Phone-to-Car FM Transmitter
(Technical Paper)

Existentialism and Engineering
(STS Paper)

A Thesis Prospectus Submitted to the

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In Partial Fulfillment of the Requirements of the Degree
Bachelor of Science, School of Engineering

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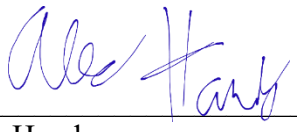
On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature  Date 4/22/20
Alec Handy

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Harry Powell, Department of Electrical and Computer Engineering

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Michael Gorman, Department of Engineering and Society

Capstone Proposal

Abstract

Megahurtz is designing and developing a device that can connect a handheld phone to a vehicle's car radio and playback audio chosen by the user on the phone. This process will be achieved through the development of a software-defined radio containing a universal serial bus (USB) connection that can connect to either an iPhone or Android device, which will in turn, power the SDR. Within the software-defined radio, there will be a FM transmitter, receiver and antenna. Once all of these circuits and systems are integrated together, the SDR will receive the audio that is played on the phone, find an open FM band on the car radio, and transmit the audio signal. There are several different parts to this project that have strong relations to current and emerging technologies such as radio communications, digital signal processing, and embedded systems. To search for an open FM band, a chip would have to be programmed to perform this function and this is related to embedded system technology. The SI4712 chip will involve both signal processing and radio communication since it includes the FM transmitter and receiver which will be used to transmit the signal from the phone to the car radio.

Background

The older and most recent car models do not contain auxiliary jacks to connect a user's handheld device to the vehicle to play back music, audio books, podcasts and more. Many of the newer car models solve this issue by using Bluetooth, however, older car models do not have this capability and there can still be complications that arise with this wireless technology. This motivated our team to come up with an alternate solution to playing back audio through the care radio from out phone. We wanted to come up with a device that is compact, low-cost, efficient, and can be easily handled by a user without increasing risks to driver safety. The technology that would produce the best results to these obstacles is the software defined radio

Software defined radios also have a large number of applications, including, but not limited to, its use for military defense, telecommunications, manufacturing plants, GPS and signal tracking, and public safety [4]. Over the past few decades, SDR technology has been progressing at a much faster rate and the applications of this technology have become endless. These devices have replaced the traditional, bulky radio that the United States Military had to use with something much more compact that can be used over a much larger range of frequencies for data and voice communication over two channels [5]. There is also research being done to use this technology as a real-time software defined radio GP receiver for indoor and vehicular navigation in areas where there may be signal blockage [6]. The automotive industry has been picking up on the benefits of this device as well.

In the past few years, the automotive manufacturers have been recognizing the usefulness of software defined radios and have been implementing this modern radio receiver technology due to its low cost and performance. The SDR is believed to be the best approach to supporting the simultaneous reception of a large number of broadcast channels, and to complying with the upcoming digital standards within the United States, Europe, India and China [2]. Automobile

companies have been replacing the traditional car radios in some of the newer models with this technology. To accomplish this, engineering companies such as NXP semiconductors have used state-of-the-art embedded digital-signal-processing cores to the present set of radio standards used in automotive applications to support AM/FM reception along with existing scenarios of seven different digital radio standards [3].

On another note, a research project similar to our approach was worked on by undergraduate students who graduated from University of Virginia back in 2017. They had designed a simple device for automobile applications that used signal power processing to scan for an unused FM frequency, and then begin a broadcast on that frequency. They used the cigarette lighter within an automobile as their source of power and had difficulty keeping the audio uninterrupted due to power level on the current channel constantly surpassing the noise threshold that was set [7]. They also encountered issues with debugging code, but successfully made a functioning device.

