The Pi^2 Robot Platform: Issues of Sustainability and Ethics

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Introduction

This paper discusses the Senior Design Project completed by our group for term 8, as well as the potential moral and ethical issues that surround it. First, an overview of the project will be discussed, followed by some of the potential benefits to society of the project. Our project is heavily reliant on lithium-ion batteries and rare Earth metals, and so a discussion of the sustainability issues surrounding these will follow. Finally, the project uses machine vision techniques for automated barcode recognition. Machine vision is quickly becoming a widely used technology, especially as it relates to surveillance. Due to the growing public concern around mass surveillance in recent years, an analysis of the topic and the application of machine vision to it are presented as well.

Project Overview

The Senior Design Project done by our group involved improving on a prototype of a robot made using a Raspberry Pi and a Pololu 3pi robot. The robot that we were given was able to move around using the wheels on the 3pi robot, and was able to detect objects with a certain RGB value using a Raspberry Pi Camera installed on the Raspberry Pi.

Dr. Shehata and Dr. Peters of the Electrical and Computer engineering department gave us several project requirements to achieve. First, the hardware of the robot had to be improved. This involved replacing the Raspberry Pi with the Raspberry Pi 2 and improving the 3D printed frame, which held many of the core components, to improve its stability and ease of access to the batteries. It also involved creating two more robots with the upgraded hardware. Pictures of the three robots we created are presented in Figures 1 and 2.

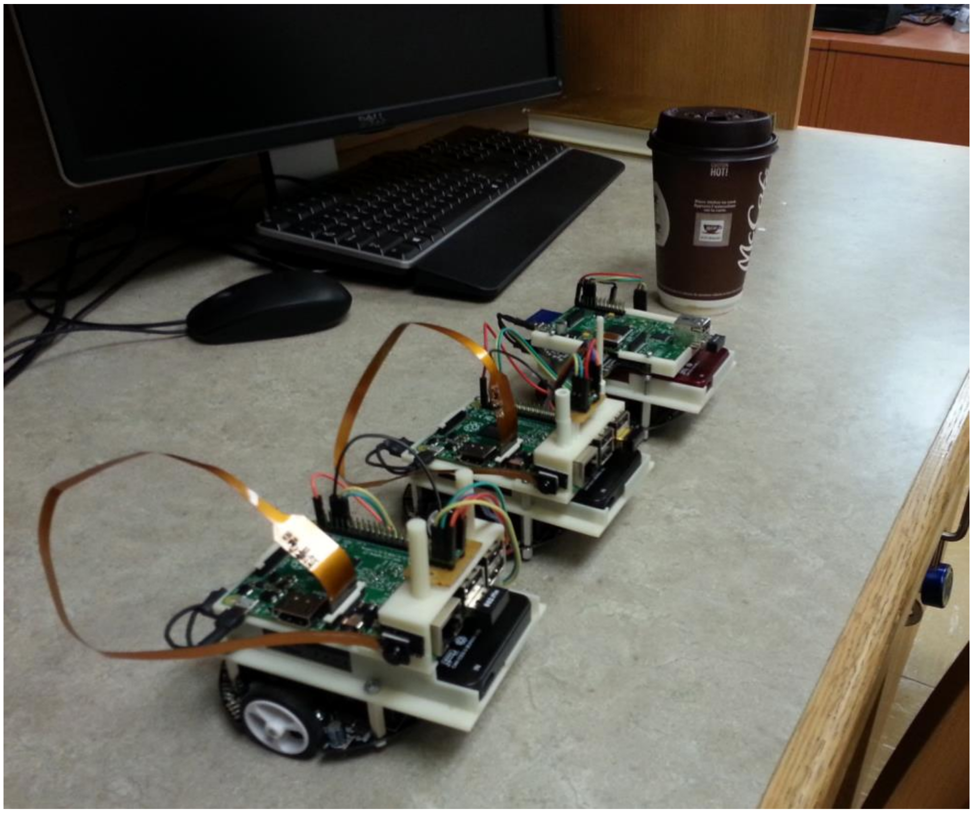


Figure 1: The three completed robots, the newest on the left and the oldest on the right.

