful

The public inventors live in a wonderland of possibilities. Each public inventor has access to an enormous library of scientific thought and access to design tools unimagined in 2022. The average high school student can create designs of complexity unimaginable in 2022, and can order them produced at a reasonable cost. Fabrication of integrated electromechanical devices is done at the touch of a button locally. The range of materials available for crafting includes diamond, titanium alloys, fibers of unimaginable strength, and intelligent polymorphic materials are approaching flubber.

The role of public invention in the success of the world is debated. The Inevitablists claim that success was alway inevitable. The Constructivists claim that success was constucted based on specific policy decisions, individuals, and organizations. The public inventors just keep inventing.

The Stoic Point of View | 6

The ancient Stoics taught a practical philosophy that is only tangentially related to the common meaning of the English word "stoic". In terms of metaphysics, they believed that we should live in accordance with nature, and it is natural for humans to use the reason gifted to them by the Gods, if they exist—the Stoics were not universally either deistic or non-deistic.

The first principle of Stoicism is to distinguish between that which you can control, and that which is outside your control. You can control only your own actions, and, with practice, your thoughts. The thougts dye the soul. You cannot control what others think of you. The praise of others is the clacking of tongues. Being in the "inner ring"—the faculty club, or being invited to the exclusive conference, or to Lady Boodle's dinner party, is not worth a fig. Alexander the Great and his mule driver are both gone to the same place, and nobody remembers much about Alexander except his name.

I believe that in all men's lives at certain periods, and in many men's lives at all periods between infancy and extreme old age, one of the most dominant elements is the desire to be inside the local Ring and the terror of being left outside. https://www.lewissociety.org/innerring/

This is similar to the idea that we are all cells in the Body of Christ.

The Stoics saw each of us as a part of a great community, each a tiny part of a tiny society in a large Universe. What is good for Society is good for the Individual.

Stocism is a great aid to the public inventor, because it armors one against disaspointment and frustration. It sees little value in accumulating enormous wealth. It asserts that reason is a gift, perhaps a divine gift, to be used for the betterment of all. Even the spiders and bees have their useful occupation. Some of us are born to farm, to entertain, to build, and some of us are born to be public inventors.

The Stoics believed that reason was a gift to humans from the Logos. The Logos might be interpreted as divine reason, or directly as God or the Gods. The ability to reason allows us to be more than beasts and to participate, at least partially, in the divine. They meant this in several senses. Reason keeps us from being inebriated all day, although as brutes we may find this pleasant. Reason makes us behave civilly towards our fellows, although it is, on the surface, to our advantage to steal from them.

Today, classes in philosophy are really the study of the history of philosophy, rather than philosophy itself. To them philosophy, literally the love of wisdom, meant the study of how to live well. Because we are gifted beyond other animals in having reason, it is our duty use our reason to learn how to live well. To the Stoics, this spanned personal hygiene, how to behave at dinner parties, how to be a citizen of your city-state, and even how to be a citizen of the world.

In the classical period of Stoicism, Universities had not been invented, and their was no model for either the private inventor or the public inventor of physical inventions. A small number of philosophers may have procured a living by inventing the constructs of philosophy, but even then only indirectly. However, I assert that in the modern world, Stoics should agree that being an inventor is a worthy profession just like being a farmer, a policeman, or a teacher.

The Stoics cultivate *preferred indifference.* They were not opposed to wealth. It is better to be rich than to be poor, but one can be good and happy while poor. But they would agree with modern psychologial research that once a basic level of material wealth is obtained, additional wealth is not particularly valuable. If you have enough, whether you have more than enough or just enough should not make you unhappy in either case. One may prefer to have more than enough, but one should not be distraught at having less than enough.

Marcus Aurelius was strongly communitarian. He wrote that what is good for the body politic (by which he meant both the Roman empire and all humanity) is good for the individual. In general the Stoics did not have a strong sense of an immortal soul. They believed death was a transmutation of the elements, and that is was natural for a person to be born, participate in humanity, and then die. The physical body was given by the mother, and then by food, until eventually it was transformed back into the elements from which it came. The mind or soul came seemingly from nowhere and went seemingly to nowhere. This should not be counted a loss or a sadness, as nothing has been removed which was not given as a temporary gift in the first place. Humans, just like the plants, the beasts of the fields, and even the insects, had their job to do. In ancient Rome there was less freedom to choose one's occupation than there is today. To the Stoic, being good consisted in doing the assigned job well, whether you were an ox, a slave, a soldier, or an emperor.

The public inventor uses reason on behalf of the universal community without much regard for their own profit.

It seems to me the Stocis would have approved of public invention. [TODO: Add citations for all of this section.]

The Christian Point of View | 7

I am a devout Unitarian-Universalist. Most Christians would not call me a Christian, though I have been highly influenced by Christianity.

We must admit from the outset that Jesus was not an electrical engineer. He never touched a soldering iron, though a soldier's iron touched Him. There are limits to what the words attributed to Christ and his followers can directly mean for public invention.

This is the Great Commandment:

> ... and one of them, a lawyer, asked him a question to test him. "Teacher, which commandment in the law is the greatest?" He said to him, "'You shall love the Lord your God with all your heart, and with all your soul, and with all your mind.' This is the greatest and first commandment. And a second is like it: 'You shall love your neighbor as yourself.' On these two commandments hang all the law and the prophets."

Matthew 22:35-40

The great innovation of Jesus was Love. The Stoics before Him and many other philosophies extolled ethics and kind, civil behavior. A Stoic would share their bread with you, out of duty. A Christian would share their bread with you, out of both love and duty. The love/duty duality is reflected in the great Christian debate of the importance of faith (the Augustian view) and good works (the Pelegian view). C.S. Lewis and most mature thinkers view them as intertwined.

But not me—I belive good works matter far more than faith, a view which is officially heretical to many Christians, and related to the heresy of Pelegianism.

God is the Creator, the Prime Mover, the First Maker. Dare I say God is the prime Inventor? To love God with all our heart, our soul, and especially with all our mind, means to love and study His creation, creatures, and work. I therefore consider all sciences, not least mathematics, to be branches of theology.

The second part of the Great Commandment is to love you neighbor as yourself. Surely this means that I must share my inventions and knowledge with my neighbor just as I share my bread. The Great Commandment requires sharing, and sharing requires free-libre open source licenses. Free software and free hardware is therefore a Christian commandment. Some us are surely meant to be public inventors and to love our neighbors by providing them open-source ventilators and machines to provide clean drinking water.

The parable of the talents (Matthew 25:14–30) is apt. A "talent" was gallon jar of silver coins, but the parable was metaphoric to begin with, and we can by happy coincidence use the normal meaning of the English word "talent" here. Talents must not be buried! Surely those who have the inclination to study math and physics have a talent, because assuredly not everyone is so inclined. There is support for this idea from St. Paul as well: " Whatever your hand finds to do, do with all your heart." (Ecclesiastes 9:10)

In Ephesians, Paul establishes the metaphor of the "body of Christ", which parallels the Stoic view of the community of humanity.

> 11 So Christ himself gave the apostles, the prophets, the evangelists, the pastors and teachers, 12 to equip his people for works of service, so that the body of Christ may be built up

> 13 until we all reach unity in the faith and in the knowledge of the Son of God and become mature, attaining to the whole measure of the fullness of Christ. 14 Then we will no longer be infants, tossed back and forth by the waves, and blown here and there 15 Instead, speaking the truth in love, we will grow to become in every respect the mature body of him who is the head, that is, Christ. 16 From him the whole body, joined and held together by every supporting ligament, grows and builds itself up in love, as each part does its work.

(Ephesians 4:11-16)

This same idea, that each of us has a precious originality, has the modern catchphrase: DFTBA (Don't forget to be awesome) [11]. "Awesome" in this case means to be your true self. I personally believe this is the meaning of "salt of the earth" saying: " 13 "You are the salt of the earth. But if the salt loses its saltiness, how can it be made salty again? It is no longer good for anything, except to be thrown out and trampled underfoot. "(Matthew 5:13) This idea is echoed by C.S. Lewis:

> "Even in literature and art, no man who bothers about originality will ever be original: whereas if you simply try to tell the truth (without caring twopence how often it has been told before) you will, nine times out of ten, become original without ever having noticed it."

(Mere Christianity) The Public Inventor must choose projects as the inner light guides them.[TODO: Cite Quakerism here.] The choice of what to work on cannot be reduced to an algorithm. The work of invention should be a thrilling, wild adventure. There will be drudgery but the work itself must remain loved by the inventor.

Jesus was many things, but by tradiditon his profession before his ministry began is translated into English as "carpenter", but David Bentley Hart has more recently translated the Greek "tectos" as "builder"[12]. Jesus was a builder. It is not a play on words to say He was a Maker. According to the gospel of John and the Athanasian Creed which enshrines the Trinity, Jesus was the Wordand the Word with God at the beginning, so was also the Maker.

The Greek in John uses "Logos". The logos is of exceptional importance to the Stoics, where it can be translated as "reason" or "nature" or "divine reason".

Christians are called to be "Christ-like". This is not usually interpreted to mean, "be a maker if you are given a God-inclination to make", but I see this as a Biblically supported view. C. S. Lewis would have us be "little Christs" and "put on Christ" by trying to be like Him, without imagining that we really are like Him. I don't think Lewis meant to apply this directly to a person's vocation. Nonetheless should not an inventor attempt to make holy inventions to the extent they can? As I have said before, all inventions can be misued and corrupted, and I suppose atom bombs may someday be good for something. But if anything is "unholy", neutron bombs, poison gas, and land mines surely are. Vaccines and solar panels are close to the "holy" side of the ethical spectrum. Therefore the Christian inventor is called to consider the impact of their inventions beyond the narrow confines of their paycheck, and to make humanitarian inventions.

The great challenge facing us at this writing is global warming. The primarily requires policy changes; we cannot invent our wait out of this

problem, because the use of inventions is always optional, and some people just want to watch the world burn. Nonetheless, academics and for-profit firms have already given us inexpensive solar and wind power and electric cars. I hope that public inventors contribute as much in the next twenty years.

Alfred Pennyworth : Well, because he thought it was good sport. Because some men aren't looking for anything logical, like money. They can't be bought, bullied, reasoned, or negotiated with. Some men just want to watch the world burn. — The Dark Knight, 2008

7.1 Tikkun Olam: Repair the World

The Jewish precept of "tikkun olam" means to "repair the world". This could be the motto of the public inventor. I am not a scholar of judaism, but my understanding is that this means to improve the natural world and to improve the social world. Clearly, we are going to be busy, because there are plenty of things that need repair. Global warming is the most obious and pressing. But mitigating financial inequity, mitigating pollution in general, impoving global health, rewilding and reforestation, rebuilding lost soil, and conserving endangered species are nothing to sneeze at.

The Science Fiction Point of View | 8

Some would oppose humanism to Christianity, but frankly I've been more influenced by science fiction than anything I knew to be humanism. The dominant theme of science fiction that I read as a teen-ager in the 70s and 80s was that a story of humanity was unfolding. The arc of this story was sometimes negative and sometimes utopian. Most generally, it was viewed as an upward zig zag or spiral with periodic retreats in progress. It was, however, never static, and never suggested that there was no arc—that human progress was completely random or outside of our control, even if it was never fully within our control.

To re-articulate this idea directly we may say: humanity came from somewhere and is going somewhere and is generally influenced by decisions that people make, in particular what inventions, whether hard (machine) technology or soft (social) it develops.

If this is true, then it is clear that invention itself cannot be thought of as an amoral activity or an external force. If a society controls its invention, it is making a deliberate decision to influence its destiny. If it allows greed and power-hunger to be the domninant force driving invention, it is likely to get an excess of weapons.

Global warmning has eclipsed nuclear war as the primary threat to civilization in our current thinking. However, it is important to remember that technological advance makes it easier and easier to build a devastating weapon. This is inevitable. It would be true even amoung a planet full of pacifist saints. Today, genes are manipulated in high school biology labs. The basic way to make an atomic bomb was well-described in the encyclopedia I read as a boy in the 70s; today much more is known. That fissile material is hard to come by is an imepdiment which is inexorably being chipped away by the general technological expansion.

Rockets were a important part of science fiction before Goddard; as so often happens, science followed science fiction. After we envisioned them, we made real rockets capable of reaching orbit. There are relatively small firms placing objects in orbit now. Another name for such a rocket is "intercontinental ballistic missile", a means of delivering an atom bomb.

The cost of building a nuclear weapon and delivering it to any place on the globe without notice is constantly going down. At one time, only the wealthiest and most advanced nations could do this. Today the number of nations that can do so is about a dozen and is always increasing. Additionally, there are corporations with assets exceeding those of small nations.

The general technological growth will inevitably increase the number of actors who can destroy any city on Earth at will. Eventually, one of these actors will be a bad actor. All though it is rarely discussed now, our choices are stark:

- Accept and prepare for the loss of a major city.

- Create an unprecedented system of global internationl surveillance and legal enforcement of limitation of specific technologies.
- Eliminate reasons for any actor to want to destroy a city.

I personally believe it would be foolhardy not do all three.

9 Universal Salvation

A sure way to incentivize terrorism is to create great inequity and poverty. It is in all of our best interest to ensure we grow into an equitable and poverty-free world.

Luckily, we are doing well at eliminating poverty, though not inequity. At the time of this writing there are many readers who will scoff at the idea that poverty has generally been reduced over time and the last 40 years in particular[6], though I suspect most of them are not old enough to remember the 70s.

Ideas have a life of their own. This is a figurative statement, but it might be literally true as well. The public inventor must act as an agent for good, but will be most effective when working on an invention that calls to them, whether they originated the project or not. Therefore many public inventions will not directly make the world more equitable. Almost every invention helps someone more than others; this is to be expected. Nonetheless, when all else is equal we should work on inventions which make the world more, rather than less, equitable. Certainly, the enormouse space of inventions which decrease poverty and decrease inequity is a rich and varied playground which none will exhaust.

I am fascinated by tensegrities, for example.

Christian Universalism, the idea that all souls will eventually be saved, is out of fashion but was the dominant idea in Christian theology for 500 years[13]. Universalism asserts that the sacrfice of Christ saved not just a few, but all of us. It is not within our power to save souls, and of course most people on Earth are not Christians. Nonetheless, we can imitate this model to the extent that we can: let us save *all* of the people from poverty and disease.

This approach has the benefit of helping everyone, including the wealthiest. It eliminates reservoirs of disease against which even the wealthiest have no certain harbor. Since it is constantly becoming cheaper and easier to create weapons of terrible destruction, it beneftis all of us to decrease the incentive for anyone to build and use such terrible weapons. I believe there will always be a small number or psychopaths and zealots, but clearly it is better to deprive them of the support of entire societies and nations which might align with the goal of destroying a city.

We cannot explore the stars together in peace while there is war, pestillence and poverty on Earth. The road to the stars runs through the villages and slums of Earth. None of us are free until all of us free, and none of us are saved until all of us are saved.

Until we are all free, we are none of us free. – Emma Lazarus

The Self-interested Public Inventor

10

Some readers may prefer old-fashioned self-interest to lofty ideas; or, if they do not prefer them, their creditors might. Although the number of people who are financially independent is greater than ever and growing, the truth is a majority of readers will not be. It is wholly proper for them to ask for more immediate rewards than the universal salvation of the entire planet.

Acting as a public inventor does not preclude making a profit; but it does preclude being primariliity profit driven. People have made billions of dollars from free-libre open source software, and the same will soon be true of open source hardware. However, the idea of forming any kind of business, whether based on closed intellectual property or shared open source ideas may be impossible for many readers, at least at the moment.

Let us then consider the direct personal advantages and disadvantages of acting as a public inventor. Incontrovertibly, it will cost time, and time can usually be traded for money, though not always conveniently. That is the one undeniable downside.

Possibly, it will also cost some expenditure for equipment of some kind, if only a computer or pen and paper. Hopefully this expenditure is modest. In wealthy nations, the cost of starting hobby-level microelectronics, for example, is about $100USD start-up cost and perhaps $50USD/month. This may not seem small if you are broke or in debt, but it could be considered equivalent to the price of taking a course or to an enternainment budget, and your friends might find your efforts very entertaining.

Public Invention (the organization) asks inventors to commit to six hours a week for six months. In our experience, you just can't make any progress with less effort than this. Let us take this as a baseline.

What do you get for $350USD and six months of effort? In all likelyhood you will have learned a great deal. This knowledge will likely be very practical, though quite possibly ridiculously specialized—like how to build snorfuzzles. I personally can think of nothing I regret learning, and I think of each project as laying a new brick in the edifice of my knowledge. Each piece of knowledge informs every other, though sometimes in ways which we cannot articulate. Howewver, some fraction of this time will be directly useful in future projects.

Language learners know this: every language studied makes the next language easier to learn, even if unrelated.

You will have something that you can "put on your resume". The real power in this happens not when you add a line to your resume, but when you can get into an job interview and have a useful and interesting story to tell about your attempt to invent an new kind of snorfuzzle. Your snorfuzzle story, whether you succeeded or not, really will make you stand out above job applicants that have not shown enough gumption to undertake a project at all.

If you followed the guidelines we're arguing for in this book, you did not try to build your snorfuzzle in isolation, but joined a team or at least shared your snorfuzzle story in an open way as you were working

on it. Maybe, if you were lucky, you made a human connection with someone else who was interested in the same thing. Possibly you learned from them; possibly you taught them. Both are precious, becasue such knowledge is often not easy to obtain with a simple internet search.

If the Precessional Principle[TODO: Is the the first mention] holds true, you likely obtained a number of ideas for new invention projects, even if your snorfuzzle was a complete failure. I cannot prove it, but my personal experience has been that every project repays to me more than I put into it, although often in unexpected ways.

Unless it helped you get a job, you have probably not received any financial reward. In fact, you are down $350 and 156 hours of labor. But, you have demonstrated inventiveness and persistence, and likely strengthened both in yourself through exercise. But for some people who are not living in poverty, this expense would still have to be counted a bargain.

I hope that anyone who wanted work on inexpensive ideas could do so without paying out-of-pocket expenses. This is in fact a goal of Public Invention (the non-profit), but we have very modest means at present.

Financial Freedom as an Enabling Goal

11

To make the world better through invention requires time more than it requires money. The greatest gift you can give to society is to spend your time and talent inventing. Giving money is useful but is really far less effective than giving time and energy. The more free time you have, the more you can give. Most people, however, have to work to earn a living.

There are more people who are financial independent today than there have ever been in the past. Nonetheless, most people who want to be Public Inventors are severely limited by the fact that they have to work to earn a living. Often, this entails grueling hours which preclude very much extra-employment creativity. If we add to this the most important job of all, parenthood, it is clear that many would-be public inventors are not able to effective moral agents through public invention at any one point in time.

