

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. My hope is to create a coherent and convincing work. 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

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THE JOY OF PUBLIC INVENTION

“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. Benjamin Franklin 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 tremendously[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.

Invention is the most spectacular way to advance human progress. It is odd that our politicians mostly ignore it. The story of human history is largely a story of technological advance careening forward from the stone age with a speed which is inexorably, and frighteningly, building, perhaps to a 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.

For the last 100 years, technological advance has been driven by two engines: profit and academic research. The modern emphasis of Universities of patenting research and the governmental practice of subsidizing research which is monopolized by for-profit firms has blurred the distinction. Nations have long recognized the value of technology for competing 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 giving the privilege of 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 build weapons. This is impossible to do perfectly. Even a pillow can be used as a weapon. Nonetheless, technologists are not relieved of the duty to invent good things instead of bad things just because it is intellectually difficult to decide what is good and what is bad. The Public Inventor accepts this burden as does the best they can.

Benjamin Franklin said, “We must, indeed, all hang together or, most assuredly, we shall all hang separately.” His wit was poignant because

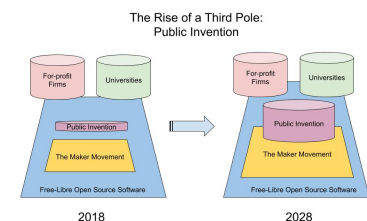


Figure 1.1: The Rise of Public Invention as a Third Pole of Progress

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 2021 his words still ring true. 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 well-being 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. Humanitarian 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 of for-profit firms, academic research, and public invention. Public invention will not replace the other two engines, but augment them. Public invention is a moral act, but it is not a moral duty. Some people will want to be public inventors some of the time.

The Arc of Progress

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 particular matter if you believe this progress is positive or negative, though Steven Pinker is has argued overwhelmingly it is astoundingly positive. [6] It doesn't matter if you see it as rooted in Babylonia, ancient Rome, Jerusalem, the Chin dynasty, the Enlightenment, or the American Revolution. The more history you know, the better, of course. But being part of a great story gives your actions meaning. It is impossible to measure out your life in coffee spoons if you see yourself as part of a great story.

Much science fiction is dystopian and dark, but almost all of it sees humanity placed in the arc of some greater 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 statments 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.

I dare not say political discourse, which disappeared when Newt Gingrich turned the Republican party against compromise.

Richard Nixon spoke of population growth and control

The Joy of Public Invention

3

Public invention takes the joy of invention and multiplies it by the joy of helping others. Making something truly new is a roller coaster ride of emotions. The inventor is fraught 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 moment. 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 out of proportion to create the trope of the lone inventor. Most invention is done by teams. Math, is, in the end, always social. 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 especially true in the act of invention. Each of us has a different voice, even if we sing the same song. 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 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 person's 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 men, including myself, are fascinated by shooting things at high velocity, such as in guns or rockets or bows or catapults or water guns. So long as the invention is not designed to harm, the invention should be allowed to be born. 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 make an object whose value is that it is a miniature version 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 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 real and can be held in hand.

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 achievement 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.

Why it makes more sense than in the past

4

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. People 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 become less imperative.

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: the 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 is 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 do astounding things that were not even possible 30 years ago. Similarly, it is now possible to design printed circuit boards on free software and have them fabricated at 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-controllers 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 world of biology and biochemistry. 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 impediment (see Chapter 25.4 for Public Invention's policy), the combination of cheap hardware, free software, and cheap connectivity has made innovation and invention much easier. Sharing and publication of inventions is a critical part of public invention, and that is also now easier than it has ever been.

4.1 Makers into Public Inventors

Makers know the joy of making. The Maker movement supports creativity, skill building, art, humor, and practical function. Makers today, thanks in large part to Maker magazine and Maker Faires, have thousands of fascinating projects to prove from. An invention has to be something novel which has never been made before. Making is not easy; it takes practice, problem solving, creativity, and ingenuity, but usually not invention. If the public invention movement had even ten per cent of the energy of the maker movement, it would be a tremendous force for good.

There is a natural progression from making to public inventing which some makers will take. This book is an attempt to create for the Public Invention movement a culture as strong and supportive as Maker culture is today.