Based on our research, the automobile industry has primarily been focusing on developing software defined radios that only contains a receiver, is powered by the vehicle, and has been integrated into the vehicle's framework. A previous capstone team also built a device similar to the approach that we had in mind. This project focuses on designing and building a device that is completely portable and solely relies on USB power that will be coming from the user's handheld device. It will also contain both a transmitter and receiver along with an RF Low Noise amplifier so it stays in working frequencies for extended periods of time, which will allow audio that is played on a user's phone to be broadcasted through the car's stereo wirelessly for an extended period of time. One other factor that differentiates this project from past work and research is that although testing will be done with a car radio, the device would be able to properly function with other radio technologies that operate on the FM band.

This project would incorporate several different aspects of our previous course work: embedded system design, digital signal processing, radio communications and RF circuit design. There will be heavy reliance on our experience with software tools such as Multisim, Ultiboard, Code Composer Studio and Microwave Office when designing the power regulators, amplifiers, and data communication between the microcontroller and chip within this project as well. Several of the group members have experience with signal processing, power systems and hardware design. One of the group members is extremely proficient with embedded C and will be able to work with the I2C interface. Through our previous coursework and experience, successful completion of the project should be achieved.

Description of Project

The device will be powered from a standard USB power supply [8], rated at 5V and 2A. This potentially could be a phone power jack, given that the phone has USB OTG capabilities, but would most likely be from a car cigarette lighter USB converter. This power will be fed into a

power regulator, which will maintain the proper voltage and currents for the device subcomponents.

The primary component of the device is the SI4712 chip [9]. This chip will process the mixing, digital-signal-processing, and transmission of FM signals. The chip will be controlled by the MSP430 chip [10], which will communicate via the I2C interface [11] and will be coded in embedded C. The transmission and receiver hardware of the device will consist of the antenna, low noise amplifier, power amplifier, and bandwidth filter. The antenna will be a simple dipole antenna, arranged in a vertical fashion. The low noise amplifier will amplify incoming FM power from the signal, while keeping the noise floor low. This will allow farther FM signals to be detected, thus decreasing the chance the user will travel into an area where their signal conflicts. The input signal will also be fed through the bandwidth filter, which will filter all power outside the FM band. The power amplifier will boost the output signal from the SI chip so that it can be transmitted via the antenna.

Upon startup, the MSP430 chip will command the SI chip to sweep through the FM band and relay the power frequency spectrum. The chip will perform an algorithm to determine an empty frequency at which to transmit. The MSP will then display this frequency on the LCD screen of the device. Once a frequency is set, the device will receive analog audio from a 9mm audio jack. This audio signal will be routed to the SI4712's analog-to-digital receiver. The SI chip will digitally mix the signal and frequency modulate the proper output frequency. The chip will then output the signal, where it will be amplified, and transmitted.

The device will also feature a button which will allow the user to reset the device and rescan for an empty band. The overall concept diagram is shown in Figure 1.

To develop this project, we intend to use CAD tools, such as Multisim and Ultiboard, to design the circuit components and PCBs. Microwave Office may also be useful to test the transmitter and receiver hardware. Code Composer Studio will be used to code the MSP, and Inventor may be used to design a 3D printed case. Metal machining for the antenna may be useful, as well as RF spectrum equipment to test the transmitter and supporting circuits.

The most anticipated problem will be finding times to meet, as we all have very busy schedules. Proper communication will be critical to ensure that we can develop the project independently of each other, and use time efficiently when we can meet.