In terms of software, we were asked to expand the capabilities of the robots to be able to detect one another using more sophisticated machine vision techniques (barcode recognition in our case) and to communicate over Wi-Fi. We also used the robots to create a "fun" tech demo which showcased the capabilities of the platform. This tech demo involved having two of the robots move back and forth on a line, and so software had to be developed to have the robots read data in from sensors on their underside and adjusts their direction of travel using a PID controller. These controllers were calibrated using the Ziegler-Nichols method. Figure 2 shows the tech demo in action. The objects on top of the robots are barcodes which they use to uniquely identify one another:

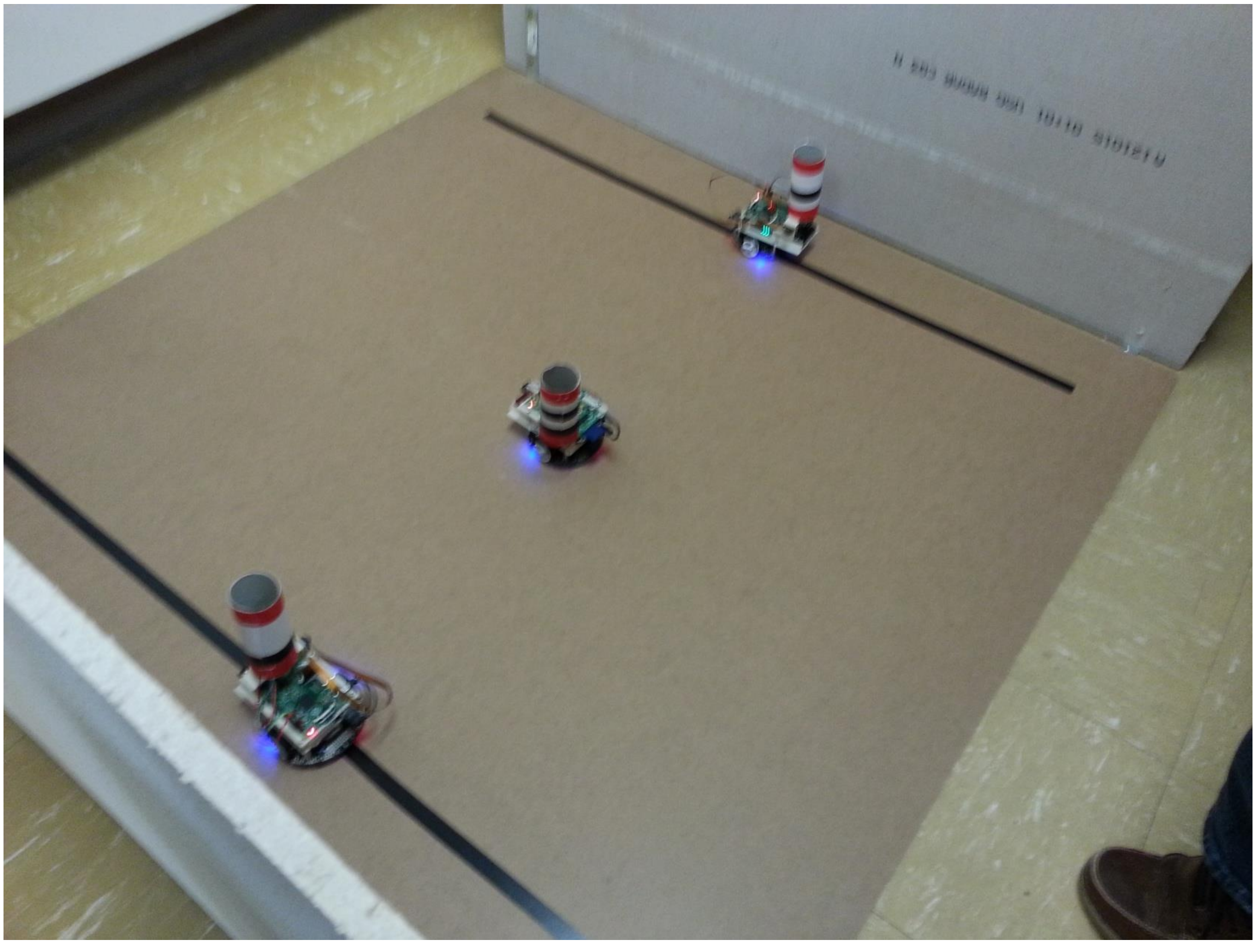


Figure 2: The tech demo for the Senior Design Project in action.