My advice to you is: make yourself free. This may seem like saying "grow wings and fly away" to some persons, and, no doubt, many people are financial trapped and will not escape in this lifetime. Nonetheless, many of the chains of finanical limitation are self-forged. We need only examine the extraordinarily large number of people with very high incomes who are insolvent, indebted, and have a negative net worth, to see that this is true. At least some fraction of people who are not financial free drive cars that cost more than a year of financial freedom and more than a year of tuition at an expensive university.

The "Financial Indepence, Retire Early" (FIRE) movement has provided many of the core concepts needed to free people with a high income from a lifetime meaningless toil. Sadly, it works less well for those of us with low income, but it is worthy of study no matter what your income level is. Our public schools no longer teach home economics and basic finance as they should. Let me attempt to summarize the whole business.

- Savings invested in the stock market can be reasonable expected to provide an inflation-adjusted 4% return every year over the lung run. If you need an income of $40,000, you need a million dollars in savings.
- Every unnecessary expense can be thought of costing you time in the future, because if it were saved it would be income in the future. If you can lower your psychological need for some expenses, you can give yourself more freedom.
- If you have excess income, you an eventually become wealthy by saving. This is not because you can save enough directly, but because of the compounding of investment returns. How long it will take is a function of how much you can save and your ability to be comfortable on a limited income.

Although many of us are mired in poverty some of us are trapped in a cage of our own expectations. That enormous amounts of money spent on advertising strengthens the bars of this cage. That we judege each other by how much money we make or spend adds further bars to the

cage. That our potential mates, spouses and lovers also judge us in this way makes it even worse. Nonetheless although each of cares what others think, none of us is entirely constrained by that. We are all partially free in our mental processes. It is our duty to make ourselves more free to the extent that we can.

Many of use have the choice to buy a luxury car which only marginally better than an economy car for actual transport, or, with the same money, to educate a child or reduce poverty. Some of us, such as myself, have benefitted for intergenerational wealth saved by our ancestors. To those and myself I repeat: With great power comes great responsibility. If you are lucky enough to be partially free of financial limitation, then put your time to good use, either as a public inventor or in some other way.

12 Social Inventions

Advances in "hard" inventions made of matter have made public invention easier, but "soft" social inventions also play a role. In particular, practices pioneered by the Free Software movement, such as the way projects can self-organize and use free software and hardware licenses, enable running a project and sharing it freely.

The free and open-source software has developed a set of cultural practices that allow teams to work together. These include:

- cultural dissuassion of unnecssary splitting or "forking" of a project,
- using recognition as an incentive for contributions,
- using version control systems to manage contribtuions,
- and using Agile software methods and big visible charts to manage work.

"The Apache Way"https://www.apache.org/theapacheway/ is a valuable starting point, as is "Homesteading the Noosphere"http://catb.org/~esr/writings/homesteading/homesteading/ and my own work, "How to be a Programmer" https://github.com/braydie/HowToBeAProgrammer

An additional practice is that documenters and maintainers are valued nearly as highly as software coders here. This is a cultural practice which is of paramount importance to public invention as a movement. Often, an invention has a kernel of math or ingenuity that can only be created by someone well-versed in the appropriate science and art. However, public invention is a team sport. Every contribution must be honored and valued. In some sports, some positions naturally have more opportunities for drama—the striker and goalkeeper on a football team, the pitcher on a baseball team. But teamwork is essential to winning. Those who manage projects, write documentation, help with quality assurance and provide financing are equally important.

Eric S. Raymond has explained this in his essay "How to Become a Hacker" in in the "Status in the Hacker Culture" sectionhttp://www.catb.org/~esr/faqs/hacker-howto.html[14]

The value of these cultural inventions cannot be overestimated. But the creation of the GNU General Public License (GPL) is of equal importance. The GPL is brilliant in its simplicity: it gives the user the right to modify and distribute a copyrighted work and works derived from that a copyright work so long as the distributor does not attempt to monopolize the works and gives the derived work freely under the same terms. The GPL and related Creative Commons licenses give creators control over how their work is used. In particular, they may choose to enable re-use, which is the point of public invention.

The work of the Richard Stallman and the Free Software Foundation in the creation of the GPL has inspired many other licenses practically created the field and practice now called "free culture". This goes far beyond the GPL, but we can use the GPL as the originating event for these other licenses.

There are also reciprocal licenses for hardware. Hardware designs are not covered by copyright, and so they are fundamentally different. However, this is of no concern to the public inventor, who as a matter a principle is giving away the invention for the whole world to use freely. It would be nice of those who take a hardware device and made improvements to it would contribute those improvements back to the project and the world as the GPL forces in software, but at present our legal structure for doing this is weak. [TODO: Can I get Marc Jones to give me a citation for this.] We may, however, rely on the "honor system", which can be astoundingly effective in practice.

Public Invention (the non-profit) has published recommended guidelines on how to use these licenses: [TODO: add url here]

Building a Public Invention Commons

13

The "commons" is that which we all share. The idea of a creative commons has taken hold, extending ideas pioneered by Richard Stallman and the Free Software community to matter which is not software. There is now a nascent free/open chip movement, a free medical device design movement, and a growing commons of other kinds of intellectual and artistic expression. Even the US patent system (slowly) creates a public commons of inventions for all to use freely. The commons is the greatest reservoir and source of wealth. We ordinarily do not perceive it as such, because we do not place monetary value on it. Yet if we were to go back in time or if we had to start civilization over, it is clear that a library of basic science and engineering textbooks would be worth more than the national debut of the US, more than all the gold and silver in the world, more than all the real estate in all the great capitals of the world combined.

Public Invention (the non-profit) participates in this with the Freespireco Project and the Open Source Medical Technology Manifesto [TODO: add URLs]

The Creativbe Commons is far from complete, however. For example, today there do not exist complete robust, free-libre open source medical device designs, for example. Public Invention (the non-profit) seeks to fill the commons with valuable, humanitarian inventions and technology.

In science, a good question is often more important than a good answer. Each solved problem tends to create more interesting problems to be solved. In general, the Commons today does not have a well-organized, easy to use list of problems.

Mathematics is the one science which does a good job maintaining list of open problems.

One of the differences between public invention and Universities and for-profit firms is that public invention in principle invites everyone at all times to work on problems. It publishes problems and ideas for solutions with the same dilligence that it publishes solutions.

You cannot just walk into a University and say "I've got six months off, I'm ready to work on something! Give me your list of research problems!" Universities are highly exclusive. You either have to apply (and pay) to be a student or apply to be professor. Both of these processes are generally competitive, sometimes highly so. You compete for the right to participate in the great adventure of expanding human knowledge.

Moreover, University researchers are under pressure to compete with each other for publication, upon which promotion (and even continued employment) is based. This "publish or perish" especially harms those trying to raise families while competing in this harsh environment. It is common for researchers to express a fear of being "scooped", that is, fail to be the first to publish a particular discovery, experiment, or idea. There is even actual theft of ideas, although I believe it is marginal and exaggerated.

One might argue that competition between researchers is a powerful incentive which increases overall technology progress. I believe history shows this is false.

Public invention as a movement advocates the democratization of the situation. It is an alternative approach which is explicitly not exclusive and not competitive. All problems and solutions are published immediately, limited only by our imaginantion and energy. There is not examination you have to take to be a public inventor.

Of course, resources are limited; volunteers will find they old maxim "you only get out what you put in" to be true. The more valuable you can be to a project, the more time and energy you will receive from the project.

Public invention is not an educational movement. Its main purpose is to increase the wealth and weal of all humanity through invention. The fact that working on such a project is astoundingly educational, perhaps the most educational thing one can do, is a side effect. Some Universities focus on education first and used project-based learning as valuable tool. In this limited sense, public invention is like a university.

This is also true of Public Invention, the organization: it is not an educational organization

Amatuer Science vs. Public Invention

14

The root of the word "amateur" means love[TODO: add citation], not the opposite of professional, although that is what it has come to mean in English now. Invention and science are closely related. Both seek to advance human knowledge by discoverying things that were previously unknown. One of the most compelling forces that improves scientific understanding is the improvement of scientific instruments. This is the realm of the inventor. Conversely, new science creates new opportunities for the inventor. Science and invention have ever been and will always be in the most useful partnership.

Yet they are not the same. The inventor does not have to care much about tree frogs. We all must say "no" to some things in order to be able to say "yes" to other things.

I happen to love treefrogs. If I am granted another life-time, I will study the badly understudied and non-descript North American treefrog, [TODO: hydracolor?]

Today there is a movement toward open source science hardware, led by GOSH[TODO: find reference]. In a sense, science was the first international open source movement. Before the terms was "open source" or "free software" were coined, scientists were sharing their work internationally by publication, in a way that was effectively open, at least to those that had the werewithal to be "in the club" of being a student or faculty member at a university. Today I believe the free software movement, which learned from academic publishing, is now putting pressure on academic publishing to become ever freer for the general public. The open science hardware movement is similarly attempting to empower the less well-funded research laboratories across the world.

As much as public invention relates to amateur science and open science hardware in particular, those beatiful fields are beyond the scope of this book.

Universities are not free, and they are not open. They invented academic freedom from which the idea of free software grew. Yet the freedom they promote is circumscribed by circles of formality and exclusion. Beyond all the isms of which they may be guilty (racism, sexism, age-ism, ableism), because they always set up a closed inner circle, guarded by football mascots, school colors, fight songs and sometimes actual walls and hedges. Generally, students pay a hefty tuition to enter this circle; it is not free as in free-lunch.

Nonetheless, ignorance is far more expensive than tuition. All the knowledge taught at universities can be learned from a book for free, but nonetheless a University education is priceless, because it:

- offers colleagues,
- teaches teamwork,
- instills discipline,
- insists on at least some diversity of learning,
- provides opportunities to begin learning almost all subjects, and
- allows personal contact with excellent researchers and teachers.

15 Limits

Public invention can mitigate global poverty and warming, but it has many limits. Love matters more than lasers. Public invention as a concept is a just a social tool. We cannot invent our way out of ignorance or hatred.

Public invention is likely to spawn many for-profit firms that will make millions, but public inventions do not confer monopolies. It will be difficult for firms small firms to make billions from public inventions by growing quickly just on the basis of those inventions. However, large firms which all already making billions will be able to incorporate public inventions into there products at low cost. In the future one can imagine three different automobiles, one of which has no open source hardware or software, one of which has 50% open source hardware and software, and one which is completely free and open. Firms making each may each be profitable.

You can make yourself lovable but you cannot make someone love you. No matter the good or how much money is made from public inventions, haters gonna hate. For the next hundred years there will be powerful voices arguing against it, like chain-rattling revenants of doomed robber barons. In America today voices try to tar anything with the brush of Socialism. Never mind the very American history of public invention, never mind the fact that is enables small businesses, never mind that it produces greater wealth. Sadly the idea of being pro-business in America has become confused with the idea of being pro-monopoly. Public Invention is indeed a natural enemy of monopolies and oligopolies of both knowledge and money. Whosoever wishes to stand for monopolies should stand against public invention.

All inventions can be repurposed to ill. Although we discourage the development of weapons, we must confront a risk that has been swept under the rug for 75 years: all technological progress making it easier to build any kind of weapon, even if seemingly unrelated. Energy saving devices make it easier to process fissile material. Basic botany eventually makes it easier to make biological weapons. As technology advances, the ability to heal advances but so does the ability to harm. The increasing ease of doing great harm means that great baleful power is given smaller and smaller groups of people. Eventually, a single dedicated lunatic will be able to do planet-shaking harm.

I know of no antidote to this problem, except to attempt to return to some sort of pastoral low-technology existence. This would increase the survival odds of our species at the mere cost of reducing our population by nine-tenths and rigidly enforcing ignorance of science. We need have no opinion about whether this is a good idea or not, because it is not going to happen.

It seems then the best we can do is to cultivate the idea that technology is not neutral, but a tremendous power and therefore a tremendous responsibility. We must develop a culture of inventing for good, rather

than inventing for greed. This culture already exists; we need only nurture it.

How to Be a Public Inventor: Principles

How to be a Public Inventor | 16

The chances of your success are zero, but the importance is infinite; therefore, I support you. – Sir W. Lawrence Bragg

The public inventor is not alone, but a part of a team with diverse skills. In rare circumstances those skills must all come from one person, but this makes for very limited projects. In the next part we discuss specific approaches to team building that unite and weight equally the universal management and communication skills that every team needs with the invention-specific technological, brainy skills. If you are more interested in leadership, management, and communications, you may wish to skip to Chapter 32 before returning here.

16.1 Motivate Yourself Through Love

He may not have been the first to say it, but YouTuber Mark Queppert introduced this to me.[TODO: add URL]

Motivate yourself not by discipline, but by devotion. Discipline is important; in any activity, there are bound to be parts that are drudgery. Stereotypically for the computer programmer, writing good documentaiton is often procrastinated because it is considered dull. Discipline can overcome unpleasantness in the short term. One can have the discipline to follow a daily exercise program even on days when you feel awful. But long term, devotion to a cause motivates far more effectively than discipline, at least for most of us.

At least my wife can.

But if we intrepret "love" as the pleasant feeling that some activity or goal engenders in ourselves, we cannot choose to love something. We either enjoy it or not. To "motivate yourself through love" then becomes a contradiction.

But "love" is also a verb. Surprisingly, we find that by actively loving something, we tend to develop feelings of appreciation and affection for the object of our kindness. We come to feel love by practicing love.

On the rare occasions that I have sought a job, I have sometimes been asked what technology I'm passionate about. I find the question embarrassing. I am not passionate about mere technology. I love about people, art, and nature. I don't love computers *per se*. But computers are very useful to all three. I spent many, many hours as a boy and in college learning to program a computer, and so came to love some aspects of the beautiful intersection of math and physics which we now call computer science. My love of computer science grew with my learning of it.

The same is true of mycology. The more you know about mushrooms the more you marvel at their miraculous capabilities. They can turn dead wood into delicious, nourishing food.

Active love requires knowledge. You cannot love a friend or a child well unless you know what they need. But also, knowledge confers love. As Vincent Price said in response to the rather cynical art statment "I know what I like", it is also true that "I like what I know."[TODO: find reference to his book on thisfor this.]

Enjoyment does not require knowledge. I loved music before I ever knew how to attempt to produce it. I tried to learn music as an adult, and I was

always miserably bad at it, but knowledge only increased my appreciation for music.

If I am granted another lifetime, I may try to become a coposer.

I even love math. Math is beatiful, but it is not cuddly. It's beauty is peaceful, but cold. It is hard to love math without doing enough homework that you start to see its beauty. The more I study math the more mysterious and beautiful I find it. If you don't love math today, suggesting you study it seems absurd. Nevertheless I insist the magic of actively loving something works.

If I am granted another lifetime, I may study math full-time.

The public inventor is not motivated primarily by personal profit, though paradoxically it is a fine way to increase your earning power. If you do not love nerdy things now, but love humanity or creation, you can be a public inventor by assisting a team with communications or management. If you do not love technology, humanity or creation itself, you do not know what you are missing! You are not fit to be a public inventor, and are probably very unhappy. You owe it to yourself to take a few years off and practice actively loving something.

16.2 Publish Early and Often

The free software movement developed a motto which has been shown to be an effective practice: release early and often. Free software projects typically are first published in a very minimal state which is barely useful to anyone. Over time, the software improves and sometimes grows into planet-wide utility. Whenever any small improvement is available, it is best to make that available to the users with as little delay as possible. This requires some practices around testing and quality control which have been developed in the last decades to a high art.

The situation is a alas worse with hardware inventions. Hardware cannot always grow smoothly. For example, you cannot have a baby bridge. A bridge which does not span a chasm and support a known load is useless or worse. For this reason, bridge-building is a well studied professional engineering discipline. It is "harder" than software.

Most hardware inventions do not threaten life and limb if they perform poorly, but some do. Even if they do not, it is almost always more expensive to build the simplest mechanical device than to install the most complex free software. Publishing an invention before it is proven to work does not confer the same benefits on end-users that publishing free software does.

However, it does assist fellow researchers. By working "in the light", and publishing everything at the end of every work day, you help the community in four ways:

1. You make the simple fact that you are working on the problem discoverable. This in itself is a service.
2. You allow others to learn from your mistakes.
3. You make it available to your team, whether your team is currently known to you or people you may never meet who are watching your work now or will in the future.
4. If you cease working on the project for whatever reason, you work remains a durable gift to the world, however small.

Modern source code control systems such as "git" make it simple to publish any sort of document with a simple command, and some services make it free-of-charge. However, students I have mentored do not automatically do this, perhaps out of shyness or a vestigial belief in keeping intellectual property secret. They need to get over it. The people who produce the best work tend to be the people who produce the most work.

At this writing, GitHub and GitLab are both *gratis* for free and open projects.

Witness Euler, Gauss, Picasso, Dali, Stephen King, Isaac Asimov, Bach, Rush.

By publishing early and often with git, a team produces a record with individual dates on specific changes over a long period of time. This was once accomplished by the dated inventor's notebook which was very important in patent lawsuits over priority. Both are valuable because they both are almost impossible to conterfeit. There is no need for the public inventor to be concerned about having their work "stolen"—the goal of the public inventor is indeed to have their work stolen, so long as the theif continues to obey the share-alike license and gives proper academic attribution! In the rare cases that someone is bold enough to appropriate credit for a public invention team's work, the dated history of the evolving set of documents is proof positive of who produced the work.

16.3 Publish Your Failures

Because it is less satisfying that publishing sucesses, you should make a special effort to publish your failures. In the biological and medical fields, much harm is done by the lower publication rate of papers which fail to show an effect. If twenty papers are written studying the impact of some dietary change on some health condition and ten of them show no impact and ten of them show an impact, the fact that the ten showing impact are more likely to be published creates an inherent bias. A reviewer of the literature will not see the papers that show no effect, and will believe the effect more definite than they should. This bias extends to other fields, though less obviously. Avoid being party to these biases by publishing your work even when it fails.

At another level there is some harm done by people publishing only the "highlight reel" of any work. If we only see successes, we think things are easier than they really are and may be discouraged by the fact that it seems easier for other people than for us. Failures can be encouraging to others.

Finally, failures are often really interesting. Public Invention recently published (in a pre-print server)[TODO: add citation] a work of some significance. I had published a personal essay a few years earlier suggesting that it was not in fact possible to do what we eventually accomplished. The initial work was a failure; the conclusion that it was impossible was a failure; but the eventual success might not have occured if I had not published the initial failure.