The millifuller

5

Science is about truth; engineering is about compromise.

At Public Invention, we 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 even discuss the humanitarian impact of two projects that may both need 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 you 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.

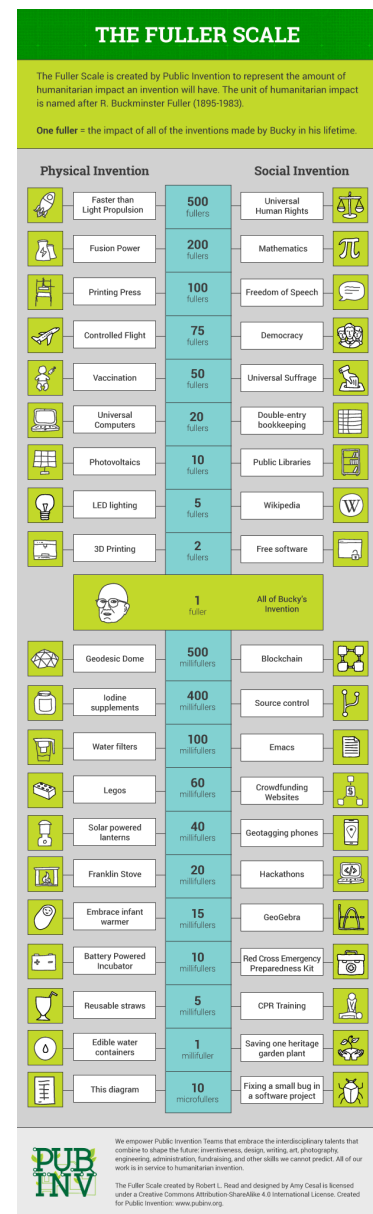


Figure 5.1: The Fuller Scale of Humanitarian Invention Value

Imagining what it will be like

6

6.1 The Near Future

With your kind permission, let me take you on an imaginative 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 poles. 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 for them to match their talents and desires to. Everyone kind of knowledge worker can contribute, because there is high demand for technical writers, photographers, graphic artists, managers, quality assurance experts, and more. 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 against 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 are willing to put their own time in to make the mentor's time well-used.

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

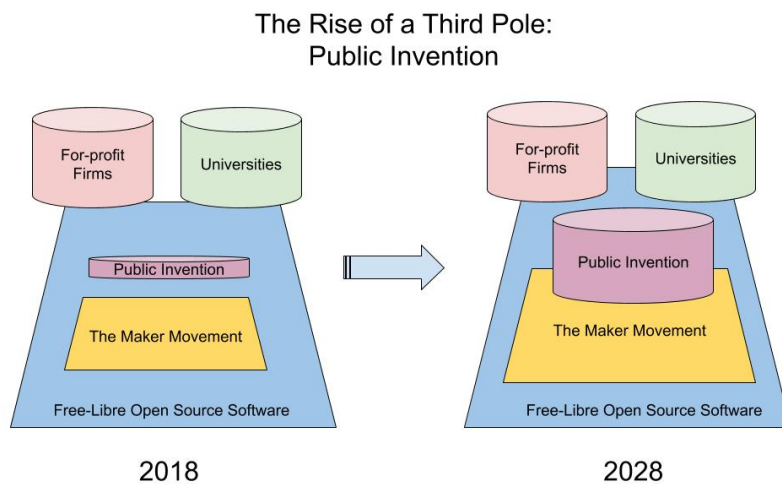


Figure 6.1: The Rise of Public Invention as a Third Pole of Progress

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 hundred 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 are never heard of, but everyone once in a while someone will say in hushed tones, “See that person with the ombre dyed hair? They were the leader of the oxygen concentrator team in 2025.”

6.2 The Far Future

In 2112, the first class of Star Fleet Academy is matriculated. Money is still in use for luxuries and to fund world wonders, such as the first generation ship, but is irrelevant for basic food, clothing, and shelter.

There are no 50 billion people on Earth and 5000 off-Earth and inside the asteroid belt. The carbon footprint of human society is now less than it was in 1945. Global warming remains a problem but is the CO₂ levels are declining.