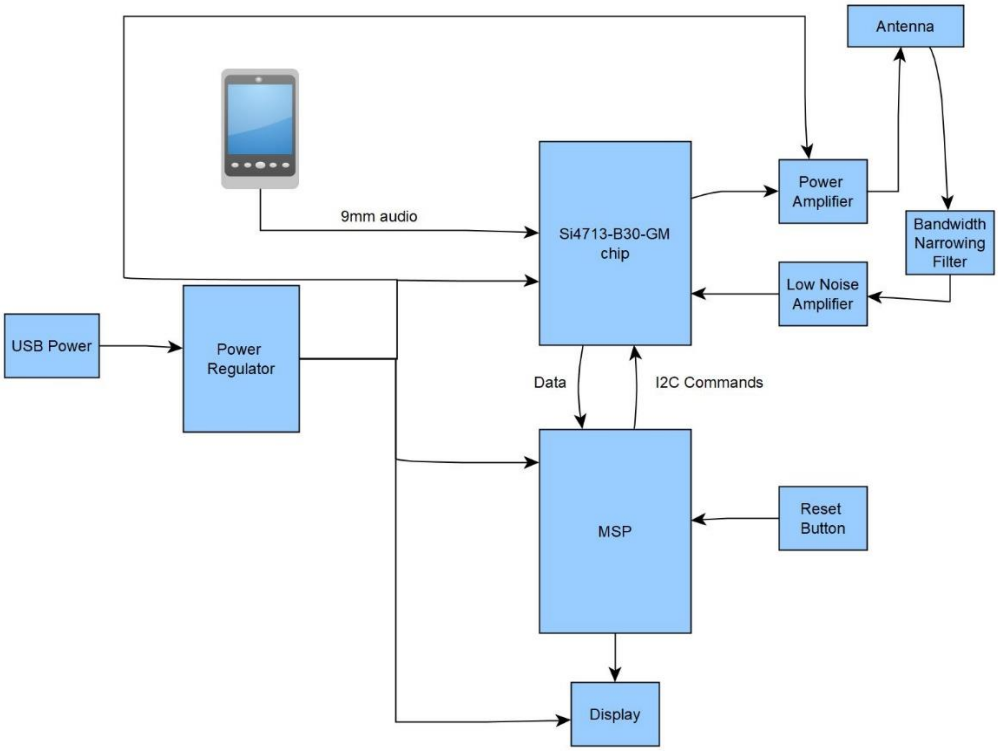


Figure 20:Concept Diagram

External Considerations

Constraints

Manufacturing

Device will be on a PCB, which includes upon it an RF module, various support circuitry, and an MSP chip. This PCB will be printed at Advanced Circuits. The display and pushbutton will be wire connected to the board in order to be easily fitted into the final casing. The casing will be 3D printed with appropriate openings for USB, 9mm audio, and the display and pushbutton. The layout will be constrained to two layers. Using components with very small package sizes will require machine soldering during fabrication. The major design goal for layout and manufacturing will be of course to minimize footprint.

Parts Availability

All parts are available from reputable online retailers such as Mouser and DigiKey. No major constraints are foreseen in sourcing components.

Economic and Cost Constraints

All parts are quite inexpensive, and cost is not foreseen as a major concern. The board will only be two layers which will save on manufacturing costs. Mass production of a final product would be significantly less expensive per unit due to bulk discounting.

Environmental Impact and Sustainability

Low to none. The only real concern environmentally would be whether silicon and other resources used in electronics manufacturing are mined in sustainable and low impact ways, although this is outside our control and little to no information is available on the supply chain of the individual components we will be using.

Health and Safety

All power levels used in the devices operation are too low to be harmful to human health. This includes both direct contact with live electrical components and the transmission power of the signal.

Ethical Issues

The major ethical concern of the project is accidental interference with a critical communication channel, such as an emergency broadcast on an FM channel. However, the device operates at low power with a small transmission distance, and moreover transmits only on low power, empty bands.

The issue of privacy arises in considering whether people will be able to listen in. The intended use case of the device is for music or other entertainment audio and not private transmission. A final production version would need to come with a warning against using the device for sensitive/private audio because of the ease of eavesdropping.

Standards

Wireless transmission in the United States is regulated by the FCC. We are compliant with Title 47 Section 15.239 subsection b, concerning home-made devices operated without license, reproduced below (E-CFR, n.d.).

(b) The field strength of any emissions within the permitted 200 kHz band shall not exceed 250 microvolts/meter at 3 meters. The emission limit in this paragraph is based on measurement instrumentation employing an average detector.

250uV/m corresponds to approximately -50dBm for a low gain antenna.