16.4 Do Not Seek Patents

As I explain further in Section 18.9, patents have a mystique that makes them seem valuable. In fact, having a patent by itself means only that you went to considerable expense in time and possibly money to obtain a legal monopoly. The word "protection" is often used deceitfully in place of the more accurate word "monopoly". Sometimes this monopoly is even dressed up as "defensive patenting", which is equally nonosensical. Publishing early and often is the best way to ensure that everyone, including yourself, has the right to practice the invention. A monopoly is inherently antithetical to public invention.

The patent database is, however, a very well-organized database of publications. There are current attempts to extend it to allow pledges and dedications to make it possibly to utilize it as an excellent publishing platform while removing the pernicious monopolistic aspects of it. When these efforts have been successful it may be possible to reconsider this position. [TODO: research this—are public dedications possible?]

16.5 Seek Community

Community gives the public inventor:

- feedback on their work,
- fresh insight,
- encouragement,
- a way to ask for help,
- a way to assist others,
- a source of potential teammates,
- a source of potential test users,
- confidence that the project is new and valuable, and
- advice on publication.

The rock-ribbed inventor who doesn't need these things is rare.

In general communities organized around a topic are friendly because of their shared interest. However, to be polite, you should obey certain ettiquette. Attempt to exhaust online resources before asking questions. Professors tend to be extraordinarily busy but I have sometimes gotten good replies from them when a question that I ask shows that I have read their papers. When asking a question, work very hard on phasing it as clearly and correctly as you can. If it relies on computer code, provide the code. If working on a computer bug, write a small test program that demonstrates the bug as concisely as possible. However, do not be afraid to ask questions. They are a necessary part of building human knowledge.

Selecting an appropriate peer-reviewed journal for a work is challenging for the inventor, especially because their work may truly be at the intersection of two fields of speciality. It may not fit perfectly in either place. Although in almost every field you can find online lists of journals and conference which you can independently study, it takes a great deal of time to evaluate them. A community that can offer any advice at all, even just steering one away from inappropriate venues, is very useful.

16.6 Learn by Doing

A large, exquisitely cataloged body of interesting problems would obviate the need for exercises. We should all aim for the unattainable ideal of world in which students are never again asked to do exercises just for the sake of doing exercises. It is always better to learn by doing something useful at the same time. Project-based learning teaches deeper lessons than exercise-based learning. Sadly, it takes a lot of time and effort to organize problems. In some cases, the problem can be solved more easily than it can be properly categorized. Nonetheless curating problems improves all technical communities. In mathematics, these are often called "open problems".

An open math problem is recognized as at least non-trivial and somewhat interesting. Public inventions are not analogous to open problems in math, because they have not necessarily been studied significantly by anybody. Nonetheless, Public Invention (the non-profit) maintain a list of over 60 projects that offer ready-made starting points to learn by doing.

Learning by doing trumps "book larnin'" even if the project worked on is not particularly inventive or new, because of the ancillary but important lessons learned along the way.

However, we will never reach a world in which all learning can be project-based. There will always be a role for exercises and homework. It is interesting to me that theorems that were first proved and published only a few decades ago are regularly given as homework execises with the addition of just a few hints. A change in perspective and a single hint makes such a difference! Even knowing how to ask the question makes a difference. The goal of project-based learning and homework is to develop that perspective.

16.7 Do Your Homework

TODO: I don't like this whole section. I may cut it or rewrite it.

Be like Herminone. Do your homework.

When it is not possible to work on real-world problems, work on contrived examples. When I was young and more arrogant than I am now, I would do the minimal homework necessary to pass a class. I now view this as a mistake. My recommendation to students is to do every homework problem in the book.

I know that seems extreme, but in many cases each problem is built on the last. Solving the last homework problem is not necessarily easier than solving all of them, if you need to learn what all of them taught you to solve the last problem. What appears to be a shortcut may in fact be a longcut.

16.8 Combine Theory and Practice

If you have to choose between theory and practice when working on an invention project, emphasize theory. But ideally harmonize them.

The rich field of play is where theory and practice kiss each other. Hardware invention, unlike pure observational science, requires some sort of underyling theory to guide the design of the machine. Unlike pure theoretical science, the results of theory must be tested for an invention to be valuable. This is not strictly true as far as the US patent office is concerned, as they do not actually test that an idea works. I suppose that a theoretical physicist could propose an invention without testing it and it would technically be considered an invention, even if the test of it was performed decades later. But that mode of working is so different than what I or the average person who will call themselves a public inventor can really do that I think we can set it aside. If it applies to you, good luck!

Most invention projects require an interative cycle of desgin-build-test. This is similar to the computer programmers code-test iteration cycle, but is much slower and more expensive. Much of the wisdom that goes into public invention is in learning to mitigate risk by testing hypotheses judiciously. By doing so, we can drastically cut down on the number of iteration cycles that an invention requires. It is completely reasonable to build entire machines for no purpose other than test a simple single hypothesis, if the result is going to guide the rest of the project.

A good rule of thumb might be to research-design-build-test in proportions of 1:2:4:2 iteratively. That is, try to spend about twice as much time designing as doing library (or google scholar) research, about twice as much time building, and about one half the build time testing. This will vary with the project.

Money and Volunteerism 17

Money matters. It matters a lot more when you don't have it. Money saves time and makes difficult things easy.

It is not, strictly speaking, necessary to public invention. There have always been amateur inventors, and there always will be. The peak of amateur contributions may have been in United Kingdom in the 19th century, when various social customs combined with a world-spanning empire created a relative high percentage of people who did not have to work very hard for a living. In that situation, some human beings will concern themselves with private pursuits, and to some of us these will appear, perhaps correctly, like idleness and dissipation. Other people with leisure will create poetry, and some tiny fraction of it will be great and of lasting value. Some people will naturally be called to be public inventors, and amongst many failures will sometimes have lasting successes that enrich us all.

I suspect that in fact in America today that are more people with the means to finance their own private careers as public inventors than there have ever been before in any large nation. This fraction of the population will only increase. If we could somehow instantly put aside both our fear of an uncertain future and our insecurity and vanity which we placate with ostentatious spending, the number would instantly quadruple.

If you are someone who dreams of following your own heart but are still enthralled to making more money than your dreams really require, I beg you to have courage, for your years are running away from you more surely than your neighbors' opinions or the mischancy downturns the future may hold. Do not waste your time to save your money.

"I wish it need not have happened in my time," said Frodo. "So do I," said Gandalf, "and so do all who live to see such times. But that is not for them to decide. All we have to decide is what to do with the time that is given us." –The Fellowship of The Ring, J.R.R. Tolkien

Nobody has a natural right to be a public inventor, any more than anyone has a natural right not to be struck by lightning. When the overall wealth of a society becomes great enough to make education cheap, it is reasonable and beneficial for that society to construct an artificial right to education. When the overall wealth of a society becomes even greater to make public invention cheap, a point which we are approaching, it is reasonable and beneficial to construct an artificial right to pulic support for humanitarian invention. Until that time, we may expact philanthropic giving to gradually increase the gifts to public invention as a general endeavor. This has probably been happening, though mainly at universities, and will continue.

In my experience, engineers are mysteriously and highly motivated by a having their equipment and supplies purchased for them. Purchasing a tool for a public inventor appears to motivate them more strongly than give them three times the cost of the tool in cash. Since the inexorable march of technology has made certain technologies cheap, supporting public inventors by purchasing related tools for them has a very high return in the form of impact for the cost in terms of dollars.

At the time of this writing, only a few public inventors (those with fellowships or working for non-profits) are compensated for their time. Their should naturally be a larger pool of public inventors who are

compensated for their direct equipment expenses. Hopefully both of these groups will increase over time.

The Emotional Intelligence of the Public Inventor

18

Invention means creating something that has never been created before. By definition, the public inventor is doing something difficult. True creation is a both a satisfying joy and a frustrating slog. By articulating some of the emotional difficulties they will likely face, we hope to prepare for them.

18.1 Getting to the Coal Face

The first problem faced, even before any insecurities, is "getting to the coal face." This means specifically learning enough abuot a particular area to have some discernment about what constitutes a good and new idea. When I was a boy, I tried to think of a perpetual motion machine. I excuse myself because of my age; but only just. Although I didn't know it at the time, I had no right to be thinking about that problem because my entire knowledge of thermodynamics was the use of the word "entropy" in a Fantastic Four comic book. I was not at the coal face—I had not done the work, analogous to traipsing deep down into the mine to where the freshly exposed ore was—and so could not hope to do real work. A person who does not get to the coal face is either ignorant, as I was, or a quack, as I hope not to be. We must treat the ignorant gently, becuase often it is not easy to tell if you are ignorant or not.

This expression can also mean "doing the nitty-gritty", I do not mean it in that sense.

One of the easiest ways to tell if some one is a quack is to see if the have gotten to the coal face. That is, can they intelligently discuss the details of particular specialized area pertinent to their invention? If they cannot, their attitude will determine their fate: the merely ignorant will take the discovery that they do not know something as a signal to study further, even if dejected by it. The quack will attempt to deny reality and become combative.

For the sake of the young especially, we must never say "No, you are wrong" without also saying "but it was a good try, and if you study this and that, something may come of it."

18.2 The Insecurity of New Ideas

For example, I recently discovered something of real if minor scientific value—or so it seemed to me https://github.com/PubInv/segmented-helixes/blob/master/doc/StackingHelix.pdf. This is quite unusual, and the more valuable something is, the less likely it is that we are the first to think of it or develop it. Extraordinary claims require extraordinary evidence (ECREE), the so-called Sagan Standard https://en.wikipedia.org/wiki/Sagan_standard, is fundamental to all scientific emprise. I of course did about ten hours of searching to attempt to verify that it had not appeared in writing before. However, even after working on it for six months and preparing the publication, I was riddled with doubt that this might simply be so well-known that

nobody bothered to write it up. In an attempt to allay my fears, I asked for help, and I think an anonymous person said it was not valuable and "pretty simple". Nonetheless, reputable journals continued to publish work which completely subsumed by my work as if it had value. COVID-19 delayed the in-person conference where where the work was accepted. I remained in a state of emotional trepidation about this work, until the conference, where nobody seemed to think it was previously known or too simple to report. Many public inventors are going to be in precisely the same position much of the time.

We will be most effective if we can put aside our egos without decreasing our emotional involvement in the work. I care about the outcome of this research, in part because I simply love mathematics itself. I am not ashamed to say I love my potential significance of my work. If it turns out to be insignificant or previously published I will be disappointed. However, we must not allow such sentiments to cause us to be in anyway biased or discouraged. We must at all times hold forth the highest standards of honesty and academic integrity. It is our duty to publish results, but we must not over-sell or exaggerate our accomplishments.

18.3 The Dreaded Scoop

About twenty times in my career as a Computer Scientist and public inventor I have somehow informally presented an idea to someone or a group of people, only to hear them say, "That's been done." Sometimes they add some additional information about who and when, but often their memory is vague. To a would-be maker, inventor, or researcher, "That's been done" can feel like a punch to the solar plexus.

My advice is: Don't you believe it.

All of the twenty times I got that sinking free-fall feeling in response to "thatsbeendoneism", and I took notes and researched what I was told. Approximately once it turned out to really be true. The other 95% of the time, the work mentioned in no way decreased the value of the project I was undertaking, and even validated it. Sometimes it seemed to have no relation whatsoever. Sometimes it was tangentially related, but the previous researchers had taken a very different approach. Sometimes they had begun and stopped, and in the twenty intervening years the march of technology, and even mathematical theorems, has since opened up new vistas.

I don't like the way the word "privileged" has come to be used in the last 20 years, but in that usage of the word, as a researcher, I have been. I can be an over-confident ass, with the redeeming feature of complete blindness to my own ignorance. I am anti-fragile. Yet, I suffer from the impostor syndrome and insecurity, just like everyone else reading this, I suppose.

Judging by the emotions I personally go through when I hear "That's been done", I'm sure those words have prematurely killed many a fine and interesting research project, invention, or even DIY craft project. We must forgive the thatsbeendoners, and understand them. They are genuinely trying to inform us. However, the human weakness of a desire to appear

knowledgeable combines with the human frailty of not listening patiently enough to our ideas before passing judgment, multiplied by the human limitation of memory. The result is that most of the time when someone says "That's been done" you should carefully note what they say, plan to carefully research it tomorrow, and not worry too much.

Many research topics can go in about ten different directions. Any one researcher may have considered two of them; the other eight are open to you. When this is not true, you will likely know, because these become recognized under the moniker "open problems".

Do your homework and spend a lot of time in the library or researching online. When you have done that, work boldly and confidently in whatever direction your spirit guides you.

18.4 Publication

By definition, the public inventor publishes. This can take many forms, but the most challenging and most rewarding is academic peer-reviewed publication. Society has creating a beautiful machine, which we might call "the body of human knowldege", or, more colorfully, the exobrain. The internet and the trend toward open-access publishing has made this knowledge more accessible at lower cost and more widely shared than ever before. Google deserves a hat tip for their role in this, which has made "to google" an understandable verb.

Tony Stark, eat your heart out!

Long before their was the internet, scientific literature was systematically categorized and edited. In fact, we can think of the peer-review by qualified reviewers as the best editorial function in terms of selecting what is worthy. Nothing stops you from publishing your work on the internet, but without peer review your potential readers must make a higher investment finding, evaluating and validating your work for themselves. In a sense, a paper worth 10 microfullers by itself is worth 20 microfullers when placed in a journal because of this editorial and validating function.

Academic publication lasts approximately forever. The exobrain is a gift that keeps on giving. If you could receive some sort of money or karmic value for your work, academic publication is the best way because it would keep paying you year after year as your work assists others. Sadly, this is not possible today, and the only people who derive economic benefit from academic publishing are the harried and beleagured class of assistant professors. In fact, because today you often have to pay open access fees, academic publishing is a slight economic detriment to the author. But it is a tremendous unmonetized economic benefit to your sibling scientists.

Publishing is, however, tedious for the public inventor. The quality bar for preparation is quite high. Finding an appropriate venue for publishing takes about half a day, and then there is a high margin for error, even after reading papers in many different venues. Finally, it takes months to receive a reply and often it appears the reviewers spent about twenty minutes reading the work and didn't seem to really understand it. Then, you may get rejected, and when you are not rejected, you often have

The decrease in the cost of paper publishing the low-end of the spectrum of publishable quality has been expanded, which I consider a good thing.

Professional academicians don't have this problem, but we cannot expect everyone to stay on top of all journals and conferences in a field.

additional work, sometimes substantive, but often just tedious formatting to do.

Despite these troubles, I strongly encourage inventors to pursue academic publication for those works that deserve it. At Public Invention most of our project aim for an acdemic publication from the first day, but other projects are art projects or exploratory in natue. Having a posse—a siblinghood of technical friends who can advise you—facilitates this decision.

Conferences and Journals

A professional researcher or graduate student who has chosen a field can be expected to be familiar with all of the publishing venues in their field, whereas the generalist inventor spans many fields. Conferences are typically yearly, and are extremely valuable to attend if one is specialized in that field. At a conference, you will meet other researchers, sometimes get valuable feedback (though not always), and may be able to form new friendships and alliances. You may see research earlier than if you only read journals, and can generally ask questions of the presenters. Some conferences have archived proceedings. Those that do not have little value to the public inventor in terms of publishing there work to the world, but may still be extremely valuable as workshops for connecting you to researchers in a subfield and getting feedback on preliminary work. In some fields, a conference paper is considered approximately one-half the value of a journal paper, but this may vary by field.

All of these benefits of attending conferences accrue to public inventors, and even more to students or those unfamiliar with a field, as they tend to learn more from a conference. However, conferences require time off work, which a part-time volunteer may not be able to obtain, travel to the conference, and in some cases relatively high fees. Also, because they occur on a yearly basis and it can take six months to get a reply on a paper submission, a conference can lengthen the time between the submission of a completed work and its publication. Since research moves at a yearly pace, this may be acceptable, but following Buckminster Fuller's dictum to tell the truth promptly, it is surely better to publish work without delay. However, conferences are appropriate for work which is still rapidly evolving.

Journals paradoxically can publish work faster. Generally journals require a higher level of quality in the writing and methodology. Students who have never published in a journal may be surprised that they demand a level of quality far exceeding any exercise they were required to do in school. Every jot and tittle has to be perfect. Journals are, by defintion, an archived addition to the body of human knowledge, and therefore appropriate for "finished" or "perfected" work. Since all science is provisional, there is no such thing as perfected work, but certainly some research is more clearly in a stable state than other.

Open Access Publishing

Both conferences and journals sometimes offer Open Access publishing. This generally means that instead of potential readers having to pay $25USD-$50USD to read one published paper, readers may read the work for free online. Obviously, the spirit of public invention is in favor of open access publishing, although it is not a moral requirment.

Often, to publish any sort of paper you have to pay a publication fee, usually of about $750USD or slightly more. Often, their is an addtional similar fee to make the paper Open Access, although some journals and conference are completely Open Access, in which case there is no additional fee. In general, professors have this fee paid by their institution, so this somewhat scandalous expense is not born directly. Public Invention (the non-profit) of course attempts to pay this fee for all publications produced by its volunteers.

The world of academic publishing is evolving toward open access. It has been suggested that a better model is that authors pay to have their work reviewed, rather than paying only when their work is published, because reviews constitute significant effort/labor in the whole publication process, and because pay-on-publication creates a slight conflict of interest in that the journal is compensated based on the number of papers it publishes.

On Responding to Journals

When you submit a paper to be reviewed by a conference or journal, be prepared:

- For your paper to be rejected for reasons relating to form, rather than merit. We recently had a paper rejected because it was shorter than the articles the journal published. This was somewhat annoying; afterall, concision is a goal, not a fault.
- For your paper to be rejected seemingly without being read.
- If you are lucky, your paper may be rejected with valuable feedback, but even then expect that some readers will have misunderstood things that you thought you stated clearly enough in the paper.
- Your paper may be provisionally accepted if you make some edits or changes. This generally means that the paper will eventually be accepted. I recommend you dilligently try to do all the editor asks. However, don't be afraid to push back on specific requests when a reviewer has misunderstood the work, which will happen in about one fourth of the changes they request.
- You may hear no response for a long time. This is generally because the editor has given the paper to a reviewer who then sits on it or forgets about it. I recently had a submission go dark for nine months. I then pinged the editor, and within a month the paper had been accepted. As a rule of thumb, it is acceptable to inquire as to the status of the review every three months.

You should always be polite in dealing with an editor. However, if you disagree with a review, especially if the criticism is unfounded and it appears the reviewer read the paper carelessly, you may inform the editor of this—otherwise they will not know when they have bad reviewers.