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, but the few who do 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. The range of materials available for crafting includes diamond, titanium alloys, fibers of unimaginable strength, and intelligent polymorphic materials are approaching flubber.

Biohacking has reached new levels, driven by necessity and pleasure. A student in England just made an English pea plant whose pods open and spill out multi-colored peas like unzipping a purse full of pearls. There is tomatoes for 413 distinct micro-climates. Luxury furniture is now grown in place as a single tree.

The Oceans are clean and productive. The by-catch has been eliminated; only the fish that are actually eaten are taken.

The forests are half-way to recovering. People gather in forests with the help of tree-climbing spider robots, which produce food that was never worth gathering before.

The role of public invention in the success of the world is debated. The Inevitablists claim that success was always inevitable. The Constructivists claim that success was constructed based on specific policy decisions, individuals, and organizations.

The Stoic Point of View

7

The ancient Stoics taught a philosophy that is only tangentially related to the common meaning of the English word “stoic”. The Stoics taught a practical philosophy: 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 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 thoughts dye the soul. You cannot control what others think of you. The praise of others 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, nobody remembers much about Alexander except his name.

The Stoics saw each of 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 disapoint 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.

- ▶ Basics of Stoicism
- ▶ Nature and Reason
- ▶ Stoic Communalism and Inclusivity
- ▶ Stoic views on occupation (Aurelius, Epictetus)
- ▶ Stoic assistance to the public Invention
- ▶ Resisting the siren songs of praise, the “in club”
- ▶ Resisting the siren song of excessive wealth

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 Christian Point of View

8

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."

What is God if not the Creator, the Prime Mover, the First Maker? Dare I say God is an 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 of 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) may apply. A "talent" was a 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 by every wind of teaching and by the cunning and craftiness of people in their deceitful scheming. 15 Instead, speaking the truth in love,

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

Matthew 22:35-40

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] (Ephesians 4:11-16)

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”[7]. 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.

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 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.

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”.

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

8.1 Stewardship

Do I have anything new to add here?

- ▶ Small is Beautiful
- ▶ The road to the stars runs through villages and slums
- ▶ None of us are free until all of us are free
- ▶ Anthropomorphised money does not love poor people
- ▶ Nor does it love rich people.
- ▶ It wants to accumulate.
- ▶ But people love people—we can motivate volunteers this way
- ▶ We cannot live together on spaceship earth while we have grinding poverty
- ▶ Cutting your own carbon footprint in isolation is of limited value compared to political action—yet we are “sold” such ideas.

Advances in “hard” inventions have made public invention easier, but “soft” 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 dissuasion of unnecessary splitting or “forking” of a project,
- ▶ using recognition as an incentive for contributions,
- ▶ using version control systems to manage contributions,
- ▶ and using Agile software methods and big visible charts to manager work.

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 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.

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.

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 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. We may, however, rely on the “honor system”, which can be astoundingly effective in practice.

- ▶ Practices pioneered by the Free Software Movement
- ▶ Internet community
- ▶ Open Source Software paved the way with certain teachings
- ▶ Projects need leaders
- ▶ Projects run on the coin of acknowledgement

“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>

Eric S. Raymond has explained this in his essay “How to Become a Hacker” in in the “Status in the Hacker Culture” section<http://www.catb.org/~esr/faqs/hacker-howto.html>[8]

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.

- ▶ Maintainers and documenters are highly valued
- ▶ Licensing matters, but has been pioneered

Building a Public Invention Commons

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- ▶ The value of a Commons
- ▶ The value of Commons of Problems
- ▶ The value of a Commons of Solutions
- ▶ Don't worry, be crappy.

Love matters more than lasers.

All inventions can be repurposed to ill.

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 to make billions from public inventions.

You can make yourself lovable but you cannot make someone love you. No matter the good that public invention accomplishes, haters gonna hate.

We cannot invent our way out of ignorance or hatred.

HOW TO BE A PUBLIC INVENTOR

How to be a Public Inventor

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- ▶ Motivate yourself through love of humanity, life, and knowledge
- ▶ Publish early and often
- ▶ Don't seek patents
- ▶ Publish your failures
- ▶ Seek community
- ▶ Help other Public Inventors
- ▶ Ask for Help
- ▶ Learn by doing
- ▶ Failure in service to a big idea plants the seeds of success.