The tech demo is a game in which the center robot is trying to avoid being "seen" by the outer robots. The outer robots are autonomous and move back and forth along the black lines, following the robot in the center using cameras. The center robot is human-controlled using a website. Every time the center robot is "seen" a counter on the website updates, and after a certain period of time has elapsed the outer robots stop moving and the game is over. The goal of the user is to minimize their score, i.e. the number of times they were seen.

Impact of Senior Design Project Design on Society

Benefits to Society of Senior Project Design

The impact of the Senior Design project described above would not be large. However, it is possible that it could have a positive impact on society if the code and the CAD model for the frame were open-sourced so that the robots could be made by anyone. This is because the platform is relatively inexpensive to construct, and it has many possible applications for hobbyists due to its ability to physically move around, process video using machine vision techniques in real-time and to communicate over the internet. Projects such as these which could be enjoyed by tech-savvy parents and their children could increase interest in programming and computer engineering, which is a field with relatively few students compared to other disciplines. Additionally, do-it-yourself project makers always find clever and innovative ways to use a platform such as ours.

A concrete example of an area where this type of robot may be useful is in the ENGI 1020 - Introduction to Programming course. Students in this course are already using the Pololu 3pi robot as an aid to help them learn procedural programming. If the robots used in our project were used instead, the behaviour they would be capable of would be much greater, which may make assignments more interesting and rewarding. Of course, this comes with increased complexity in programming, but this could largely be resolved by having the instructor fill in most of the details and leaving the students to fill out more trivial parts in the business logic layer.

Detriments to Society of Senior Project Design

The impact of a project on society in its current state is quite modest. As such, this paper focuses mostly on the potential negative consequences of two important components of the project: the batteries used to power the robot and the machine vision algorithms used for object recognition. We speculate on what would happen if our project/product was a runaway success and had to be mass produced and disposed of such as smartphones are today.

The main hardware components of our projects are the Raspberry Pi2, the Pololu Pi and a lithium-ion battery. These small computers need to be made with rare earth metals and other chemical elements while the lithium-ion battery requires the consumption of the earth’s lithium reserves. Meanwhile, the mounted camera could theoretically help groups perform mass surveillance on society. These issues are discussed in the remainder of this paper.

Lithium Ion Batteries

Lithium Supply

Lithium is the first metal on the periodic table, as such it holds atomic number 3. It has half the density of water and is highly reactive. Its most well-known usage is in our laptop, cellphone, and electric car batteries in the form of Lithium-ion batteries. It is also added to glass and ceramics for heat resistance and can be smelted with other metals such as aluminum or copper to create very lightweight alloys. Lithium is most commonly mined from groundwater underneath salt lakes and closed basins. The water is pumped to the surface and evaporated to extract the dissolved lithium compounds that are present in high enough concentrations for economical mining. Outside of this method, lithium can be found in certain types of rocks such as pegmatites (Bradley & Jaskula, 2014).

Although lithium itself is, percentage-wise, a small component in a lithium ion battery, it is a vastly important component of them. Lithium has become increasingly valuable in recent years. In 2015, the spot price of a tonne of lithium carbonate doubled in just two months due to demand in China. Lithium-ion batteries are used in smartphones, laptops, power tools, electric cars and as electrical storage from the power grid during low demand periods (The Economist, 2016).