Most journals and conferences are always in need of reviewers, and are often not too picky about your credentials; it is entirely possible to be a student and act as a peer reviewer. Of course, a good editor will take your review with a grain of salt. Reviewing technical papers is a very useful service to provide to the community and is very educational and informative to the reviewer.

18.5 Humility: Be Foolish

An invention project which is guaranteed of success is hardly worth the name. The public inventor must therefore be prepared to fail. Sometimes we learn the universe is harder to manage than we thought; this learning is valuable. Sometimes we learn that we have been foolish. This is an equally valuable lesson, though it can be a jagged little pill to swallow.

18.6 The Inventor's Courage

I have only taken classes from one person who had received an honor equivalent to a Nobel Prize. That person was Edsger W. Dijkstra, who received the Turing Award in [TODO: 19XX] which is the highest honor a researcher in Computer Science can obtain. I did not know him well, but I will assert I know what the key to his genius was. Like anyone, he may have been in some sense biologically smarter than average, perhaps markedly so. But so are many people.

What made Dijkstra stand out was his courage to research what he believed was most important. He seemed to the immune to the opinions of other researchers about appropriate research topics. He did not follow trends. In some cases, he set them; perhaps in other cases, which are now forgotten, he did not.

The winds of fashion can blow us about all to easily. At the time of this writing, blockchain and machine learning are all the rage. If you follow your own heart and own thought, you may be researching something much less exciting. Your colleagues may hint that you are wasting time. You may fear missing out on important work, or missing a once in a lifetime chance. One may even be making good progress and find it hard to get published or hard to get people to pay attention to the work. When progress is slow, it is doubly hard to stay motivated.

Most Public Inventors have an inner voice that guides them to do work that they find interesting, and to which they are well-suited. Have the courage to listen to that voice. Professional institutions that are well-funded may be better suited to following the latest research trends than the typical public invention team.

Dijkstra said "80% of problems are trivial. 20% are impossible. We must work at the thin boundary between the trivial and the impossible." It takes judgement to discern the difference, and courage to work there.

18.7 The Glory and the Impossibility of Comprehension

The Universe is "Infinite in All Dimensions."[15]. When Freeman Dyson titled his book of essays that, he did not mean only in the spatial dimensions. It appears to be infinite as we look out and as we look in. It appears to be infinite as we look at the large and at the small. Human progress has created, or perhaps has been driven by, an ever expanding understanding of the richness of the creation we inhabit. Most recently, the discovery of thousands of known exoplanets implying a galaxy full of them, is a spectacular example.

"Space is big. ... I mean, you may think it's a long way down the road to the chemist's, but that's just peanuts to space." – Douglas Adams, The Hitchhiker's Guide to the Galaxy

There does not appear to be any end to new art forms, and the old art forms are made larger by the creation of the new art forms. Photography has not hurt painting. Recorded music has not hurt music in general. Free versehas not hurt poetry.

It has decreased the breadth of musical mastery in the general population.

https://quoteinvestigator.com/2021/05/24/poem-tennis/During the question period afterward, someone asked: "Mr. Frost, do you ever write free verse?" and Frost gave his famous answer: "I would no more think of writing free verse than of playing tennis without a net." Vance spoke to the U.S. poet Carl Sandburg and presented his rejoinder: " ... I would have him know that I have not only played tennis without a net but have used the stars for tennis balls."

Amongst this embarassment of riches the public inventor may feel a little small. You can study all day for years and not master a single corner of the sciences, and most of us cannot make that investment in first place. I personally feel that I cannot master even differential equations and basic electronic circuits.

It is a personal shame of mine that I know almost nothing about chemistry. If I am granted another lifetime...

However, we must support each other in our attempt to learn what we can in our brief time here together. It is not a question of knowing everything about anyting, but a question of what we should invest in learning. In this, the inventor has an advantage over the specialist: invention is often the combination of elements from disparate fields. The public inventor gets a pass on studying any one field, in exchange for a demand of voracious study of many fields. I personally could live no other way.

18.8 Feeling Unappreciated and Ignored

Somtimes the fruit of your labor sinks without a trace. Time and time again, great work has been ignored, only to be rediscovered, with great praise and thanks, thirty years later or more, when the original author is dead or has been denied tenure! And those are the lucky ones.

Sometimes an idea is ahead of its time. However, it is also entirely possible to do excellent work, and simply receive blank stares and yawns. In fact the work may never mean anything to anybody. This happens to artists fairly commonly. The only remedy when this happens is to do some other excellent work.

Working hard on a project for a long time that is completely ignored almost always positions you better to do some other project. I suppose it must happen that this is not always true, but it has never happened to me.

18.9 Patent Envy

There is a mystique around patents. The word "patent" is sometimes pronounced with certain breathless excitement, as if it confers success, riches, or some proof of merit. Don't be fooled—it gives none of these things, and costs money and time. About the best thing I can say about the patent system is that provides an extremely well-organized and useful database of clearly explained ideas. This is still useful, but was more useful when publication on paper was the only route. By making an invention sufficiently narrow, it is possible to get a patent in almost any field. This does not mean it has any value to anyone.

A patent provides a monopoly for 20 years on some idea. This is antithetical to the entire premise of public invention. It made more sense when publishing ideas was harder. The long monopoly did not seem so long when the patent system was established in 1790.

All of humanity is in peril of extinction if each one of us does not dare, now and henceforth, always to tell only the truth, and all the truth, and to do so promptly — right now. — Buckminster Fuller.

Patents do occasionally prevent large firms from using the work of individual inventors without compensation, which is a positive feature. However, more often they are collected by large firms who finance their issuance from flimsy actual innovations and then use them to compete with other large firms and to create barriers to entry to the market for small firms. It is an idea that was useful in its time and in its form, that utility is now passed, and the patent systems needs to be reformed.

There are people who will passionately argue that without the monopoly provided by patents nobody would research new drugs, for example, or other useful inventions. There has been plenty of great research in software and mathematics which luckily was only slighlty tainted by patents. Being the first mover in a market with an invention provides a tremendous financial incentive. If those prove insufficient, society could finance pharmaceutical research through taxation or even donations. However, public policy should not influence what the public inventor does.

The question is: will an invention serve the public better by being patented? The answer is usually no.

Patents give the inventor the right to file for one year after a public disclosure. Furthermore, by law, all inventors must be named in the patent. Both of these stipulatons are nearly impossible to accomplish in the modern, open-source way of working. The modern way to develop is to work "in the light", not keeping one's work secret. Since public invention invites broad participation on projects, there are often dozens of volunteers that work on a project, and sorting out who contributed what is a thorny nightmare.

Whatever one may think about patents, they have no place in public invention as a movement.

18.10 The Need for and Difficulty of Fellowshp

There is no more secure entry to friendship than a shared interest. The public inventor often wants friends, and wants to share their enthusiasms. Often, even when working in the light, this need is hard to satisfy.

A detractor could argue I am writing this book to have a lot of virtual friends.

In an all-volunteer project in which nobody gets paid, volunteers are ephemeral. They may come and go. Sometimes they are seeking to learn but are not really ready to contribute, and cannot really be a peer. Sometimes people are enthusiastic but have limited attention spans; they seem to honestly be interested but then something more interesting distracts them and they flit from project to project without ever getting traction.

Somewhere below stubborn intransigence is an clear-eyed steadiness that can keep a project moving forward while remaining alert to technical opportunities. Ideally, team members complement each others weaknesses and reinforce each others strengths.

A fellow inventor can help:

- think of better ways to do something,
- validate good ideas,
- translate overreach into testable hypotheses,
- remind one of the value of the project when it has been forgotten amongst the detailed frustrations,
- shore up weaknesses in a skill set,
- check your math,
- improve your coding style,
- multiply the happiness of minor victories, and
- half the frustration of minor defeats.

18.11 Mentorship through Collaboration

Public Invention's motto is "Invent in the public, for the Public." Inventing in the public means working "in the light"—letting everyone see the work product as you go along. In a sense, working in the light is a form of mentoring that is available to all for free.

I'd like to thank Dr. Tyrone Grandison for recognizing the value of this motto before I did.

But people need one-on-one, personal mentoring as well. I learned so much from my personal mentors and other influential people in my life (some of whom probably wouldn't remember me) that I personally feel it is a universal duty for each of us to mentor whenever we can. Here is what I try to do.

The best mentorship is collaboration. The most lasting insights I ever got were from watching my father solve a computer programming problem. He offered no advice; he just solved the problem out loud with me looking on. In fact, he reconstructed Bresenham's line drawing algorithm[TODO: add citation], from first principles, I'm pretty sure without ever having seen it, writing neatly on a sheet of graph paper. We programmed it in assembly language on my TRS-80. It could draw lines across the screen so fast you couldn't see them move. In 1979 on that computer, that was a big deal.

My second mentor, Dr. Martin L. Smith, worked closely with me on certain problems in geophysics and then closely guided my reverse engineering of Hypercard for the Sun Windowing system in 1987[TODO: Add citation to SP&E]. This was better than any mottos he could have produced. We wrote a paper together, and in that way he demystified academic publishing for me.

I had the pleasure of coding for an hour with Kent Beck. It was a very informative hour, even though we did nothing that he hadn't already written about in a book that I had already read.

I try to work directly with people as colleagues whenever possible. Sometimes this can be done in near equality; for example, a recent volunteer, Lauria Clarke, was a better PCB designer than I was, and on that project we could be equals. In other cases, particularly when it involves pure computer programming, I am so far ahead of a student that there is no point in pretending we are equals. In these cases the teaching is asymmetric, but it is still focused around collaboration: we are getting something done, and if I may be doing most of the typing and coding, we are still doing it together.

Occasionally young people appeal to me for career advice in various ways. I am of course honored by this, but approach it with great humility. I have only lived one life and I'm not at all sure that I've done it successfully, so I can't tell anyone what to do. But I can share a lot of experience that may be relevant. The mentor must always be humble.

Young people are inexperienced. They may miss major opportunities because they simply know nothing about a possibility. You may greatly help young people by sharing such experiences, and allowing them to take what they can from it. For example, I went to college, failed disastrously to be a physics major, and then succeeded in computer science. I went to graduate school and had some dismal experiences, though I eventually graduated, and am glad I did. I share failures and successes in equal proportion, because, for most of us, that is what life is.

I try to be upfront about my biases. For example, if someone is trying to decide if they should go to college or graduate school, I tell them before we start talking that I will likely always say "yes, you should." With that out of the way I try to listen with an open mind.

My face doesn't show it, but I am a deeply enthusiastic person. This level of intense enthusiasm and optimism can be off-putting or intimidating at times. It is sometimes nice to have someone telling you that you can do anything, that no endeavor is beyond your reach. That is what my heart says. It is not always true, and can seem pushy.

But it is true that trying and failing is almost always better than not trying. This is a percept, not a concept. Efforts often fail to produce their goals, but they rarely fail to produce some unlooked-for result that falls into your lap like magic. Perhaps my greatest mentor of all, my grandfather, taught me a little homespun wisdom. Like a dark lake it is simple on the surface, but surprisingly deep. "You can't catch a fish if your hook ain't wet." It means taking an action is more important than talking about the action. You can't win if you don't play.

In the end, I can do neither more nor less than share the light that has been shared with me.

18.12 The Darkside: Going Closed Source

During the great pandemic ventilator rush of 2020, there were several teams that made high-quality open-source ventilators and respiration tools and then chose to continue developement in a closed manner, probably because they enterred contracts with manufacturers who either pressured them to do so or took over development and were unwilling to continue in an open source manner.

I suspect many of these contracts ended up being "catch and kill" operations; that is, the teams got only a piece of future profits, and the firm never seriously committed to make the devices. Thus they "killed" the project, and removed a potential competitor, and nobody was helped at all. This may have occured unintentionally.

Because the open source licenses for hardware are more delicate than the GPL for software, going closed-source in these cases may not have violated the law, but certainly violated the spirit of the projects. It also violated the expectations of most of the people (myself being one of them) who supported those projects with money, equipment, and time.

To bring inventions into practice, we need for-profit firms. The natural life-cycle of a public invention is to mature into something that can make a lot of money for someone who takes on the effort and risk of manufacturing and distributing it. Profit is good; monopoly is bad. It is essential to public invention that enormous amounts of money be made from open source inventions, and in general only a small fraction of that money, if any at all, will go do the inventors. However, it is absolutely essential to keep the invention free and open so that it may be improved and constructed by anyone, including firms which are competing with each other.

If a firm comes to you and says "We will make this invention, but only if you make the project closed-source so that we may have a monopoly", you should say, "No, that is not in the spirit of public invention. However, you are welcome to exercise the rights already given you by the licenses we have used to publish our work."

A copylefted work may be continued as a closes-source work only by the copyright holders. Since a public invention team may be diverse, it is often problematic to determine who the copyright holders are. However, if all copyright holders agree to continue the work in a closed-source manner, they may do so and the previously published work remains a free and open project. However, the world will benefit more if the work of all contributors continues "in the light", and that is more in the spirit of public invention.

When a work goes closed-source, it tends to become invisible. This deprives the community of not only the work itself, but even knowledge of if the work is progressing.

"Very hard to see, the dark side is." [TODO: Add Yoda reference]

18.13 Competition is Obsolete

Competition dyes our every thought. We were taught and we teach our kids to play competitive games. Physical sports are the most emotionally

vivid of these, but even the board games we play, for Sorry to to Chess are fundamentally competitive. School, science fairs, scholastic aptitude tests, college entrance, and tenured university positions are all contests that are deeply competitive in nature. To slip the mental chains of competition requires a heroic effort. Yet, competition is a fundamentally obsolete concept.

I'm happy to say their seem to be a rising number of cooperative games, such as Pandemic[TODO: add reference]. Fantasy role playing games have always been mostly cooperative.

Buckminster Fuller tells a narrative of history:

> For thousands of years, the things needed to stay alive were scarce. It was literally true that my children would be more likely to survive if I clubbed you over the head and stole your clothes and food and land. However, in 1970 a tipping point was reached: there is now enough for all, and taking you goods does almost nothing to improve my life. There is plenty for everyone.

Whether you believe that story or not, it is absolutely clear that Earth produces sufficient material wealth for all eight billion of us to live better than royalty did just 150 years ago. We have so much wealth, we waste it by taking perfectly good grain that people can eat and feed it to cows in order to eat beef rather than grain just because it tastes better. Edible corn is made into alcohol to be burned as fuel in vehicles that will soon be electric. People take a tour of space for the mere price of a four-year University education for ten persons. There is no reason for people anwhere to go hungry now. Similarly there is no reason for anyone to be unclothed or unsheltered. That people are homeless, unhoused, don't have running water, and are sometimes hungry is not a problem of scarcity, but a moral stain on us caused by our inability to design a distribution system that provides basic needs to all. If you wish you can call this greed, though it is not so much greed as stupidity, because it wouldn't cost very much in absolute terms to feed, water, clothe, and house everyone.

Buckminster Fuller would say it is largely the residue of millenia of habits of competition that prevent us from moving to an age of cooperation. Today, we worry about sending our kids to prestigious schools and driving expensive cars, both of which are largely symbolic competitions. The speed limit is the same whether your drive a Ford or a Ferrari. Children learn by doing, not be setting foot on the campus of hallowed Harvard.

We are too a large extent chasing phantoms. I personally sought to be perceived as better than others before I was even good; to get an "A" rather than to understand. I wasted a lot of time making money for people who were already rich in exchange for a fistful of dollars building software I wasn't proud of. I spent a lot of my life trying to earn the respect of people who, on clear-eyed inspection, where fundamentally unrepectable.

Competition is the foundation of most human institutions, but especially Academia. Children compete for grades, and compete to see which school they can get into. Schools compete to attract the best students. Graduates students compete (sort of) to get PhDs, and then compete for post-doctoral positions and then jobs. Then as assistant professors they compete to get tenure. The whole system from top to bottom is based on

the idea of scarcity. The idea is that because there is not enough money, or time, prestigious postings, or attention to go around, we must decide who will get money, time, positions and attention by choosing the best, and the way to choose the best is to create artificial competition.

But the premise of scarcity is now wrong. The walls of the prison have dissolved and we are such creatures of habit that we refuse to leave the prison yard.

There is not much that an elite University offers that cannot be had much more simply by sharing. Already, to their infinite credit, MIT, Yale, Stanford and others have placed many of their courses online where they can be taken for free. Of course, you have to do the homeowrk—that part is not free—but so do the students there. Universities offer the best teachers—or did until it became possible to get the very best content for free, such as that offered by ThreeBlueOneBrown, ActionLab [TODO: add citation], and many others free resources. It is true those schools have better electron microscopes than you can afford at home; but the difference is far less than it once was.

It turns out that in the end what elite schools offer is in fact the most intangible thing that the public inventor needs: community. When you got to a University, you are slotted into a ready-made age cohort that is exploring similar interests to you. As I state repeatedly in this book, this community is invaluable. I still would advise anyone who can to go to the most expensive school they can get into for that reason. If you can support a child going to university, please do so.

My hope is that the universities will continue to open—open their courses, open their doors, open their minds to those who cannot attend them as students. In the future, everyone should go to Harvard—in a limited sense. We cannot all attend Harvard for four years but there is no reason why the whole world cannot participate in a Harvard course and a shared learning community, perhaps for only one semester.

Until that time, public inventors need to build their own learning communities that are not exclusive in terms of geography, tuition costs, age, or previous research history. People's time will remain scarce. There is no way to expand that time. But wisdom can be published and shared as broadly as possible.

We will probably never remove competition for honor from human society. All the great religious teachers and philosophers warn of competing for badges and the praise of our fellows just as much as competing for the money and prizes. Nonetheless we can move towards a world in which we compete to be good rather than to be rich, famous, attractively dressed, or good at sports. We can compete to be the best team player, the greatest contributor, and the best child to our parents and the best parent to our children. Most of all, to be the best sibling to our brothers and sisters. I will be long gone before we explore the planets together in peace, but I hope our children will compete to be the best spaceshipwrights, the best crews, the best explorers, and, dare I say, ambassadors.

18.14 The Principle of Precession

"If you want to find something, there is nothing like looking."[TODO: Is this a C.S. Lewis quote? Or from Alice in Wonderland?] You almost always find something, even if it is not what you set out to find. This principle applies to almost all research and public invention work. Buckminster Fuller called this the "Precessional Principle".[TODO: find reference] Analogous to the precession of a gyroscope, applying effort in one direction tends to have an effect in a different direction, often different than the impact that you at first suppossed.