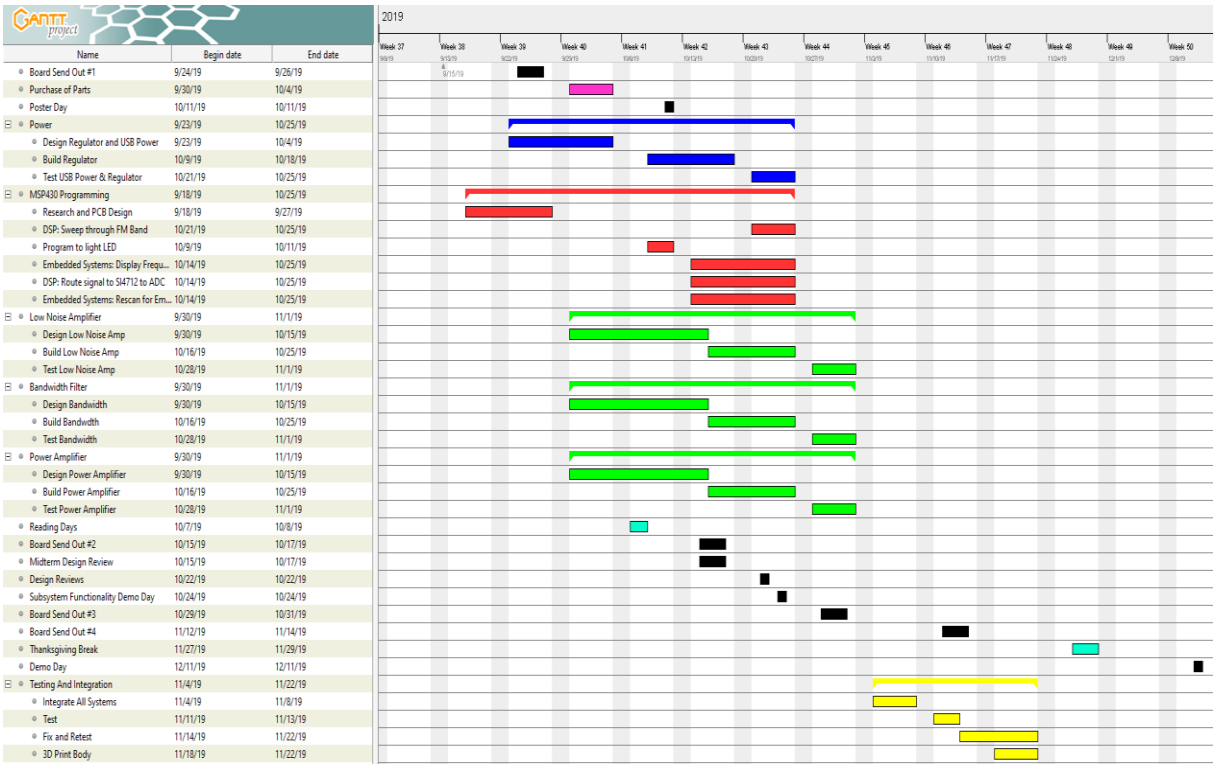
Deliverables

Our main deliverable is a printed circuit board (PCB) that will contain of the hardware for this product. This includes the chip, the MSP, an SMA connector to attach the antenna, the LCD display, the button, and the USB cord. It will also contain our designed power amplifier, low

noise amplifier and filter. Our second deliverable is 3D printed case to house our PCB board to ensure a more professional end product. This will make it so the user can only see the LCD display and the USB cable. Finally, to ensure that we are on track, our midterm subsystem deliverable will be programming the MSP to turn on a test LED and establish communication via I2C with the chip

Part	Cost
Si 4713-B30-GM Chip	$13
Antenna	$15
MSP	$25
LCD Display	$10
RF Quality BJTs	$15
High Q capacitors and inductors	$15
PCB fabrication cost	$10
Total	**$103**

Timeline



Color	Meaning
	Deadlines
	Purchases
	Power
	Programming
	PCB
	Holidays
	Testing & Integration