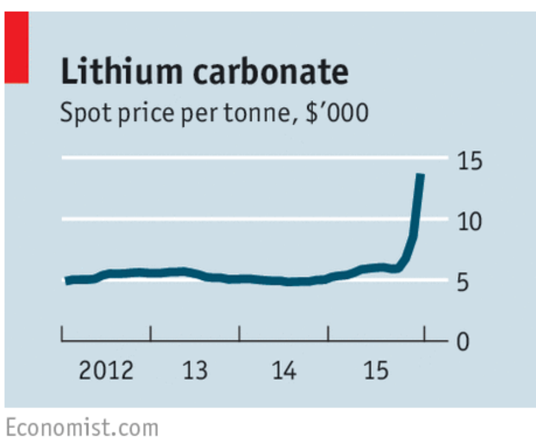


Figure 3: Lithium carbonate's value spiked rapidly in 2015 due to growth in demand (The Economist, 2016).

Recent speculation, based on current trends in the electric car industry, indicate that production of Tesla cars in the next few years will require doubling or tripling the global production of lithium-ion batteries (Fisher, 2013). This underlines how we must be ready to dispose of and recycle lithium-ion batteries. One of the current issues lithium-ion batteries is that they only hit their technological popularity in the early 2000s. That means our upstanding of their lifecycle management is relatively limited compared to lead batteries which have been around since 1859 and there is still plenty of research left on the subject.

Current estimates state that there is approximately 39 million tonnes of lithium in the world, of which only 13 million tonnes are currently economically extractable. The U.S has substantial lithium reserves but currently does not produce lithium on a large scale. The major producers of lithium include Chile, Argentina, and China. Lithium is a key element for modern technology. There are over six billion cellphones in the world and lithium-ion batteries power most of them. Luckily, lithium is capable of being recycled infinitely which makes it a very viable battery component in the long-term (Bradley & Jaskula, 2014).

World Mine Production and Reserves: The reserves estimates for Argentina, Australia, and China have been revised based on new information from Government and industry sources.

	Mine production		Reserves[6]
	2014	**2015[e]**	
United States	W	W	38,000
Argentina	3,200	3,800	2,000,000
Australia	13,300	13,400	1,500,000
Brazil	160	160	48,000
Chile	11,500	11,700	7,500,000
China	2,300	2,200	3,200,000
Portugal	300	300	60,000
Zimbabwe	900	900	23,000
World total (rounded)	[7]31,700	[7]32,500	14,000,000

Figure 4: Summary of known lithium reserves and production worldwide (Jaskula, 2016).

Lithium and E-waste Recycling

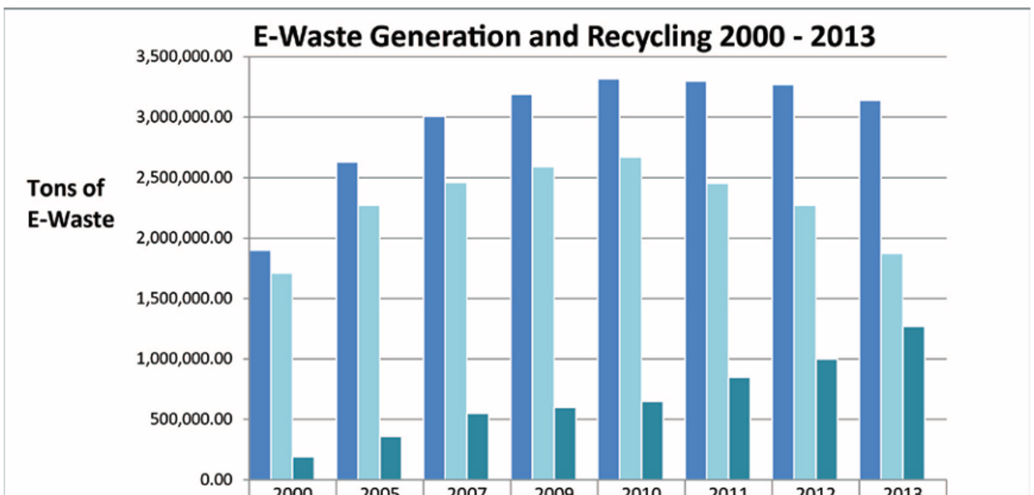
The recycling of lithium is still quite small. The first American lithium car battery recycling plant was just opened in 2015. Meanwhile, the global production of Lithium increased by 5% from 31,700 tons to 32,500 tons between the years 2014 and 2015 (Jaskula, 2016).