Public invention projects often fail to reach their intended goal, but rarely fail to acheive something. Being open to recognizing this when it happens is a key to becoming a happy and efficacious public inventor. As Isaac Asimov said, the most exciting words in a reasrch laboratory are not "Eureka!" but "That's funny..."[TODO: find reference to Asimov]

Being able to make use of a new opportunity exposed by an effort (whether successful or not) is sometimes called by modern project management the ability to "pivot". To "pivot" means to change course to an originally unimagined destination when, in the course of executing an original plan, it becomes apparent that an even greater prize can be won. This takes a certain amount of experience to perceive, and a certain courage to let go of the original goal. It creates the risk that a team will never complete anything, but be led about by a siren-song of ever more enticing and harder to acheive results.

18.15 The Value of Honest Mediocrity

Antoine St. Exupery wrote a book which is under-read, "The Wisdom of the Sands". The image that stuck with me the most is that of the mediocre sculptors. The narrating character is the emperor of a small land and he values great scuplture. Yet he knows it takes 20 mediocre scupltors to make a great sculptor. Whether from what is learned from the 20 bad sculptors or as a competitive incentive for a great sculptor to best the others, you cannot hope to see greatness if you do not foster mediocrity.

Thanks to Prof. Corey Anton for suggesting this book on his YouTube channel.https://www.youtube.com/watch?v=tUSBKq5bTik

I would rather be a great public inventor; but I accept my mediocrity as a requisite sacrifice for someone else to achieve greatness. In that way I become a co-creator in the greatness, even if time efaces my name more quickly than that of the great inventor. And so do all public inventors, however mortifying our mediocrity and ill-fated our flops. An honest failure done in the light is a beautiful thing, for it is a stepping-stone tread on the way to success.

To echo Pink Floyd, I would rather have a walk-on part in a war, than a lead role in a cage. Sometimes when one reads a scientific paper, one comes away thinking, "Well, that was not worth the paper it was printed on. What a waste of time." But it is important to remember that mediocrity is the junk-heap from which greatness is constructed, the compost from which fresh fruit grows[TODO: Add Edison quote about Junk]. To use one metaphor[TODO: add citation to Esperanto Novel], every published paper or github repo is a single tile in an enormouse

"Wish You Were Here" [TODO: Add Reference]

mosaic being constructed by humanity. Not every tile is brightly colored, but every tile is an indispensable part of the overall mosaic. To have placed one tile, however small, is a worthy human labor.

18.16 Small is Beautiful: The Power of Restraint

At present most of our volunteers are working part-time on projects with tiny budgets. Mythical inventors like Daedulus and Tony Stark have no such constraints. Professional researchers, such as university professors, generally have larger budgets but have to spend a significant fraction of their time writing grants to get it. There is no such thing as a free lunch.

If one thinks of a limitation as a self-imposed restraint rather than an externally imposed constraint, it can spur creativity. Budgets limit more the kinds of thing that can be worked on than the quality of the work that can be done. A large budget can be used to save time, either in terms of calendar time or in terms of hours of labor. Time is the one resource we can never recover. However, I think if most of us count up the time we spend watching entertainment or playing computer games we will not be too quick to bemoan having to spend extra time on an invention project due to a budgetary constraint. We must also remember that many things are almost free now that were expensive in the past: computing cycles, powerful microcontrollers, intricate parts that can be 3D printed, certain kinds of biohacking (of which I am woefully ignorant.) Finally, theory has never required much more than pencil and paper, and Ramanujan[TODO: add citation] did great work when he could scarcely afford paper.

A limited budget argues for taking very small iterative steps on a project. You can risk less, so you taking smaller steps. Restraint may compel you to do design work upfront to decrease the cost of machinery earlier in a project than a well-heeled team might do. Both of these in themselves can be sources of strength.

18.17 Anti-quackery

Unfortunately, some of us are quacks. I hate con-men but love quacks, and try to be gentle with them. We must love the quack and hate the quackery, whether in ourselves or in others.

There are a number of reliable litmus tests to detct quackery. The first one is: Do you understand why Free Energy is nonsense? A surprising number of us still try to make free energy machines; I have met two, not counting myself—I gave it up at the age of fourteen.

A general understanding of basic thermodynamics is a bedrock understanding for physical inventors. Related to this is an understanding of the basic conservation laws of mass, energy, and momentum.

I have personally been accused of stiflying innovation with this attitude by people who correctly point out that there have been many things that were thought impossible until they were accomplished. However, the people who accomplished those things could clearly articulate they way in which

their approach might succeed against the conventional wisdom. There was no fuzzy thinking in the Wright brothers or in Einstein. I am all in favor of people searching for the free energy machine, but I insist they do their homework. If you cannot articulate how you hope to liberate us from the known laws, you must go back to your learning and study more until you can. "Extraordinary claims require extraordinary evidence." Often the modern quack will say, "I will provide extraordinary evidence when I am given the money/energy/attention that my brilliant idea demands", without the ability to articulate why their idea is brilliant. The maxim that I use in practice is: "Extraordinary claims require extraordinary clarity." If you don't understand why your claim is extraordinary or can't articulate your approach with extraordinary clarity, the world should not waste time on your idea until you can.

(ECREE), the Sagan Standard.[TODO: find citation]

A Publishing Disconnect between the Free Software Movement and Open Science

19

19.1 The Problem is Terminology

This chapter was originally published as an essay co-written with Marc Jones after a hackathon for Project Drawdown. [TODO: add citation]

Academic researchers and the Free Software Movement (FSM) use the word *publish* differently. The difference in meaning in the word publish (and publication) creates a disconnect when the Free Software and Academic communities try to collaborate or when Academy adopts the ethos inspired by the Free Movement and the Creative Commons community.

Free Software Publication means putting anything, no matter how trivial or unrefined, online and potentially accessible to world, expecting it to be revised periodically and possibly linked to by others.

Academic Publication means putting a work in academic journal after it has been critically reviewed and circulated for review by peers and trusted advisors, where it will be eternally unchanged, and possibly referenced by others. Free Software culture expects that works are "published = made accessible and known to a limited audience" from day one. Academic researchers often expect that things are not "published = announced in a peer-reviewed forum" until they have been thoroughly vetted and refined. This difference in expectations can challenge free software developers and academics who work together on projects. Nonetheless, such collaboration is extraordinarily useful and becomes more so every day. Creating a productive working relationship means creating a common understanding about expectations, the language used to describe the process, and the process of implementing the project. This chapter is an attempt to explain this to facilitate these communities working together.

19.2 The Mutability of Published Works and Expected Quality

Expectations in the free-libre open source movement are that works are eternally mutable: they are constantly improved and are never in a final state. In a free software or public invention project, the contributors may not know who will make the next improvement, since in theory a wide audience is invited to contribute. Contributors are recognized rather discreetly, sometimes not even by name, in the commit logs and spread out in comments throughout the code. Contributors to a free software project are not individually responsible for its overall quality. In academia the expectation is that a definite list of authors will take responsibility and great care for moving the work from conception to final, published state, after which it should not need any serious revision. Academia demands non-repudiation: each author is expected to stand behind the conclusions of the work with their reputation. Free software and public invention hardware designs are "published" immediately.

By published, free culture authors mean it is available for anyone who cares to discover, to examine, comment upon, and and even build a rival to. There is no expectation that the work is highly usable, let alone finalized. Everyone accepts that some bugs will exist. In fact, the expectation is that you will make it available before having a confidence it is bug free! Functionality often is achieved before all of the possible ideas the original author have come to fruition. The ethos of "release early and release often" embeds this idea. Well after first publication a project will reach the first point of functionality. At that point free software or public invention authors will frequently make a "release." The "release" of an open source software project is symbolic; it is an assertion of readiness rather than a revelation of information. Once a "final" release has been published it is a indication that the authors believe it has some degree of usability. To working programmers and inventors, the release is a non-event; the development process immediately continues to revise the code base to add more functionality and fix any bugs, which are expected to be discovered in the previous release.

19.3 Quality Standards

Academic publication (and traditional writing at large) has a different standard to meet for publication, which is a momentous event. The work product is the explanation of an idea. Authors are judged and criticized on how accurate or complete the idea is. Significant flaws in the idea or its explanation are problems indicating that publication and sharing the idea was premature. Publication is a seal indicating a level of quality and finality.

Not only does free software not have this sense of finality but the standard for quality, minimal functionality, is entirely different. Typically in academic publication there is no similar standard to being functional. English prose can only express an idea; to the extent it is a "useful" idea (as opposed to just an abstract idea) it requires someone to apply it through more work. Free software has the advantage of doing work in its current state, typically without the user even understanding the ideas expressed.

Free software developers often expect works to be accessible to anyone or "Open from day one", even before anything useful is done. To them published does not mean publicized. The expected audience of a nascent project is tiny. Nonetheless, developers expect the underlying ideas, goals and data involved to also be shared publicly. They will expect every mistake and half-way step will be made freely available to any party that cares to go looking. They will not be concerned that mistakes will reflect poorly on them early in the process and expect to be judged on the progress and the process initially and only on the quality of work when the developer specifically states they believe it is high quality. Software is never "done".

In contrast academics have the expectation that works are only shared broadly with others when they have reached a final "done" or permanent state. The final, permanent state requires that the first publication be of high, even meticulous, quality and free of all serious flaws. The finality

of the state turns the work into an artifact that allows others to judge and critique it as soon as it is published. Any reputational impact rests on the state of the work at the moment of first publication. Academic publishers seek to be respectful of their readers' time by producing the highest-quality work possible.

Free software developers have the advantage of being able to layer the fixes over there bugs that get buried in the revision control history. Academics mistakes are hard to correct silently once an article has been published.

19.4 Rivalry

In some cases there is a race to reach this final point of publication since reputational interests are disproportionately granted to those who publish first. Those who follow cite previous works, increasing the reputation of the previous works. In academia, sharing too much too soon might enable someone else to craft a publication that preempts the work and the reputational rewards that it carries. Authors of an academic paper circulate select drafts of the paper before publication to only a few individuals the author trusts. The author hopes that any criticism will be in private and that the carefully selected reader won't attempt to compete or usurp the opportunity to be the first to publish by rushing to the presses.

FSM developers expect that anyone could look at the work in progress and criticize, contribute to, or be inspired to create a rival to, the work. These activities have largely been embraced by the free software community and turned into opportunities to accelerate the progress of the body of free software generally. Rival works are common and to some extent validate the value of the work they seek to supplant. It is impossible to count the number of competing GNU/Linux distributions, LLVM has long been competing to supplant GCC as the default compiler in the free software world. These rivals encourage diverse approaches until one dominant modality emerges, which can only rest on its laurels for so long. As an example, in the important field of version control systems, RCS was replaced by CVS, which was largely supplanted by SVN, which lost to a competitive field of distributed source code control systems, until git as emerged as the dominant player.

[TODO: Add citation]

19.5 Method of Reuse

Despite the different understandings around the meaning of "publish" and the expectations that come with the act of publishing, there are many similarities between writing an academic paper and developing free software or public inventions. Both recognize the need to build on the works of others. Academic papers do this through a rigorous method of citation. Free software and public invention does this by incorporating libraries written by previous authors into the work, or by modifying existing software or hardware designs directly. Both methods of production also recognize the need to circulate works prior to their

general release to communities of knowledgeable individuals that can offer critical feedback to give a diversity of thought on the quality of work done so far and identify further work.

When a research paper cites a previous work it acknowledges the priority of the earlier work. Academics acknowledge the contributions of those who have expressed ideas previously:

- to give credit to those who thought of it first,
- to show that they are contributing something new beyond what has been expressed previously, and
- to give the reader a pointer to valuable reading on related ideas.

There are, however, no legal restrictions on the use of the idea in an academic paper, the citation process is not directly regulated by law, but rather by industry standards which carry consequences.

For instance, suppose you write a paper criticizing another person's paper for a logical flaw: you need to cite the flawed work to give readers a reference point. But if your reference point was not fixed in time and after reading your paper the author of the original paper repaired the logical flaw, your criticism no longer makes sense in reference to the now corrected paper. The change to the underlying paper being criticized robs those who criticize it of the reputational reward undermining the motivation to interact and collaborate to move the ideas and the field forward.

In contrast, Free software references code which changes frequently. By using some software, you are providing a small reputational reward to the author, not for having any particular idea fixed in time, but for having working code. When you borrow the implemented code you have a social requirement of acknowledgement. Typically it is even a legal duty, since you are literally textually copying copyrighted software into your work.

Software languages have been designed to make a weaker form of reuse by reference possible by the use of "libraries", which facilitate the use of software created by other authors. Often the expectation is that you will only reference the functional work rather than textually including the work, because there is a recognition that the softwares functionality will change and you want to be able to easily take advantage of the improvements. If someone fixes the flaw in the software you are incorporating into your software, your software doesn't typically stop working — just the opposite — the hope would be that your software now works better because it benefits from the fix as well.

19.6 Conclusion: How to Cooperate

Free software developers and public inventors typically have different professional reward systems from researchers, and different expectations around mutability, rivalry, and means of reuse of their work, but this does not imply they are at cross purposes on a particular project. The key is to create a shared understanding and language to be able to precisely discuss the goals of the individuals and the goal of the overall project. The natural language of these groups diverges most around the terminology

of publication. We present the examples below as a guide to clarifying this confusion.

FSM developers and public inverntors should be ready to say:

> "... publish the software and design..." ... by which we mean... "... place it in a publicly accessible repository without publicizing it."
> "... release the software and design..." ... by which we mean... "... make a minor release which will only be noticed by dedicated parties."
> "... make a major release..." ... by which we mean... "... we will make a public announcement which, while largely symbolic, will attract a lot of attention."
> "... make this freely available..." ... by which we mean...
> "... make it accessible with documentation and a license that it allows it be vetted, shared and improved, but does not carry with it any expectation that it is perfect, free or error, or even works very well."

Academic researchers need to be prepared to say:

> "... data not ready to be published..." ... by which we mean... "... we don't mind people looking at the data, but we don't want to publicize it yet."
> "... algorithm and model is not ready to be published..." ... by which we mean... "... we don't mind it being in a public repository under a public license as long as documentation and version control clearly reflect that we are still working on this and track our changes."
> "... of course we invite people to improve this work, but we have not published it yet..." ... by which we mean...
> "... we want it to be made accessible under a license but with an understanding that using this without giving us academic credit should be considered plagiarism."

Math and Programming 20

Math is Deep Magic to the inventor. A little goes a long way, and you can never have enough.[TODO: Add reference both to Lewis and the Eric Raymond here]

Of all the skills that an inventor can have, what we call math is the most enabling and differentiating. In slang we use it as the touchstone of truth when we say "Do the math". But we can also say "Do the math" to become a better inventor.

New mathematical findings, whether they are called discoveries or inventions, are within the compass of public invention. Math is eternal; semiconductors may not be. I hope someday we invent biological circuits that replace silcon chips, but mathematical inventions never become false, and only rarely become useless.

One might even argue that technological advance has made some kinds of math easier and cheaper, just as cheap microchips have made some kinds of mechatronics easier and cheaper. There are now very powerful free online tools that allow very powerful computations and assistance. Not being particularly good at math myself, I use these crutches without shame.

I dream of the day that we will fill a stadium to see not a football game but a math lecture. I long to hear there was a riot and cars were set on fire in celebration of a particularly elegant new proof.

However, you don't have to be good at math to be a good inventor, and those who are good at math may not be the best inventors. Still, any clear-eyed public inventor must know enough math to know what they know and what they don't know. Some nuts can only be cracked with the hammer of the math; others don't need it.

Computer programming, on the otherhand, is not so deep. Rather, it is of ubiquitious utility. Computer programming is the most commonly useful skill that an inventor can have today. Even if an invention has no computer in it, it will likely be analyzed or simulated or measured or at least viewed with a computer. Being an inventor today with no knowledge of computer programming is like writing a page with only intransitive verbs; it is possible but bland.

No child should be deprived of learning math and programming, both because of their utility or their beauty.

...Euclid alone Has looked on Beauty bare. Fortunate they Who, though once only and then but far away, Have heard her massive sandal set on stone. – Euclid alone Has looked on Beauty bare, Edna St. Vincent Milay

What If You Cannot Be a Public Inventor?

21

Some readers may wish to be public inventors, but may not feel able, and may ask "How can I help?"

Almost every project requires assistance in a wide variety of skills (see Section **??**); almost everyone has some skill that can help in some way. However, some people may not have the time to volunteer in any way at all. Try to remedy that situation.

If you cannot find time, you can provide projects with moral support. A kind word is a powerful talisman for those struggling to create something truly novel and useful.

If you cannot spare a kind word, then spare money. The best way to give money to a public invention project is to charge your gift with the emotional force of your own love and enthusiasm for a particular project. More money is better than less money, but money that you target for a project that you believe in will be more satisfying and effective to both you and the project. Just as undeserved praise rings hollow, money means more when coming from someone who supports a project out of conviction for the project itself than an uninvolved but generous donor.

If you can do none of these things, you can try to grow into a position where you can.

21.1 Universally Needed Skills

The broad range of invention topics includes almost any field of study, and often several at once. Often invention is the combination of two previously unconjoined techniques, such as magnetic ferrofluid and chemistry.

However, there are many skills that almost every project needs. The universal skills are equally important though sometimes wrongly denigrated as "soft" skills or people skills. In reality all skills are equally necessary, as all organs of the body are equally necessary to a whole human being. It is of course true that we can do without our appendices and our spleens without too much trouble, so not all organs are equally important—but all organs are equally part of what a human is. In fact the people skills are valuable precisely because they are needed on almost every project. If you can contribute these, you can be an important part of a public invention team, and therefore, by definition, a public inventor.

The first skill is communication. Every project must be communicated to the public in some way or it is not a public invention. It is true, of course, that most people speak and write some language, however awkwardly. However, a skilled communicator who is willing and able to fully understand the invention can magnify its impcat tremendously. I was born in the late middle of the last century, and so to me communication tends to mean writing. However, the world is moving toward graphic and audio/video communication more and more. A modern invention team

needs some combination of skills drawn from graphic art, videography, technical writing, and perhaps speech or acting.

Projects don't manage themselves. It has been a bittersweet surprise of my professional career that people seem to value my ability to make and maintain lists of the things to do more than my ability as a researcher. Management skills are absolutely essential. Of course, most humans can manage some things, a little—but not every public inventor can actually manage a project well. A good manager can make a huge difference.

Leadership it the third major category of skills. It is the ability to motivate and inspire a team or a person. In a way, it is rarer and harder to define that management, but it is also a learned skill. Public invention teams are a great way to practice leadership, because there is usually not enough of it.