The above Gantt Chart that was designed shows MegaHurtz planned project schedule, which includes the largest components of our project, as well as deadlines and upcoming holidays. The four major parts of this project includes developing a source of power and a regulator, designing and building the three major electrical systems that will be found on the main PCB, computer programming, and then integrating all of the systems and testing it. Some of these tasks can be done in parallel, such as developing the low noise amplifier, power amplifier, and bandwidth filter since they are all essential to the function between the antenna, and the transmission and receiver hardware. The power regulator, and connections between the SI4712 chip and microcontroller will be the first steps in approaching our design. Without these systems, there is no other way to power all the system's subcomponents or allow interaction between the chip and microcontroller. Establishing connections between these two components must be done early on in the process to allow as much time for programming the MSP430 so that it can sweep and locate an empty FM band, display the empty frequency on an LCD display, and reset/rescan for an empty band whenever necessary. The design of these systems will be done before the deadline for the first and second board send outs. All the other electrical systems will be completed afterwards. Only when the power, PCB, and programming has been completed, can all the systems be integrated together and tested. Throughout the design of this device, tests on individual systems will be done before integrating them together.

Kaelyn is taking the primary role of implementing the algorithms and I2C interface necessary to determine the empty frequencies at which audio should be transmitted. She will also be implementing the code that is needed to show the empty frequency that was found on the LCD display, as well as resetting and rescanning empty FM bands whenever it is required to be done.

Since Finbar and Alec have experience with wireless communications and RF circuit design, they will be taking the role of designing, building and testing the power amplifier, low noise amplifier, and bandwidth narrowing filter. They will be determining all of the necessary components to develop these systems in order to make them compatible with the SI4712 chip, and allow audio signals to be transmitted to the antenna. Michael, who has a strong interest in power systems, will be taking a secondary role in this portion of the project, and will assist with correctly designing and building the power amplifier to create a strong enough output signal

from the SI4712 chip, which can be relayed to the antennae. He will also be assisting Finbar and Alec with the use of the CAD tools such as Multisim and Ultiboard to design the PCB.

Michael will be taking the primary role of designing the source of power due to his experience with power systems. He is tasked with developing a power regulator that will correctly maintain the necessary voltage and currents needed for all of the subsystems found in this device. Michael is also responsible for determining if the selected power source will have sufficient power to allow the entire system to function after integration.

Expectations

Grade	Criteria
A	Device scans and locates an open FM band LCD Displays the correct FM frequency that was found Audio from smartphone is broadcasted through car stereo Software-defined radio powered by USB connection SDR resets/rescans after button is pressed
B	Device does not meet one of the tasks required for and “A” grade
C	Device does not meet two of the tasks required for and “A” grade
D	Device does not meet three of the tasks required for and “A” grade

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STS Prospectus: The Existential Engineer

Remark: Much of this Prospectus was directly adopted into the final Thesis Paper.

Introduction

Science, Technology, and Society (STS) is an inherently interdisciplinary subject with roots in anthropology, sociology, history, political science, and philosophy. It has been able to establish insightful models for understanding the actions of groups within engineering and scientific communities, such as normalized deviance, trading zones, or actor-network theory. Each of these has immense pedagogical value and they certainly ought to be expounded upon. However, I feel strongly that the discipline misses the value in discussing science and technology from the perspective of the human individual, who is not reduced to a purely rational actor, but is understood as a feeling, living person who acts not merely through rational thought, but through emotion as well. STS scholars certainly reacted against the idea of scientists and engineers as rational agents, but they focus on social or group dynamics – networks among actors. Historians of science and technology may focus on individuals, but this is often in consideration of a certain historical figure's actions, motivations, etc. One may be tempted at this point to turn to the lens of psychology, but this still misses the core of the problem which is failing to consider the actual humanity of scientists and engineers. The gap I see is failure to consider the experience scientists and engineers may have with the human condition itself. It thus becomes clear that something else is needed, and I believe that existentialism is the appropriate area to discuss these issues of the individual. It is also curious that existentialism and modern science/engineering shared their infancy in the 19th century and blossomed immensely in the 20th century; as the golden age of science came to an end, especially in the post-war world, as it became apparent to the masses

that technological advancement was not the road to utopia and the end of suffering that had once been imagined.. A brief introduction to existentialism is provided followed by descriptions of several issues able to be faced with existentialism, such as the creation of personal meaning, and bad faith and professional responsibility.