According to the EPA (2015), “recycling one million laptops saves the energy equivalent to the electricity used by more than 3,500 US homes in a year” and that “for every million cell phones we recycle, 35 thousand pounds of copper, 772 pounds of silver, 75 pounds of gold and

33 pounds of palladium can be recovered." It is therefore evident that electronic waste (e-waste) recycling can have a large impact on the environment.

Another EPA report states that Americans generated 3.14 million tons of e-waste in 2013 and from that, only 40% was recycled. This means that the remaining e-waste was sent to landfills or was incinerated. From these 3.14 million tons of waste, there were at least 142,000 computers and 416,000 mobile devices (each requiring their own lithium ion battery that may not be removable) (Electronics TakeBack Coalition, 2013). This is an environmental problem because discarded electronics can leave behind lead, mercury, cadmium, and other toxic byproducts. Worldwide, an estimated 20-50 million tons of e-waste is generated and this volume of waste is growing at a rate of 4-5% (Electronics TakeBack Coalition, 2013).

Although this may sound dreadful, there is hope as recycling rates for e-waste increases due to manufacturer recycling programs and government legislation. Figure 5 outlines this paradigm shift nicely but the EPA has stated that positive trends may be exaggerated due to improved data collection in 2013 and due the trend of electronic devices decreasing in actual weight (Electronics TakeBack Coalition, 2013). A more detailed breakdown of E-waste in the United States can be found in Appendix A.



	2000	2005	2007	2009	2010	2011	2012	2013
Total e-waste generated	1,900,000	2,630,000	3,010,000	3,190,000	3,320,000	3,300,000	3,270,000	3,140,000
E-waste trashed	1,710,000	2,270,000	2,460,000	2,590,000	2,670,000	2,450,000	2,270,000	1,870,000
E-waste recycled	190,000	360,000	550,000	600,000	650,000	850,000	1,000,000	1,270,000
Percent Recycled	10.0%	13.7%	18.3%	18.8%	19.6%	25.8%	30.60%	40.40%

Figure 5: Total e-waste generation is steadily increasing and so are recycling rates (Electronics TakeBack Coalition, 2013).

Researchers have been studying the impacts of certain regulations on e-waste recycling rates. Criticism has been placed on the U.S because their state-level laws are often shown to be very ineffective and in 2013, there were 37 states with no e-recycling laws in place. California is an example of successful e-recycling due to legislation. In 2004, their government required that cell phone retailers collected old phones and recycle or dispose of them properly. These laws make Californians seven times more likely to recycle their old phones and other electronics. Meanwhile, the European Union has been praised for its ability to create e-waste regulations as a unified body that, due to its global market power, can force manufacturers to change all their products to meet E.U regulations. In addition, there have been many cases in which electronics manufacturers have voluntarily signed agreements to phase-out harmful chemicals such as CFCs or soldered lead (Anderson, 2013).

Because lithium-ion batteries are often non-removable, such as in the iPhone, they are often viewed as part of the smartphone, but are not covered under the EU's e-waste regulations. The Germany Federal Environment Agency has once suggested that non-removable batteries should be banned to improve device recycling methods. Recycling of these batteries is desirable because the majority of the metals, especially cobalt, in the batteries are currently obtained from primary mining operations in countries with weak environmental regulations. Companies such as Umicore have been able to recycle lithium-ion batteries with a 90% smaller ecological footprint than primary mining but recycling rates remain low, yet increasing rapidly due to regulations, in the EU. In 2014, the UK reached a target of 30% battery recycling when it was around 4% in 2009 and the EU as a whole is aiming to each 65% over the next few years through its Waste Electronic and Electrical Equipment Regulations directive (Smedley, 2014).