There are a few other skills which are also universal and in some sense just as important as these, though perhaps not on every project. Fundraising enables bigger projects to go faster. Without fundraising, Public Invention can still occur but it is drastically reduced in scope and speed. Lawyers serve an essential role in all projects that use free-culture licenses. It is true, one can generally learn what you need by leveraging previously written documents, thanks to the generosity of lawyers who have documented practices for us. However, as projects become bigger and more imporant, particular when they have more of an engineering flavor, legal advice may be needed.

How to Start a Public Invention and Humanitarian Engineering Club at your University

22

One of the most impactful things you can do is to start a Public Invention and Humanitarian Engineering (PIHE) club at your University. (We recommend that PIHE be pronounced "PIE-hee"). Although one could of course start a club devoted solely to public invention, by including humanitarian engineering the appeal is broadened.

Humanitarian Engineering, [is the] the application of engineering to improving the well-being of marginalized people and disadvantaged communities, usually in the developing world.[16]

22.1 Humanitarian Engineering

Humanitarian engineering was first offered as a minor by the Colorado School of Mines in 2003. Organizations like Engineers Without Borders (EWB-USA) have made it a nationwide activity with over 300 chapters (see map below) [TODO: Include image]. The blue dots are EWB chapters, many of which are student chapters associated with Universities, and the red dots are community projects within the USA. EWB-USA focuses heavily on civil engineering (e.g. clean drinking water projects) in low and middle income countries. The COVID-19 pandemic, however, has made both the need for and abilities of humanitarian engineering clearer. Helpful[TODO: Add Citation] is one of several volunteer organizations created in response to COVID-19 dedicated to humanitarian engineering. Humanitarian engineering has leveraged advances in digital manufacturing and open source sharing of designs to aid the world by creating personal protective equipment (PPE) and even sophisticated medical devices like ventilators. There is a need for humanitarian engineers in every kind of engineering discipline.

22.2 Starting a PIHE Club

Public Invention and Humanitarian Engineering are both movements that seek to use human ingenuity to help society and the planet. There are always highly motivated students interested not only in learning and increasing their earning power, but also by a desire to help their fellow beings and move society towards a sustainable state. These students deserve a place to congregate, socialize, learn and teach together. The project-based nature of Public Invention and Humanitarian Engineering movements are a great way for students to be mentored and gain practical experience to augment their studies. We think every university should have a Public Invention and Humanitarian Engineering club.

At most schools, the students have the power to start a club simply by asking to do so, sometimes by filling out some paperwork to assure the safety of the students and that the club accords with the principles of the school. The university usually lets the club meet in a classroom or other room, and sometimes provides a small amount of money for things like pizza.

A student-formed organization may require a faculty advisor, and sometimes a minimum number of students to serve as the initial officers of

the club. Usually, a statement of the purpose of the club will be required. We recommend that you use some variant of this purpose:

> The purpose of the [your university name] Public Invention and Helpful Engineering club is to explore and support the use of technology for the betterment of humanity and the planet, particularly how technology can address problems not being addressed by the private sector.

You do not need the permission of anyone outside your school to start a PIHE club, and your club doesn't have to follow any dictates that it does not itself choose. Every club can be independent. You are encouraged, however, to inform us at Public Invention (email: <read.robert@pubinv.org>) so we can give you a shout out as well as connect you to other club directors and presidents. We will help you find speakers and mentors as well.

Here is the preamble drafted for the University of Texas at Austin club:[TODO: Replace this with something from Auburn]

> The local Austin Public Invention and Helpful Engineering Chapter is intended to support student awareness and participation in humanitarian engineering projects and free, open-source inventions with the public interest in mind.

22.3 What a PIHE Club Should Do

Whenever two or three people are gathered together, a spirit arises which is greater than the individuals. A PIHE club doesn't have to do anything beyond talk about the ideas of Public Invention and Humanitarian Engineering. But a PIHE club could also:

- Invite speakers to talk specifically about PIHE concepts, practices, and projects. Public Invention (the non-profit) will be happy to come speak at your club!
- Take on real projects that can really make a difference. The organization Public Invention has published a growing curated list of such projects analyzed for difficulty, joinability, and skills that you can use as a starting point.
- Interact with a local Engineers Without Borders professional or student chapter, or consider starting one!
- If not ready to do a real research project, take on a learning project to improve your PIHE skills, such as building an open-source device useful for humanitarian purposes.
- Brainstorm new public invention ideas, and contribute those ideas back to the public invention list of ideas.
- Invite discussion of the philosophical, religious and ethical aspects of PIHE.
- Seek out ways engineering and technology can help in your local community, such as:
  - Mapping invasive species,
  - Providing sanitation to the homeless,
  - Recycling plastic with recyclebots into 3-D printing filament,
  - Measuring and decreasing the local carbon footprint, etc.

Of course, you can probably think of a dozen other useful and fun things! EWB student chapters have a very well-defined way to make a big impact by working with local low-resource communities internationally, but a PIHE club does not have to be structured that way. Your PIHE club will not be a chapter of a larger organization, so you are free to focus wherever you like. Some clubs may wish to focus on real-world project-based learning. Other clubs may want to chat about how an engineering career can be part of PIHE. Some clubs may focus on the environment, others may focus on poverty and inequity. What they all share in common is that they share their inventions and development to the commons!

22.4 What the Students Should Get Out of a PIHE Club

Although every club may be different, the students of a PIHE club should obtain certain benefits:

- The joy of sharing a common interest with your fellow students.
- The satisfaction of helping others, even if that help is abstract and potential, existing in the future rather than today.
- Learning how technology can positively affect the real world.
- Understanding the open-source and free culture movements.
- An introduction to modern project management tools such git`https://git-scm.com/`, GitHub`https://github.com/` and GitLab`https://gitlab.com/`, and Appropedia`https://www.appropedia.org/Welcome_to_Appropedia`.

If a PIHE club is ambitious enough to undertake its own humanitarian invention project, perhaps with the help of a professor or Public Invention, then students can expect mentors, real-world experience, practical motivation of their studies, and a great project to talk about in a job interview or when applying to graduate school.

How to Be a Public Public Inventor Specifically in the 2020s

Public Invention 101: Pre-requisites

23

To be a public inventor, you have to be honest, courageous, loving and enthusiastic, invest in communication, and know algebra.

You must above all be honest because the Universe cannot be tricked, cajoled, bullied, seduced, or lied to. You cannot build a functioning machine based on a lie or a fraud. If you lie to yourself, you will not be able to persevere efficaciously for very long. If you lie to your team, you will not be able to contribute to that your team for very long.

You must have courage because invention requires you to undertake things that which has never been done before. You are setting sail in the dark. The chance of humiliation is real. The chance of ultimate failure is high. The chance of frustration is near unity.

With love and enthusiasm, the borders of the possible are bounded only by the impossible. Without love and enthusiasm, you will be useless or worse to those around you, and, just as bad, you will waste your own time.

What should you love? The verb need not be transitive. But it is useful to consider the four classical loves as elucidated by C.S. Lewis: *agape, phileo, storge,* and *eros*.[17] *Agape* is perhaps the most fitting for the public inventor, as can be translated as *charity*, or love for one's fellow beings universally. *Phileo* is the love of friends, and is almost but not quite enough to carry an invention project forward. Teammembers may love each other because of their shared interest, which is the fastest way to friendship. *Storge* is affection for those that are known to you, and includes rooting for your home team. Storge is the basis of teams which are competing, such as FIRST robotics teams or robot combat teams. While I frown on competition, it cannot be denied that the desire to see your own team win is a powerful motivation. *Eros* is primarily thought of as romantic love, but its second sense includes desire for beauty in many forms. Many makers have an erotic (second sense) desire to create art, whether traditional or novel.

The public inventor is a communicator. If you are not willing to invest in communicating well, you miss the adjective in public inventor. It is wrong to demand that an inventor be a great writer, or even write grammatically. An inventor need not be a charismatic speaker. The inventor usually has the benefit of an artifact to assist in communication, and an artifact is worth a thousand pictures, and hence a million words. However, an effort must be made to share effectively. The entire point of public invention is to communicate the invention in a usable way to other people.

Finally, you must know algebra. If you don't, you are not permanently disqualified, but you must remediate yourself by learning algebra. This is not because a public invention team could not make use of you, but because you need and deserve it, and satisfying that need in yourself is more important than any service you could do the invention team. Do not be frightened of this, it is relatively easy. Take a course if you have to. Do every problem in an algebra textbook if you have to.[18]

Public Invention 101: Basic Skills 24

24.1 Computer Programming

The computer is the most versatile tool. That this should be true could not perhaps have been predicted before Ada Lovelace and Alan Turing laid some physical and theoretical groundwork, but in hindsight it is obvious. The computer allows the automation of very, very simple mental tasks. That very complex, very useful tasks can be composed of very simple tasks is the beauty of the science we now call Computer Science. Everyone needs to see how this works to appreciate it. It can be done in one semester, and requires patience because computers are astoundingly frustrating, but does not require unusual intelligence.

I have been programming for 40 years and am more of a journeyman than a master. Learning to program, at first on a cardboard computer called the CARDIAC and then on a TRS-80 opened my eyes and awakened me intellectually. Looking through my Sears microscope a few years earlier had been similar emotionally in terms of observing the natural world, but but computers gavve m something that I could actively do.

Small computers called microcontrollers combine this versatility with two extraordinary properties of electricity to make them the most common and versatile of tools for the modern inventor. You can purchase a wide variety of sensors that sense temperature, humidity, light, pressure, vibration, and pH, just to name a few examples, and convert them to varying voltage. You can read those voltages into a microcontoller and calculate with them. In combination with the similar ability to control motors and lights with electricity manipulated by a microcontroller, you have a general purpose sense-and-respond machine. This would sometimes be called a robot, but it could be much simpler than that.

These microcontrollers are programmed just like much more powerful computers. Therefore anyone who can program, even a little, instantly opens a door to creating a wide variety of machines whose activity and purpose is more limited by our imagination than their physical limitations.

You do not need to become a highly skilled computer programmer, but everyone should learn some basic programming for three reaons. Firstly, it is fun. Secondly, it gives you some understanding of what a computer can do and what a computer cannot do. Thirdly, it helps you communicate with programmers. For all of these reasons, a public inventor neeeds to know some computer programming.

24.2 Debugging

As I wrote 20 years[**HowToBeAProgrammer**], debugging is really the heart of computer pogramming. The word “debug” technically means to remove an error, but in practice it means something deeper: gaining visibility into a running program. Programming is so complex that one

soon encounters errors. This happens even if you are an error-free genius, because you often work with ambiguously or erroneously documented systems. Even if you make no mistakes, you are working with imperfect materials. In the case of microcontollers, electrical connections come loose frequently, even if you make no mistakes in connecting them.

You aren't.

If you make no mistakes in building your circuit, you are far more precise than I am.

Debugging is not taught hand-in-glove with computer programming as it should be—or at least it was not when I left graduate school in 1995. If I could give advice to young people, it would be: insist that someone teach you debugging, whether that is your teacher or someone in your class or some more advanced student.

Debugging is closely related to the more general skill of troubleshooting. Long ago people learned troubleshooting on internal combustion engines trying to keep cars running; that is more difficult now. The principles remain the same. In your mind, construct the space of everything that can go wrong. Then, design an experiment that comes as close to isolating the problem into one of two equal-sized halves of that space as you can. Then perform the experiment. Repeat this with the now smaller space until you have isolated the problem.

For example, with internal combustion motors, a typical way to divide the problem space is to ask: is the problem with the fuel delivery, or with the electricity? The inital test for this is simple: if the motor "turns over" when you try to start it, it is probably a fuel problem and not an electrical problem. The process must then be carried on.

In a computer program, the process is similar. At first, a student will have no idea what "the space of all things that can possibly go wrong" could mean. But with time and patience, like anything, your brain will automatically start to figure it out.

24.3 Source Control

Public invention is social. To interact with others in the modern technological landscape requires interacting with documents, and documents must be managed. The modern way to manage documents is with a source control system, such as *git*. Explaining how to use git is beyond the scope of this book, but everyone should know how a source control system works.

A source control system keeps a record of a directory of files. This could be small or gigantic, shallow or deep. When you modify a file, you can issue a command to make a permanent record of this modification. This is done automatically for you by comparing the current version to the previous version. Each version is a given an internal name or number which allows it to be uniquely identified, and the order of these modifications is carefully controlled.

By examining these records, you can magically look back in time to obtain the files as they existed at any point in time. If you make a change you wish to remove, you can do this by rewinding to an earlier point in time. In fact, you can usually remove just a single edit, even if you have made complex changes since that edit.

The final magic is that this system allows multiple people working in a completely distributed way to work simultaneously on the same files and rarely have to worry about a collision. When they do "collide", or make incompatible changes, there are specific ways to resolve that issue.

This is similar to, but more powerful than, the "track changes" feature or "redlining" offered by some text editors.

With practice, the use of a source control system becomes second nature. It ceases to be mysterious and becomes just a normal way of doing things. Public Invention (the non-profit) begins every project by creating a git repository.

Public Invention 201: Intermediate Skills

25

Intermediate invention skills are not technically required, but are so universally useful that every inventor should work to learn them. Although somewhat subjective, we will assert they are:

- Trigonometry
- Calculus
- Vectors
- Linear Algebra
- Being Able to Skim Scientific Papers
- Google Scholar
- Effective Writing
- Brainstorming
- The ability write "Hello World" in any programming language
- Know how to write Conway's life in at least one language
- Electromagnetism
- Basic thermodynamics
- Use of a Multimeter
- Microelectronics
- Very Basic Analog Circuits
- Breadboarding
- Soldering
- PCB design
- 3D printing/CAD design
- Statistics
- Free-libre Open Source Licensing
- Agile Project Management

25.1 Math

Trigonometry and basic geometry is used in almost all mechanical design and discussion of periodic behavior.

Archimedes invented calculus, a Roman soldier murdered him,[TODO: add source here] and the secret was lost until Newton and Liebniz rediscoved it. The essential ideas of calculus are so beautiful and useful that everyone should understand them. The actual need to be able to take derivatives and anti-derivatives of polynomials has been obviated by freeely computer-based symbolic calculation systems, such as Wolfram Alpha. Nonetheless you should understand the principles of the the derivative, the infinitessimal, l'Hospitals laws of limits, and integration.

Vectors are so useful that any mechanical invention is likely to require them. Sociology and economics also require them. I suspect even the "soft" sciences like history and linquistics would benefit from them more than people realize.

Linear Algebra extends algebra to express operations which are "linear". The most obvious usefulness of this is in computer graphics, where

operations such as scaling, rotation and translation in space can be expressed as combinations of linear operations.

25.2 Research Skills

Google Scholar is now an indispensable, but fallable, tool for doing research for any invention project. It is a simple keyword (and author) search mechanism that returns ranked results which are all scientific papers in one way or another (some will be preprints, which have not been peer reviewed). It is similar to Google Search in operation, but limited to academic results. An hour of using it can give you a very good idea about related research. However, there is the danger that you do not know the correct words to search for. Someone else may have done work on snorfuzzles but called them thimbrackles, in which case your results will not help you. However, if you find the best references you can for snorfuzzles and skim them, with luck the word "thimbrackle" will occur in a paper or a title of a cited reference, and suddenly your doorway to the world of thimbrackle research opens.

About two-thirds of the results returend by Google Scholar will be behind a paywall. You can still obtain the result by simplying paying for it if the abstract seems apropos. However, this is expensive and often you regret the purchase when it turns out the paper has no actual relevance. An alternative is to attempt to get the right to use your local university library, which can often be done through a state library system. Universities usually allow access to articles that are otherwise behind pay walls. Luckily, the other third the results you get will be free to read online, or a relevant preprint will be available online for free.

Scientific papers can be intimidating and confusing. Often editors enforce rules of jargon, notation and concision which, whether by design or not, make it very difficult for begineers to understand even what is being said, much less follow the arguments for why it is true. Nonetheless, the antidote is practice; it gets easier with time. It gets easier MUCH faster if you an find an expert to explain the notation to you. Any scientific paper should be read at different levels and in some cases multiple times to determine if it is relevant to your project. Most papers will not be; but you cannot be sure until you have skimmed them. Usually, one should try to understand the abstract or the conclusion if there is no abstract. Sometimes jargon and notation makes this impossible. Sometimes you can skim a paper to understand its "shape", which helps you understand the activity that was undertaking, noting in particular figures or tables, which are often illuminating. Finally, if the work remains relevant, you may have to carefully read it line by line and devote signifianct time to understanding the equations, if there are any.

The first math paper I tried to read when I was in High School completely stymied me by using the greek letter ϵ to mean set membership (which is a very common convention), and I couldn't figure out how multiply by "e" could make any sense. I did not even notice it was a Greek letter, not the letter "e".

I sometimes can't tell what a theoretical math paper is even about.

25.3 Programming

Computer languages come and go. A skilled practitioner should be able to operate in any language quickly. In that sense, a computer language is really more of a "notation" than being akin to a natural human language.

A public inventor should be able to write a very simple program in any language quickly.

Like math, the inventor should constantly advance their computer skills. My favorite exercise, which was taught to me and I have passed on to others, is called "Conway's Game of Life". It is perhaps the most fasinating, even research-worthy, program that can be written in a few dozen lines of code. It demonstrates visually how tremendous complexity can arise from a set of very simple rules.

Thanks to Mike Perlman of CS 321 at Rice University

TODO: cite the journal here

25.4 Physics

Electromagnets are used everywhere. Even if your invention project has nothing to do with them, understanding some basics about them will likely prevent you from making some mistakes.

[TODO: expand this section] Thermodynamics underlies the universe and helps explain much of what natural world, including at least analogs in biology. The conversation of energy and the second law are valuable backstops to thinking about many physical sytems.

25.5 Microelectronics

The field of hobby microelectronics is now a versatile, inexpensive, and, above all, well-documented set of tools for all sorts of measurement and control functions. Even biohackers should be familiar with it, if only for building lab equipment and performing experiments.

A multimeter, of which the voltmeter to measure voltage is the most common mode, is indispensable for debugging electronic circuits, which will be necessary in almost any microelectronic work, including bread-boarding.

A breadboard is a little plate with sockets for you to poke wires into. Some of the sockets are connected to others, allowing you to make electrical connections by just plugging in wires with hard little ends called jumper wires. Almost everyone starts a project by building a circuit on a breadboard before moving to sturdier construction.

Soldering with a tin, lead, and silver based solder is easy, fun, slighly toxic and a slight burn risk. Generally it is a step up from breadboarding in terms of difficulty and sturdiness. It takes perhaps four hours to master. Because of the ease of modern printed circuit board (PCB) design, I've noticed that some young people skip soldering altogether and go directly to PCB design, but I recommend against that.