The Existential Engineer

The motivations of people in STEM fields vary immensely, from monetary gain, to personal satisfaction, to serving higher virtues or ideals. My intention is not to disparage those motivated my monetary gain; it is certainly a critical issue I consider myself, as desire for an above average standard of living is a perfectly understandable phenomenon. It is also a natural offshoot of capitalist market competition, since engineers are a highly sought-after type of skilled worker. However, one must be wary of whether financial gain leads one to act in ways inauthentic to themself, like being complacent with goals they do not intellectually or morally agree with, or believing they are stuck in some particular undesirable job because of the anxiety of leaving to find a more desirable one.

Secondly, though, we may consider both personal satisfaction and the serving of ideals. There have always been critics to the field of engineering, who look upon the such fruits of the profession as pollution/destruction of the environment, the creation of terrible weapons of mass destruction, and even new anxieties that arise among people as they come to live in an environment with new technology in every direction. They extend from this that all technological advancement is bad for society. This is a serious existential question that people like Samuel Florman in his book *The Existential Pleasures of Engineering* have gone through great pains to refute. His argument is detailed, but in essence it involves arguing that man is inherently technological, and appeals to a pre-technological past are Golden Age fallacies. Issues of

weaponry and the environment should not be brushed aside, of course, but the idea that engineering is fundamentally detrimental to society is refuted.

Of greater interest is what Florman says about engineering in an existential light. Assuming if we will that it can be safely refuted that engineers are not evil, what can we say about their *dullness*? There is a common stereotype that engineers are practical, analytical, and non-emotional automata. It is a view that frightens me personally a great deal, one which has made me question if I can in good conscience see myself become like that. Wernher von Braun famously said that the engineer experiences "the satisfying reward of knowing he has contributed to the advancement of all mankind." But this reflects less an introspective description of feeling than a sense of fulfilling duty. Professional engineers in professional spaces *always* externalize the value of their work. It leads me to believe that many engineers fundamentally misattribute the basis of the satisfaction they derive from their work, and certainly ought to take a closer look. I certainly imagine that there are engineers who do find their work fun and fulfilling, but I think it is important that these people do not have these feelings contingent on the serving of ideals, but on the fulfillment of the work in and of itself; human advancement is a contentious idea, as others may fail to see value, or even see maleficence in certain endeavors.

The essence of existentialism is disenchantment with the larger world. Inner emotions like passion, yearning, and anguish, are above all scientific or philosophical viewpoints from the subjective perspective of the individual. An engineer pursuing philosophical curiosity may then at once be attracted to and skeptical of existentialism. Attracted to because it provides an avenue for contemplating being and feeling individually, but at the same time a bit alien because its appeals to emotionalism may be at odds with the concrete, rational mind of an engineer that has come to tacitly feel comfort only in logic and science. Moreover, there is a longstanding tradition

of anti-materialism amongst the existentialists, as well as self-styled "spiritualists", or even the Periclean Greeks like Plato and Plutarch. Historically speaking, however, materialism, in the sense of man's relation to creating and solving problems around him, has always been there, from the very first proto-humans using bones as clubs, to man's setting foot on the moon.