Besides being used in cellphones, lithium-ion batteries are used in automobiles. Because lithium-ion car batteries are a newer technology, the recycling methods and end-of-life procedures are not yet well established. Although some materials such as glass and alkaline batteries have weak cases for their recycling due to non-toxicity and costs such as shipping distances, recycling any material has the benefit of reducing are consumption of non-renewable resources and, if done locally, can reduce dependencies on imported resources (Gaines, 2014).

Likewise, one example of a manufacturer sponsored recycling program is from Honda. In 2012, Honda, in an attempt to improve the greenness of their products and reduce the Japanese company's dependence on Chinese imported materials, became the first auto industry company to start recycling their hybrid auto batteries. They said this was part of their goals to reduce pollution, fight climate change, and to further support renewable energy frameworks. Soichiro Honda, the company founder, was known for reminding workers that the automobile industry has a responsibility to reduce their greenhouse emissions (The Associated Press, 2012).

This is also a very dark side to the disposal of e-waste. Rich nations are known to send their e-waste to very poor countries where they go to landfills that operate with very questionable practices. The United Nations estimate that 80% of e-waste that is claimed to have been properly disposed of is actually sent to developing nations where the e-waste is then burned, buried, or dissolved in chemical baths. These methods will pollute the land and watersheds near the landfills and jeopardize the public's health (Anderson, 2013).

The materials recycled from a phone are only worth around $1. This means that economical recycling (concerned only about profit margins) requires low cost extraction processes. This would either be sophisticated large scale recycling operations or, in reality, cheap labour in developing countries. One of the reasons for the low value is that amateur recycler are only able to retrieve 50% of the gold with their crude processing techniques. In contrast, high-tech recycling facilities are able to extract 95% of the gold from processed e-waste (Iftikhar, 2015).

Whole communities in developing countries base their local economies on crude e-waste recycling using techniques such as burning the electronics in open fields to smelt them down to their base materials. Meanwhile, the e-waste in the nearby landfills is breaking down and seeping toxic chemicals into the local water and soil. Exposure to these kinds of extreme pollutants can cause lung, liver, and kidney damage, infertility, and reduce mental ability in children. To make things even more tragic, the recyclers are usually desperate economic migrants and child laborers. Even in developing countries, this is the kind of work that only the most marginalized groups will take part in (Iftikhar, 2015). In such places, other metallic wastes such as lead-acid batteries are also recycled by exploited children in crude operations that dump lead-contaimnted acid into the water and provide no emiission control for the toxic smelting fumes (Gaines, 2014)

Ifitkhar (2015), quoting Sheila Davis, executive director of Silicon Valley Toxins Collection, states that “We need to figure out ways to have circular economies, where all the materials that go into products can be recovered and recycled and put back into new products, so the market continues to expand and we're not tapping the Earth unrealistically for resources." In addition, it is suggested that we need to increase cell phone recycling rates and use high tech recycling so that we reduce the amount of non-renewable materials we use that are sourced from mining. Another way to mitigate our environmental impacts is to substitute one material for a more sustainable one. In 2008, electrical bonding wires were made from 90% gold and then in 2014 they were made from just 50% gold (Iftikhar, 2015).

We can reflect on how we handle lead-acid batteries as a model of success. To start, it achieves the success criteria that the recycled product is good enough to be reused or repurposed for a different application. In the USA, 99% of all lead-acid batteries are recycled because simply dumping them is illegal in most states and importantly many states require the consumers of lead-acid batteries to place a monetary deposit. Getting your hard earned money back is always a good incentive for consumers. Lead-acid recycling also has technological reasons for its success. The necessary recycling method for lead-acid batteries is able to turn a profit partially because the battery designs are standardized to facilitate mass recycling and because the chemical composition does not require separation of the core components (Gaines, 2014).

Lithium and lithium-ion batteries are now a fundamental part of our technology. We must work towards a sustainable future in which we recycle the lithium-ion batteries and the e-waste that usually comes with it in such a manner that doesn’t exploit marginalized groups to squeeze a little bit more profit. It is evident from the research that this can be best obtained by government legislation on the national and international level. The best incentives to recycle are financial and legal penalties and when a major world economy adopts a higher, more sustainable standard, market forces are often required to adapt to their consumer needs. The USA, EU, and China have the ability, and responsibility, to be world leaders in resource and e-waste recycling. If they do it, so will everyone else. The reserves of economically minable resources on our planet are finite and the environmental impacts of “bad” recycling are terrible so we must adopt cradle-to-grave plans for our electronics.