The simplest kind of soldering is called "through-hole soldering". You stick a wire of an electical component through a hole in a resistive board and then mount it securely by melting a little cone of solder around the wire and onto a "solder pad" built into the board. In some cases you make connections by adding a little mound of solder connecting two or more of the holes. In some cases connections already exist, in a printed circuit board.

More difficult is "surface mount" soldering. In this method there are still solder pads, but no holes. The component devices can be much smaller because they are free of the need to have evenly spaced holes. The decrease in size can make the whole board much smaller but may require magnification and much steadier hands. In some cases a hot air gun is used instead of a solder iron. The very close proximity of solder pads which must not be accidentally connected makes it challenging for me, but there are some specific techniques that rely on the "wetting" properties of solder and copper that make it possible.

I'm 56 and my hands shake

A printed circuit board traditionally was created when multiple copies of the same circuit where to be manufactured. However, modern, *gratis* PCB design tools such as EAGLE[**eaglecad**] and inexpensive mail-order houses with relatively quick turn-around times have made them practical as a prototyping tool. Because of shipping, they will always take more calendar time that soldering, but are useful part of the overall design development process.

In most electronics projects, the issue of how to enclose and protect the circuit can be delayed for about six hours, but it usually comes up sooner than inventors think. It an aspect of mechanical engineering which is surprising complicated. We cannot see electricity and we can see boxes, so we think boxes are simpler, but in practice as much effort can go into the enclosure as goes into the circuit. Enclusures are almost always required if you are giving a circuit to someone else to test. They are absolutely essential for any instrumentation exposed to weather. Luckily, 3D printing is a very effective way to design an enclosure if you only need a few, though if you are making more than ten there may be better options.

25.6 Very Basic Analog Circuits

Because most microelectronics is based on digital circuits, in which voltages represent logical levels that might be described as simple HIGH or LOW or ON or OFF, understanding analog circuits is not necessary. Certainly the ability to analyzer LRC circuits as taught in an early electrical engineering class is not needed. However, you do need to know Kirkoff's Law ($V = IR$) and how to use it. You need to understand that that Watts are equal Amps times Volts, and that power is equal to voltage squared divided by resistance.

It is very useful to know that all batteries can modelled with an internal resistance and why this makes a 12-volt car battery different than a tiny 9-volt transistor battery.[TODO: Improve and add reference to the law.]

25.7 3D Printing, Laser Cutting and CNC Milling

3D printing can be used to make boxes with that open in various ways. Basic parametric designs for enclosures that can be easily modified to fit any project are freely available at Thingiverse.

More generally, 3D printing now allows you to make almost any ship, not matter how complicated. Inexpensive desktop printers, although a bit finicky and hard to tune, can make anything in a few kinds of plastics. More expensive machines can make things in metals and more exotic materials. These parts are more expensive but can be easily ordered online and arrive a few weeks.

Laser cutting of wood or acrylic can also be used to make parametric enclosures. You can generally get the user of a laser cutter at a maker space. Thin plywood and a wide variety of plastics can be effectively laser cut and engraved into very complicated, even artistic, 2D shapes.

CNC milling can make things out of sheet metal. [TODO: I am less familiar with this.]

25.8 Computer-aided Desgin

3D printing requires understanding its limits; you cannot build large parts cheaply this way. However, more fundamental is to be able to produce a three dimensional design using a computer-aided design tool. CAD work involves knowing how to use the tool and also how to design something in space. It is a rich field in and of itself, and many useful and beatiful things can be made this way.

I prefer OpenSCAD because it is similar to computer programming.

25.9 Communication Skills

Effective writing allows communication through space and time to large numbers of people. It is not stricly necessary, but very, very valuable. It requires practice. Good books on the subject are easily obtained but practice is required.

I attended a Science Fiction critiquing circle called Slugtribe for years to improve my writing. Go sluggers!

Brainstorming relies on the ability to withhold judgment. Whether working by yourself or with others, you simple list ideas without naysaying or critiquing them. Then they can be carefully examined and judged. When I was young, I was not very good at listening to someone else's idea and not immediately explaining to them what I thought was wrong with it. Yet respect for peers and simple manners requires this, not too mention the fact that occasionally they are right and you are wrong, and without time and consideration you will miss this.

I got better.

Being an informed citizen of the world requires understanding statistics. In some cases, understanding computer algorithms and being able to read scientific papers requires statistics. Ideally, the public inventor will also know enough statistics to be able to design a statistically valid experiment, or be conversant in the concepts.

I have done this in the past but could not do it today without refeshing myself on the concepts. Luckily, I know enough to know what I don't know about experimental design and how to learn it.

A public inventor should have read the common free-libre open source licenses and understand the difference between a reciprocal or share-alike license like the GNU Public License and the permissive license like the MIT or Apache license. They should understand the basics of patent and copyright law.

Finally, modern project managment techniques such as Agile software development apply directly to invention projects. These focus on testing,

gaining information early through hypothesis testing, and incremental feature development. I personally cannot run a project any other way. However, the formality that project needs depends on the number of people in it. I often act as Invention Coach for a single inventor, and in such cases I do not use a strict Agile discipline. On larger projects, it is very useful.

Public Invention 301: Advanced Skills

26

I do not claim to have all of these skills.[TODO: fill this in]

- Differential Equations
- Analog Circuits
- I2C and SPI
- Numerical optimization techniques
- Fourier Transforms
- How to use an Oscilloscope
- Functional Programming
- Solar power
- Some wet chemistry
- Some bio hacking

The Technological Landscape: 2022

27

I hope parts of this book will be read in the year 2100, and that this chapter, based on observations in 2022, will be obsolete.

- With the relative decline of the COVID-19 pandemic, I hope that maker spaces and Maker Faires will resurge and grow.
- The hobby electronic houses of Sparkfun and Adafruit are providign a great service by packaging equipment in a way that makes it easy to purchase and use and is generally well-documented. We should support them whenever we can. Adafruit, in particular, continued to ship to engineers working on pandemic-related technology even at the height of the pandemic as a service to the community.
- The Arduino ecosystem is going strong and will likely continue on the basis of its open-source hardware approach. Single-board computers will be a major tool for all public inventors.
- The RISC-V open-source chip architecture is on the rise and will likely be the wave of the future.
- The Raspberry PI and related full-power systems that run the GNU/Linux operating system will likely continue to get smaller and cheaper and more embedded. More and more smaller and smaller controllers and even components will use this.
- The rise of Python as a way to program microcontrollers directly will likely continue.
- Robotics platforms will continue to get more powerful but in particular easier to program. The current fad of machine learning will transform into usable off-the-shelf modules and services that can be directly employed.
- 3D printing as-a-service will continue to rise with more powerful capabilities and minor decrease in costs. A wider variety fo materials will become available.
- Fabricaton as a service will expand to include the integration of PCBs with enclosure designs and other components.
- Biohacking will continue to be more accessible.
- Through-hole electronic components designs will continue to slowly decline in favor of SMD designs, at some risk to the prototyping community.
- So-called AI software, which is really just "big database" software, will continue to become easier to use.
- Today "Open Hardware" tends to mean free-design PCBs and free-design microchips. In the future, this will expand to include hardware systems of that include more physical components, such as internal compustion engines, robots, drones, optical scientific instruments, lab-on-a-chip design, and open-source medical devices.

Selected Invention Ideas 28

"The world is full of interesting problems to solve." – Eric S. Raymond

Talking about specific invention ideas inevitably will impose the author's own limited imagination on the reader and paint a distorted, cramped view of what is possible. Nevertheless to speak only of principles without examples seems even more likely to lead the reader astray, either by leaving them with too low or too lofty an idea of what is actually within the scope of low-budget, volunteer public invention. Here are a few invention ideas that I consider appropriate for Public Invention as an organization (the subject of the next part) to address.

28.1 Extant Inventions

A Passive One-way Air Valve Made only of Ferrofluid and a Magnet

An Open Source Mechanical Ventilator

A Polymorphic Robot Controlled by An Isomorphic Puppet

A Portable Battery Powered Biological Incubator

A More Efficient Pot for Open Wood Fires

28.2 Invention Ideas

A Font Based on Blocks of Color

A Miniature Dog Poop to Biochar Production Machine

Euler Notebook

How Public Invention (the Organization) Operates

Public Invention as an Organization

29

This book is an attempt to create a movement called public invention. I have also created an public charity of the same name. Public invention, the movement, has always been and will always be more important than Public Invention the organization. Organizations come and go. You are free to create a different organization to support public invention, and I hope you do. Why then have such an organization at all, when it is clearly not strictly necessary?

Public Invention is a US 501c3 tax-deductible public charity.

Hardware invention and non-theoretical science projects require more capital outlay for tools and consumable supplies than pure software and math projects. Once a project starts to spend a significant amount of money, it is useful to have a formal business organization. People who want to support a project want to know the money is not spent negligently. Being a non-profit registered by the IRS makes gifts tax-deductible for some givers in some circumstances, which may increase donations.

Maintaining a list problems or projects worthy of effort is extremely valuable. Plenty of very valuble organization of entire fields is done by dilligent individuals.. However, some work requires input from several individuals, and this work must be judged and evaluated in some way which is best served by an organization. In particular, the attention of any one individual is limited in time. Some projects and work demand to be sustained across periods of time longer than a human lifetime. Organizations can persist such work better than individuals.

For example, "Ten Semi-Grand Challenges for Quantum Computing Theory" by Scott Aaronson TenSemi-GrandChallengesforQuantumComputingTheory

Similarly, an organization can sometimes serve an editorial function. Positively, an organization can embody conventional wisdom that evaluates the importance of certain problems. More negatively, an organization can serve as a badly needed quack-filter. There is always the danger, of course, than an organization will engage in group-think, and repress valid ideas. Nonethelesss, an enormous amount of time and is wasted by frauds and crackpots.

Newcomers benefit from an obvious starting point. An established organization provides such a starting point, even if the newcomers later develop their own interests which take them away from the organization.

Of course there is always a danger that an organization will attempt to control or monopolize a project or even a problem space, or worse, a group of people. In such cases, creating an alternative or competing organization may be required.

Sadly, it may be necessary to have organizations which conduct business in different human languages or in different geographic regions. In a sense, it will be a great validation for public invention (the movement) when someone feels it is necessary to create an alternative to Public Invention (the organization).

The Public Invention Organizational Values 30

Public Inventors follow these principles:[TODO: Change these to bold face.]

- *Share everything equally and immediately.* Do not seek patents that imply a monopoly that is the antithesis of sharing.
- *Work in the light.* In addition to publishing successful inventions, publish failures. Publish mediocrity. Publish everything. Work in the public for the public.
- *Keep it real.* Always be working towards a real invention that reallys helps people. It is better to make something tiny and real than to make something grand and awesome that is not real. A roller skate is better than a toy space fighter.
- *Don't build weapons.* Technology is not neutral. Some things are more easily used for good and harder to pervert than others. Invent things that heal, help, educate, entertain, enlighten, strengthen, and ennoble humanity.
- *Ideas are cheap.* Invention requires a flash of insight, an inspiration. But that is only 1% of the work of developing an idea.
- *Seek egalitarian usefulness.* All else being equal, inventions which make us more equal are better than inventions that make us less equal.
- *Collaborate whenever possible.* Even if it slows you down, try to involve others whenever you can.
- *Honor and value every contribution.* Some inventions require specialized math; all inventions require general communications and the most specialized and the most general skills are all needed.

30.1 Appropriate Projects

"One must work in the thin boundary between the trivial and the impossible." – Edsger Dijkstra (I heard him say this, but can't find it mentioned in writing anywhere.

Not every project is appropriate for Public Invention. A small non-profit cannot take on research which requires hundreds of thousands of dollars in equipment. Further, an all-volunteer force is likely to move slowly, so there is little point is researching areas which are changing rapidly or being researched by many people.

However, a true invention is something that is indeed non-obvious, and there are many such inventions which are simply not being explored by anybody. The ideal project for Public Invention is something that is a little bit "out there", not too expensive, and primarily requires intellectualy effort and testing.

30.2 The Value of a Huge List of Projects

"The things to do are the things that need doing: that you see need to be done and that no one else seems to see need to be done. Then you will conceive your own way of doing that which needs to be done – that no one else has told you to do or how to do it. This will bring out the real you that often gets buried inside a character that has acquired a superficial array of behaviors induced or imposed by others on the individual." R. Buckminster Fuller

Public Invention curates a spreadsheet of over 60 projects. We would like to grow this to 1000. Ideally any volunteer would have a variety of projects to choose from that suit their interest, skill, and difficulty level. Technologists change jobs frequently and ideally someone could easily

slot effectively into a project that suits them well for a month while they are seeking or waiting on a new job. In practice we have not obtained this, for three primary reasons:

- We don't currently have enough volunteers to form teams around more than four or five teams at a time. This means that even if a new volunteer would like to work on a particular project, they might have to start it and work alone on it.
- Invention projects require more effort than ordering a meal *à la carte*. Although we could build a database that would filter out projects based on skill or interest, in the end the inventor is going to have to take some time and effort to decide which project fits them.
- It takes effort to write a one-page summary of each invention idea with proper external links and/or bibliographic references for people to make so momentous a decision quickly, and we have not paid that price in effort. We welcome volunteers who can help us with this; this requires less commitment than joining an invention team.

The Invention Team Model | 31

The basic organization of Public Invention is around a team led by an Invention Coach. The coach is not just an advisor, but is analagous to the coach or manager of an athletic team. The Invention Coach combines the roles of technical lead and managerial lead. Sometime the Invention Coach initiated and invention idea, but sometimes they agree to lead an idea created by someone else that resonates with them.

Although we hope to have enough volunteers to separate these roles at some point, our experience so far has been that the Invention Coach requires a certain amount of technical knowledge, though need not be the strongest member of the team in terms of technical knowledge. It is harder to find people with the devotion and leadership to drive a project forward than it is to find people with technical skill.

Many of our teams consist of only the Invention Coach, though this is never optimal. The ideal team size is between five and eight. Part of the reason Public Invention exists as an organization is to provide continuity to projects as volunteers come and go. Most volunteers, even if they are lifetime makers and inventors, will not stay on a team forever. Public Invention is currently asking for a minimal commitment of six hours a week for six months. Public Invention projects are intellectually challenging, whether you are acting as engineer, a writer, a video producer, or any other function. Onboarding new volunteers takes significant amounts of time, so a minimal commitment is necessary to the forward progress of the team. This model will likely evolve as Public Invention learns how to complete invention projects more rapidly.

It is a personal fantasy of mine to have a steady "strike team" of highly skilled inventors, engineers, writers and videographers available and resting on the bench. When a good invention presents itself and the time is right, this time could swing into action. Because the teammembers all know each other, they could efficiently move a project forward or complete it in a single strenuous quarter, and then return to their lives for a while until the time is right for the next sprint. At present, Public Invention projects are stretching out over too much time.

Public Inventors, assemble!

The "strike team" concept applies in particular to disaster relief. Organizations such ad the Red Cross/Red Crescent have developed practices that apply to acute crises. Every crisis is different and demands inventive problem solving but we generally do not call that activity "invention". Nonetheless organizations such as Engineers Without Borders USA[19] have recently pioneered crisis engineering, for example by quickly assessing structural integrity of buildings by professional structural engineers. Recently Open Source Medical Supplies[**osms**] has worked with an international community and Glia to attempt to supply tourniquets to the Ukraine conflict. The the production and manufacturing of these tourniquets is mostly engineering but in some sense could be called invention because it is a new product. In the future we can imagine teams of public inventors swinging into action in response to acute problems like the COVID-19 pandemic or an earthquake, and the whole planet being a little better because of them.

Team Composition 32

Invention in general reeks of elitism, even when it is "in the public for the Public", attempting to democratize knowledge and power. One form of elitism we resist is the idea that specific technical knowledge and skill is more important than general management and communication skill.

Let us call the technical skills the "I" skills. These skills are invention, innovation, engineering, math, making, and science. Let us call the communication skills the "C" skills. These skills include coaching, communications, publication, graphic art, fine art, finance, management, leadership, bookkeeping, and fundraising.

Ideally, the "I" skills should be roughly balanced with the "C" skills. This principle was taught to me by Kent Beck, in the context of pure software teams. In the software industry in the early 2000s it was common for teams to have more "I" skills and be starved for "C" skills. In some ways this may still be true. Kent argued that there should be a rough balance between software engineers ("I" skills) and what he called the customer-facing part of the team, consisting of technical writers, managers, artists, and quality assurance experts ("C" skills).

We visualize this balance with a halved circle: [Put diagram here]

An ideal team would be four people heavy on "C" skills and four people heavy on "I" skills, with no one person completely incompetent at any of the skills. Sadly Public Invention has never had a team of eight active volunteers! Generally, we obtain these skills by forcing individuals, often the Invention Coach, to wear many hats and have many of these skills. As an organization, we support teams with some of these skills such as fundraising, so the teams do not have to do it. Nonetheless, Public Invention teams must always have these skills, even if not embodied in specialists. This is why we insist that the "C" skills are just as important, and frankly as hard to find, as the "I" skills.

As an all-volunteer organization, one of the things that we can do is to acknowledge peoople and thank them, which we do at the end of every year with formal awards. It is important to us that the "C" skill people be treated as "Public Inventors" just as much as the "I" skill people.

Project Lifecycle 33

Often an idea comes out of a conversation and it is hard to remember who really first conceived the idea. Brains are enclosed in skulls and skin that makes them seem quite separate, but in a sense all persons are a society of mind, containing different mental functions and even contradictory beliefs. Two or three persons together may be thought of as simply a large society. Project ideas always come out of such societies, no matter how many brains are involved.

One of Public Invention main organizational functions is to collect, catalog, and curate such ideas. Public Invention as an organization allows project ideas to survive the death or disinterest of the originators. The purpose of the organization is to make projects durable across space and time by sharing them publicly.

Every project begins as a conception, which may be more of a problem statement or a need than a solution. Certainly, at the beginning, the solution is quite vague. We typically try to create one-page explanations of a project idea, often with a few external links and a simple drawing. As of this writing we have more than 60 such one-page ideas, which anyone is free to work on. Most of these projects have never had any further attention; about 15 have been actively worked on, some very, very actively.

The natural progression of a Public Invention project is from conception to one-pager to active status to publication to production. Production means production by an outside firm, generally a for-profit firm. We are not aware that any of our projects have yet been produced, but we publish them with licenses that do not require anyone to inform us when they use them.

Publication in a peer-reviewed journal of conference with an archived proceedings is a fine stopping point for a project, because at this point a gift to the world has been made. You can lead a horse to water but you can't make them drink. If the world chooses to do further research (for example by citing the paper) or not is up to them. If you are the kind of person who considers it a failure if an invention does not become actively used (and bless you if so!) then you are as much a business person as an inventor. We do not require that Public Inventors be concerned about business and profit-making.