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

Money and Volunteerism

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- ▶ Despite appearances, more of us have more time than ever before
- ▶ Gandalf “All we have to do is to decide what to do with our time.”

The Emotional Intelligence of the Public Inventor

15

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 one of the frustrating slog. By articulating some of the emotional difficulties they will likely face, we hope to prepare them.

15.1 Getting to the Coal Face

The first problem faced, even before any insecurities, is “getting to the coal face.” This means specifically learning enough about a particular area to have some discernment on 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 hope to do no 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, because 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 they 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 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.”

15.2 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 enterprise. 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. COVID-19 delayed the in-person conference where the work was accepted. I remain in a state of emotional trepidation about this work, and unable to judge if it is quite significant or trivial. Many public inventors are going to be in precisely the same position.

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 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; in a sense, this is therefore self-promotion. But we must not over-sell or exaggerate our accomplishments.

15.3 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 “that’s been doneism”, 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 that’s beendoners, 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.

15.4 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 created a beautiful machine, which we might call “the body of human knowledge”, 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 there was the internet, it was systematically categorized and edited. In fact, we can think of the peer-review by qualified as 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 beleaguered 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 unrealizable 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 usually just 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 a academic publication from the first day, but other projects are art projects or exploratory in nature. Having a posse—siblinghood of technical friends who can advise you—facilitates this decision.

15.5 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.

15.6 The Glory and the Impossibility of Comprehension

The Universe is “Infinite in All Dimensions.”[9]. 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.

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

Amongst this embarrassment 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.

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 anything, 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 anyone one field, in exchange for a demand of voracious study of many fields. I personally could live no other way.

“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*

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.”

It is a personal shame of mine that I know almost nothing about chemistry.

15.7 Feeling Unappreciated and Ignored

Sometimes 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 and 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.

15.8 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 used for, but was more useful when paper publication was the only route. However, it should have no mystique. 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.

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 slightly 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.

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.

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 stipulations 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.

15.9 The Need for and Difficulty of Fellowship

There is no more secure entry to friendship than a shared passion. The public inventor often wants friends, and wants to share their passion. 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. In some circumstances, people are simply jerks.

15.10 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 development in a closed manner, probably because they entered 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 personally 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 had no incentive to make the devices. Thus the “killed” the project, and removed a potential competitor, and nobody was helped at all. This may have occurred unintentionally.

Because the open source licensed 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 when they said they were open-source. 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 public inventions, and in general only a small fraction of that money, if any at all, will go to the inventors. However, the key is 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 close-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 close-source work only by the copyright holders. Since a public invention team may be diverse, this may be problematic. 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 continue “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.”

- ▶ Getting to the Coal Face X
- ▶ What to do when you are scooped X
- ▶ Dealing with publication X
 - Rejection
 - Timeliness
- ▶ Surviving being foolish X
- ▶ Investing in learning without pedantry X
- ▶ Feeling unappreciated and ignored X
- ▶ Fuller’s theory of technological maturity and ripeness
- ▶ The need for friendship and siblinghood
- ▶ The siren-song of closed intellectual property
- ▶ Patent envy and the patent mystique X
- ▶ Dealing with disappointing teammates X
- ▶ The insecurity of insignificance
- ▶ Competition is obsolete
- ▶ St. Exupery’s comfort of mediocrity - 20 bad sculptors are needed
- ▶ “A walk-on part in a war or a lead role in a cage”
- ▶ Paul’s call for each to do their part: Ephesians 4:11-16
- ▶ Small is beautiful
 - Giants are built from small accomplishments, as long as they are published.
 - Thinking small is often a useful constraint.
 - Nothing does big things as well as doing small things.

15.11 Anti-quackery

- ▶ Litmus tests
- ▶ Do you understand why Free Energy is nonsense?
- ▶ Do you understand basic thermodynamics?
- ▶ Do you understand Conservation Laws:

- ▶ Mass
- ▶ Energy
- ▶ Momentum

A Publishing Disconnect between the Free Software Movement and Open Science

16

16.1 The Problem is Terminology

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, as we learned at a recent hackathon on behalf of Project Drawdown. Publication: 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 essay is an attempt to explain this to facilitate these communities working together.