Whatever way one chooses to look at it, creative acts have always been a fundamental human drive that exists independently of the serving of higher ideals/virtues, or the serving of some tenuous notion of societal good. In modern engineering (ie post 1950s), almost completely vanished is the faith in a utopic future that so defined the outlook of the late 19th and early 20th centuries, when any all technological advancement was lauded and looked upon with great excitement. "Progress" becomes a more and more difficult idea to define; few agree on what the "correct" direction for humankind is. Florman sees the analogy to Sisyphus useful here: there will never be a time to rest upon the mountain top in a new utopia. There will always be issues facing the absurdity of the new problems and failures that come both directly and indirectly from technology. But the engineer is well within his rights to reject the idea that he is a villain or false prophet, because of course no essence precedes what he chooses. He may also reject the idea that he is a tool of the technosocial transformation of the world, but a radically free individual defined only by his own choices. Engineers carry on the legacy of humankind to create, both for instinctual gratification and the existential expression of their own authenticity. (Florman, 1996)

Bad Faith and Professional Responsibility

It should not be implied from anything said previously that engineers have complete free reign and are not beholden to any sort of standards of conduct. The reason *why* one must act ethically is a very philosophically fraught, but suffice it to say for now that by behaving ethically, humans do not impede others' freedom or wellbeing and thereby do not maliciously hinder others' ability

to express themselves authentically. In any case it is widely accepted that engineers ought to, insofar as they are reasonably able, eliminate any risk to personal safety, act only in their areas of competence, be objective and truthful with the public, act as faithful agents to clients, avoid deception, and conduct themselves overall honorably and ethically. (These canons are taken from the National Society of Professional Engineers Code of Ethics). Ethical engineering practices are in general well defined and not a serious source of contention. But what I propose it that in bad faith can be used to understand such phenomena as normalized deviance. The individual, as Sartre would say, always has a choice. Of course, there are almost always obstacles limiting absolute choice, (often referred to as existentialists as facticity), and it should not be implied that every tragedy ever stemming from engineering was solely the lack of an individual's choice.

Similarly, an engineer cannot blame others for the moral or ethical bankruptcy of an action they are in any way complicit in; this is bad faith as well, pushing the blame external to oneself. The bottom line is the individual always has a choice.

Existential Joy

Florman firmly believes that "at the heart of engineering lies existential joy." Whence this pleasure comes from is complex, ranging from the aesthetic beauty of machinery, to creating the things in the world that artists and others interpret, to the grappling of the inherent beauty of fundamental natural laws. Each of these is certainly valid, but what I find most valuable personally is the desire of the engineer to create and change the world around him; it is emphasized that such an impulse is not contingent on the need of mankind for change. Rather, all humans are by nature not satisfied accepting the world as is, and are driven to change it. (Florman, 1996) Engineering is a modern designation that delineates a certain type of technical creation, but shares with artists and craftsmen a creative spirit. Existentialism itself is inherently

creative, as man is forced to create himself, and so it is altogether fitting that creative acts appeal to our existential sensibilities. Acts of creation are moreover authentic acts. Some existentialists may argue that an act of creation must be self-expressive and therefore artistic to be authentic, but it is my sincere belief that all creative acts are self-expressive even if the process seems entirely systematic as they often are in engineering; it is the mere shaping of the physical world in some way that is self-expressive and authentic.

Response to Comments

How one might go about "working existentialism into engineering" is not something that can be prescriptively stated. Grappling with authenticity is a very personal experience that one must explore themselves. It is rather the results of this process that I believe lead to useful results. First, one realizes their radical freedom and the fact they always have a choice in any situation. Second, one becomes acutely aware that they are directly responsible for the consequences of their actions or inactions, and that passing blame solely to others is bad faith. Third, one realizes that satisfaction in their work is not limited to a final outcome, or achievement, and failures are not somehow failings of self-worth; rather, one derives pleasure from engagement in the creative practice of engineering itself.

Automated decision tools like machine learning, and automated design tools may seem disagreeable to existentialists, since personal choice is and personal creativity seem to be limited by them. But ultimately, I believe they are merely a new type of tool, the function of which is of course to make work easier, or facilitate new types of work that were impossible without the tool. The user should not blind faith in the tool, though, and should understand its operational principles and thereby whether the tool is in a condition to perform its task or needs to be

fixed/modified. Also, when using new tools, it is healthy to have a certain amount of skepticism, a familiar attitude to both existentialists and engineers.

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