Of course, some ideas are not worthy of a peer-reviewed publication, but are still fun. For example, I created a project to draw very fine lines in oil paint using a pizza cutter and some cotton wads.[TODO: add citation] It worked reasonably well; I published it as a personal blog post but it was not worth a peer-reviewed publication.

Our experience has been that publication is not always enough. Although technically publishing the complete plans for an open source hardware device allows anyone to construct it, in reality there are certain economies of scale (which are as much mental as fiscal.) We therefore have what we call a "short-run production" strategy. In cases where a device would benefit from serious user testing, we plan to manufacture (by hand) a

small number of devices, between 5 and 30. This allows us to place them where they can be used and get feedback about them. We followed this strategy with our VentMon ventilation tester/monitor[TODO: add citation], and are planning to follow it with our PolyVent Educational Ventilator Platform. Our hope is that short-run production may increase the confidence in an invention enough for a firm to undertake production at a larger scale, with is outside the mission of Public Invention.

For each project, we hope for a terminus in publication, short-run production, or production at scale. However, another fate often awaits projects: they can be frozen. Sometimes, one learns that an underlying assumption is wrong or questionable. This happened recently with a geotagging tool that we hoped could be useful in the conflict in Ukraine. Despite holding a small micro-conference, we were unable to confirm it was needed. We therefore made a decision to freeze the project. The nature of open-source licenses and our policies of being open from the first-day and publishing everything immediately makes the cost of starting a frozen project up again simply one of overcoming mental inertia. It would of course be better if every project always made forward progress, but to do that, we would have to be select project carefully. It is more egalitarian to provide curation to projects in proportion the interest Public Inventors have in them. If someone takes the time to write a one-page description and agrees to release it under our licensing guidelines and it is not obviously quackery, we will accept it as project. It may however, advance no further; but of course nobody needs to inform us if they choose to pick it up.

[TODO: Add a figure showing the lifecylce of a project here.]

Policies 34

34.1 The Public Invention Licensing Policy

A basic policy of Public Invention is to share everything immediately. This means that each project is free and open from the day it is conceived. The first action of beginning a project is to create a git repository that is publicly hosted, create a README file describing the project, insert the licensing policy, and, in many cases, create an empty technical paper as a starting point. One of our values is to publish everything, even embarassing failures, immediately. Any free and open project provides value to the world, even by failing, if it does so in the light.

In order to invent in the public, for the Public, one must insure that the Public can see and use the invention.

In practice, this is done by choosing appropriate licenses which maximize the ability of others to not only use your work, but to build upon it. This means using licenses which safeguard the right to use and reuse the work as much as possible. Although the details and legality may change with time, the basic principle is eternal: share your work as much as possible.

Public Invention has produced a specific licensing policy`https://github.com/PubInv/PubInv-License-Guidelines`. Licensing is sadly complicated by the fact that there are a number of similar licenses for each style of license, but the true complication reflects a deeper reality: different kinds of work should be used and reused under different conditions. For scientific and artistic works, maintaining the attribution of the creator is essential to the the integrity of the work. For computer code, keeping track of who wrote what work complicates any reuses and is largely irrelevant. So, for each different kind of work, we have chosen the license that best promotes use and reuse and sharing of that work.

Of course, the goal of the policy is for it to be reused, to the policy is written in the form of a template in which the name of a different organization can be easilly substituted, and the policy itself is released under the Createive Commons Zero (public domain) license so it can be easily modified.

34.2 Public Invention Teaches, But is Not a School

The secret output of Public Invention is better inventors. Although we are organized around projects and measure our worth in the benefit to people our inventions provide, we always try to advance the career and knowledge of the volunteer. We want every volunteer to leave us with a positive experience and more knowledge and more capability.

However, we are not an educational institution. When you go to school, you perform exercises and homework. You do projects for the sake of

learning which are not intended to be of any real use to anyone. This is anathema to Public Invention—we do not make "fakes". That is, making a robotic R2D2 may be a fine learning project, but Public Invention would never support such a project, because it is a not a real invention. It derives its worth from a conception that already exists, even if it is intellectually quite difficult to make a model R2D2.

Additionally, University are typically exclusive in one way or another, and Public Invention is not. There is no entrance exam and no admissdion committee at Public Invention. It is true that to protect our time the time that we give to volunteers if proportional to the value that they give to the project, but that is not they same as excluding someone.

People learn best by doing. I believe, and our volunteers will tell you, that they learn a tremendous amount working on Public Invention projects, precisely because they are difficult and real. In the words of Buckminster Fuller, education is a precessional effect of Public Invention—the harder we push on completing invention projects, as an unexpected side effect the more our volunteers learn. Similarly, although Public Invention does not exist for increasing the earning power of volunteers, work on our projects make volunteers much more attractive to graduate schools and employers.

Universities charge tuition, we don't.

34.3 Supporting Material Costs

The basic practice of Public Invention (the organization) is to attempt to support the projects which we deem the most active and highest-priority by paying for material costs. We call this the "NOOPE" principle—No Out-Of-Pocket Expenses. For example, we will pay for printed circuit boards, 3D-printed parts, tools, experimental apparaturs, micrcocontrollers, breadboards, batteries, etc. We do not envision being able to actually pay public inventors for their time, with some rare exceptions, generally associated with producing "short runs" of devices in which we actual obtain a number of working devices. It has been our experience that engineers and inventors are highly motivated when people buy them equipment, even if the cost of that equipment is small compared to the salary they could likely obtain. This policy therefore has a high return on investment, measure in terms of impact, for every dollar donated.

The Public Invention Response to the Pandemic

35

Public Invention began addressing the pandemic on March 16, 2020. We began investigating the shortage of ventilators. It quickly became clear that there were many teams working on this problem without talking to each other. Our response was to create a large spreadsheet with an objective rubric evalutaing each of the teams. Eventually, this spreadsheet had over 100 teams on the ventilator page.

We chose not to attempt to build a ventilator in competition with these teamas, but to assist all of the teams. To that end we developed and gave away for free 30 VentMon devices. The VentMon is is a Wifi-enabled flow and pressure monitor that produces a real-time graph at a public data lake of basic respiration data. These graphs are what engineers need to test and verify the performance of their designs on the bench. Flow meters to accomplish this tend to be very expensive. By developing this as an open-source device and publishing all of our software and defining standards for interoperability of respiration data, we hoped to contribute maximally to the overall global open source effort. This invention is perhaps our greatest success.

As the pandemic evolved, we continually argued for a cooperative ecosytems of interoperating devices. We named this ecosytem "Freespireco" for FREE ReSPIRation ECOsystem. The fact that many human respiration devices need to carefully control medical gasses makes this a true ecosystem: cooperationg software and hardware standards can be greater than the sum of their parts.

We took a major step forward when we proposed to an existing ventilation team, PolyVent[TODO: add citation], to join Public Invention and Freespireco and they accepted. Although Public Invention sometimes grows teams from scratch based around ideas in our curated list, an even better way to grow is to form an alliance with existing projects. In the case of PolyVent, this made perfect sense because their ventilator became the flagship of the Freesprieco Project, and they got financial and software programming support from Public Invention.

The heart of the Frespireco system is a pair of data standards, one for representing human respiration pressure, flow, temperature, humidity, and FiO2. The other standard is a universal control system for mechanical ventilation.

By creating an open ecosystem with standards that modularize components, we create many research and business opportunities. Instead of having to make entire systems, a development team or manufacturing firm can focus on one relatively small component. This allows progress to be made faster. It also provides supply-chain resilience. If one critical part becomes unavaible, the part containing that component can be redesigned to avoid the missing part, without having to redesign the entire medical device.

As part of our work on the pandemic, we hosted four virtual conferences focused specifically on human respiration medical devices.

In answering the urgent call to save lives threatened by the COVID-19 pandemic, Public Invention slightly shifted away from invention and toward engineering. However, following the Principle of Precession, it was a net benefit to us and the world.

35.1 Conferences

In response to the pandemic, we served the community by building a big spreadsheet with numerical evaluation of ventilator projects along several different dimensions based on a published scoring rubric. Perhaps surprisingly, nobody ever complained about the score they received, though people did ask to be re-scored when they had made significant progress.

Even more importantly, we organized four distinct conference starting in 2020: VentCon, VentConQA, RespiCon, and RespiraCon II. These might be called "pop-up" conferences because they were organized quickly for special purposes. Although never attended by more than 120 persons, these conferences served a very valuable role in forming a global community. As is often the case, the "hallway" conversations at a conference are as important as the talks. Although all of these conferences were virtual, we took pains to encourage connections between participants as much as possible. Anecdotally, there were many valuable connections made at these conferences.

It takes about 120 hours or more of organizational effort to run a good virtual conference. Much of this work falls on the program chair, who must recruit, communicate with, and schedule all of the talks. Additionally, significant effort in promotion is required.

A basic approach can be summarized:

1. Fix a date well in advance. If it is an international conference, you pretty much have to start at 8:00 AM Pacific time, which allows the Americas, Europe, and Africa to participate in the day time. Sadly Asian and Oceanian participants will have to adjust their schedules, but there is no one time that works for all. Our planet is round.
2. Create a webpage that can serve at the home page for the conference using a technology that you can easily edit.
3. Create an EventBrite that summarizes it and points to the webpage. It will be difficult to keep the EventBrite up to date if you include the entire scedule there, so have the EventBrite point to your dynamic webpage.
4. Choose a video presentation technology (Zoom is a safe standard), but also choose a separate technology for "hallway conversations" such as ReHive[TODO: cite link here], or choose event conversation that supports both.
5. Create a text-based way for all participants interacting during the conference, such as Discord or Slack.
6. Recruit an opening and closing keynote speaker.
7. Leverage your keynote speaker to attract other speakers with a "bandwagon" effect.

8. Publish the speaker bios as soon as you have commitments and use each speaker as a reason to promote the con.
9. Fill out the program as richly as you can. Plan a way for each speaker to be made available in person after their talk to the rest of the conference.
10. Intersperse talks with panels or other interactive activity.
11. If you have panels, carefully design the questions you will ask and give them to the panelists ahead of time.
12. Publish a code of conduct.
13. Offer practice speaking rounds to all of your speakers and offer to let them practice their talks, both for content and to make sure they can use the technology.
14. Recruit a staff of three or four volunteers to help during the actual conference. The roles you need are:
    - The Master of Ceremonies (MC), who may introduce each speaker, make conference-wide announcement, and, most importantly, keep each speaker to their alotted time.
    - One or two hosts to meet-and-greet partipants. Their job is to try to get conversations started, deal with problems, and, in the unlikely event of a code-of-conduct violation, kick someone out.
    - You may wish to hire or appoint an archivist or graphical recorder to take notes and gather material to be sent to each participant after the conference.
15. Leading up to the day, send out well-written targeted reminders. Be SURE to check all of the links that you are sending out, because they will have been evolving.
16. On the day of the conference, expect something to go wrong—it always does—but remain calm. Whatever happens, it will be okay! If you have not charged for admission, expect about 1/4th of the registrants to attend.
17. Thank all your speakers personally after the conference.
18. If possible, post a video of each talk, and make sure the speakers are aware of them for them promote separately, thereby promoting themselves as well as your conference.
19. Thank the participants with a link to all of the talks and possibly a survey.

35.2 Open Source Medical Devices

As part of the 2022 RespiraCon conference and the Freespireco Project, we created the Open Source Medical Device Manifesto, which reads: [TODO: Place Manifesto here]

You can sign it here.[TODO]

Public Invention's mission is not the same as this manifesto. Eventually, other organizations will have to create open source medical devices and shepherd that community forward. In accordance with the Precessional Principle, this often happens: you set out with one goal in mind, encounter resistance, and go in a new, fruitful direction. The new direction does not have to eclipse the old; neither is it limited by it.

Open Source Medical Devices will provide for the world all the benefits to health that free sofware and open hardware have provided to computing and microelectronics, but it will be more challenging because the devices are safety-critical devices that require regulatory approval to be marketed in most jurisdictions. In the US, the Food and Drug Administration (FDA) regulates the marketing of devices for intended medical purposes.

We in no way oppose medical device regulation, and recommend developing an open culture that shares knowledge of how to deal with it. In the end, tranparent and open design and testing should create safer devices than closed secretive ones. However, this requires a great deal of documentation, paper work, and even legal work, which the free software community was able to avoid or at least delay until it had grown quite large. This is a challenge worthy our greatest minds. We might say this is in general a "C"-skill invention challenge. It requires combining legal and business thinking with international relations.

Allying your Project or Submitting your Invention Idea to Public Invention

36

Since free-libre open source licenses preclude monopolies, their is no meaningful sense in which a project or idea may be "given" to Public Invention, except in so far as it is "given" to the whole world. Public invention (the movement) does not need Public Invention, the non-profit organization. Nonetheless, to build community it may be useful for some teams, projects, and ideas to be associated with Public Invention (the non-profit.)

36.1 Vetting and Alignment

The conditions for aligning any idea or project with Public Invention are straightforward:

1. The idea or project must be released under licenses as specified by our license guidelines.
2. The idea or project will be vetted to meet certain simple criteria:
    a) It must be novel enough to be considered a true invention. Roughly speaking this corresponds to the same novel and non-obvious tests used by the US PTO. We will fudge the novelty a bit for open source devices of great humanitarian value for which no open-source version currently exists, such as open-source medical devices needed to fight the COVID-19 pandemic.
    b) It must not be obviously wrong. Nobody has the ability to say with certain that something will not work, but we will not waste time on ideas that seem, in our judgment, to have a low probability of success.
    c) It must not be be tainted with quackery. The most obvious tests of quackery are violation of the laws of thermodynamics. Free energy claims still abound. But in truth, we would consider a free energy device if someone can present a cogent underlying theory of operation.
3. Alignment with our missions and values. To wit, the invention must be "livingry and not killingry" in the words of Buckminster Fuller. We don't build weapons.

36.2 What to Expect for an Idea

One of our values is that "ideas are cheap". It is not ideas that are valuable, but the work elaborating them into something functional that is valuable. Nonetheless, cheap does not mean worthless. We will accept any idea that has a well-written one page explanation that meets our other tests.

When I conceived of Public Invention, I naively assumed that we could become a clearinghouse for ideas. That once an idea was published, a small cadre of inventors would turn their attention to it and dilligently

work on it to completion. I also imagined that by this time there would be a dozen invention teams of eight or more highly skilled researchers working consistently, though part-time, on fascinating invention projects. I was wrong.

If you present us an idea and a one-pager to us and agree to have it licensed, we will:

- Help you review the one-pager,
- Categorize it as to the difficulty and the skills needed to join it,
- Add it to our spreadsheet,
- Mention your idea to new public invention volunteers if they seem to have an overlapping interest or skillset with it, and
- Form an invention team IF public inventors come forward and want to work on your idea.

Your idea probably deserves better. This is not much, but it more than nothing, and it is what we can do.

36.3 What to Expect for a Project or Team

If you are actively working on a project, or even have a team working on a project, you can also consider associating it with Public Invention. Once again this is not "giving it" to Public Invention. You will retain all copyright and intellectual property pursuant to US law (if you are in the US). However, by publishing it under open-source licenses you give us, and the whole planet, the right to create derived works under the condition of those license irrevocably. You cannot take this back. However, you still own the copyright, and we do not; this means that you could ALSO sell it a third party. You could accept money and agree not to work on the public version of the project further. You could not, however, take back what has been given to the world. Public Invention and everybody else would have the ability to keep working on the project. If anyone develops it further, they would have certain intellectual property rights (such as copyright) under US law which are independent of your rights (though some of those rights may depend on your rights.) Additionally, you would have to agree to abide by our anti-harassment policy.

Public Invention is a US 501(c)3 public charity which writes grants and tries to raise money from the public. We have paid a small number of inventors small amounts in the past. However, our budget is very small. We do not have a permanent staff or a paid executive director. Although we will try to help you raise money, you should probably not think of aligning with Public Invention as a source of money.

On the other hand, you would then be able to ask donors to give money to a reputable, registered 501(c)3 with a professional board of ten industry professionals, which might help you raise money for your own project. We would of course earmark such funds for your project. You would get the advice of our Head Coach (me). You might be able to use our (unpaid) Volunteer Coordinator to help you recruit new team members to your project. You could have a project page at our website[TODO: Add Link].

For many projects that might be fewer resources and professionalism than you already have; but for many project these modest advantages might be worth the small price of following our suggested licensing guidelines.

We Need Invention Coaches | 37

When I began Public Invention seven years ago on my 50th birthday, I wanted to create a movement. Creating the non-profit also called Public Invention was a tool for doing that, but I always imagined it would be much smaller than a global movement to create open source hardware inventions by "Inventing in the public, for the Public." It has turned out to be even smaller than that!

Although we have done some great work, Public Invention is not growing quickly. We are organized around open-source projects of intellectual interest and humanitarian value, and try to recruit teams to work on these projects. Some of the projects were created by me, but some were proposed by others, or even started as independent projects and absorbed into Public Invention. In general, we try to pay for all the tooling and equipment expenses of an invention team, so that the inventors don't have to pay anything out of pocket, even though they are not compensated.

We have, in fact, had good luck recruiting Public Inventors. But in order to scale up, we need to recruit what we call "Invention Coaches". You could use different words, like Project Manager or Team Lead or Technical Lead. Projects don't run themselves. They require leaders. Ideally a leader has technical skills as well as being able to manage and motivate a team; but perhaps any two of those three essentials is enough. Leading a team takes commitment, dedication, and a willingness to work through technical and personnel failures. But more than these, it takes time. At least six hours a week is the rule of thumb we use.

The world is full of beautiful, intelligent people who believe in the core principles of Public Invention. Not all of them are leaders. The ones that are leaders are all highly in demand in the job market. Very few people have the discipline to meet all of their commitments and have six hours a week left over. The number of people who have the time, the character, and the skill all at the same time is a small fraction of the population. Only a small fraction of that fraction are willing to do it for zero pay and gold stars, which is all Public Invention can offer today.

But I know such people are out there. This little article is an attempt to reach you. Maybe you are a young person who is a gifted leader. Maybe, like me, you are a mature person on the downhill side of your career or semi-retired or "funemployed". Maybe you are already running a project that aligns with our principles and think being a part of Public Invention could help your project along.

If you can manage, motivate, or technically guide a team (pick two), can dedicate six hours a week to leading a team without pay, and are motivated by a sincere desire make all of us healthier, wealthier, and happier, then please contact us.

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Marc Jones co-authored chapter 19.

TODO

Add a chapter distilled fromthe paper with Zewski.

Can I get better names for the “I” skill and “C” skill stuff?

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