16.2 The Mutability of Published Works and Expected Quality

Expectations in the FSM are that works are eternally mutable: they are constantly improved and are never in a final state. In a free software 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 is “published” immediately. By published, free software authors mean it is available for anyone who cares to discover, to examine, comment upon, 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 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, 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.

16.3 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 their bugs that get buried in the revision control history. Academics' mistakes are hard to correct silently once an article has been published.

16.4 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.

16.5 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. Both recognize the need to build on the works of others. Academic papers do this through a rigorous method of citation. Free Software does this by incorporating libraries written by previous authors into the work, or by modifying existing software 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.

16.6 Conclusion: How to Cooperate

Free software developers and researchers typically have different professional reward systems and 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 should be ready to say:

"... publish the software..." by which we mean... "... place it in a publicly accessible repository without publicizing it."
 "... release the software..." 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.”

- ▶ The magic power of the inventor
- ▶ A little goes a long way, and there is never enough
- ▶ Mathematical inventions count
- ▶ The touchstone of truth - “Do the math”

What if you cannot be a Public Inventor?

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- ▶ Give moral support.
- ▶ Give money in a way which is spiritually meaningful to you.
 - A small amount given to a small project is incredibly impactful.
 - People aren't compensated, but paying for equipment has a multiplier effect
 - It is psychologically important.
- ▶ Try to put yourself in a position that you can
 - Educate yourself.
 - Become financially sound—remove the desire for luxury

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

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

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, or [click here](#)). 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 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.

Humanitarian Engineering, [is the] the application of engineering to improving the well-being of marginalized people and disadvantaged communities, usually in the developing world.[10]

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 at the University of Texas at Austin club:

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.

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 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!

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 as git<https://git-scm.com/>, GitHub<https://github.com/> and GitLab<https://gitlab.com/>, and Appropediahttps://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.

PUBLIC INVENTION IN THE 2020s

Public Invention 101: Pre-requisites

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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 would be able to persevere efficaciously for very long. If you lie to your team, you would be able to add 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 waster 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*.^[11] *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 in competition, it cannot be denied that the desire to see your own team win is a powerful motivation force. *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 disqualified, but you must remediate yourself by learning algebra. 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. If you don't understand elementary algebra, you cannot be a member of an invention team in a meaningful way, even as an artist, project manager, or writer. It is of course possible for a team to use the services of someone who does not know algebra, but they cannot be a full-fledged team member. Without algebra, irrespective

of the invention, your understanding is likely to be so murky that you will be a danger to the team, like a drunken sailor or a soldier with bad weapon discipline.^[12]

- ▶ Source Control
- ▶ Programming

Public Invention 201: Essential Skills

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- ▶ Calculus
- ▶ Vectors
- ▶ Linear Algebra
- ▶ Effective Writing
- ▶ Computer Facility
- ▶ “Hello World” in any language?
- ▶ Write a recursive and an iterative factorial
- ▶ Write Conway’s life in at least one language?
- ▶ Project Management
- ▶ Electromagnetism

The Technological Landscape

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I parts of this book will be read in the year 2100, but this chapter will be obsolete.

Selected Invention Ideas

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

HOW PUBLIC INVENTION OPERATES

Public Invention as an Organization

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This book is an attempt to create a movement called public invention. I have also created a 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?

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 valuable organization of entire fields is done by diligent 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 such work better than individuals.

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, that an organization will engage in group-think, and repress valid ideas. Nonetheless, 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).

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

For example, “Ten Semi-Grand Challenges for Quantum Computing Theory” by Scott Aaronson
[TenSemi-GrandChallengesforQuantumComputingTheory](#)

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!

25.1 Sharing Immediately and Broadly

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.

25.2 The Public Invention Licensing Policy

25.3 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 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, Universities are typically exclusive in one way or another, and Public Invention is not. There is no entrance exam and no admissions committee at Public Invention. It is true that to protect our time the time that we give to volunteers is proportional to the value that they give to the project, but that is not the 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.

25.4 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 apparatus, microcontrollers, 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 actually 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.

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