Lithium Ion Battery Fires

There have been many cases of lithium-ion batteries randomly igniting. It is important that we understand the risks of using them and form strategies to mitigate the dangers associated with them.

Lithium-ion batteries obtain their desirable properties from that fact that Lithium is the least dense metallic element on the periodic table. This means more energy can be contained in the battery for a lower weight but it also means that the element is highly reactive. There have been several fires caused by lithium ion batteries when an electric fault or damage to thin internal battery barriers causes excess electricity to flow and overheat the battery. Then, because the lithium is so reactive, this excess heat can quickly build up and create a dangerous fire. Both the Boeing 787 Dreamliners and Tesla Model S had to be re-engineered following unexpected lithium ion battery fires (The Economist, 2014).

A lithium battery recycling facility near Trail, British Columbia has caught on fire at least six times since 1995. In one instance, 40000 kg of batteries were burned by a fire releasing toxic fumes into the atmosphere. During another fire in 2009, firework style blasts and projectiles were sent shooting out of the concrete storage bunkers that warehouse the lithium-ion batteries. Residents had to stay indoors while the fire created a toxic plume of sulfur dioxide gas. There are additional complications when fighting lithium fires; lithium is highly reactive with fire thus limiting conventional water on fire extinguishing methods. In the 2009 incident, firefighters had to wait 22 hours for the fire to die down before finally extinguishing it. (CBC, 2009) As lithium-ion batteries become so dominant in our technology we need to consider how we handle their combustion risk and engineer forward thinking solutions. There are no current trends that indicate lithium-ion batteries are going to be replaced anytime so we need to be prepared. Our project is a part of the lithium-ion chain and we too need to be concerned if our hardware is not posing a fire risk and is disposed of properly.

Rare Earth Metals

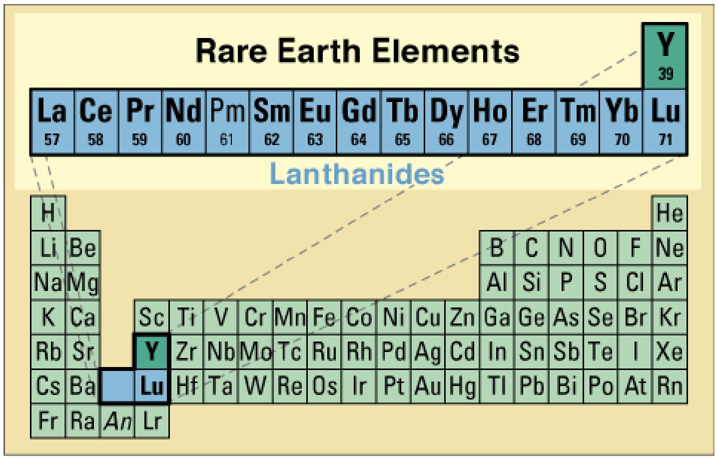


Figure 6: Rare earth elements on the periodic table (Haxel, Hedrick, & Orris, 2002)

Rare Earth Elements (REE) are chemical elements discovered in the 18th and 19th centuries that were contained in mineral specimens that were considered rare back in those times. Ironically, REE are actually very abundant in the Earth's crust but not usually in localized concentrations that are economically mineable. Most REE are more common in the crust than silver or mercury and their deposits are usually found near each other due to their similar chemical properties (Long, Van Gosen, Foley, & Daniel, 2010).

REE have extensive uses in our modern technology. They are involved in processes such as glass polishing, lasers, magnets, batteries, refrigeration, storing hydrogen gas, and telecommunications. The element Erbium is the only known element that can amplify lasers over long distances in our superfast fiber-topics cables. On top of this, other REE are required to make permanent, light-weight, magnets that we need for our computers, cars, audiovisual equipment, and communication devices. These REE magnets are what allow us to have portable hard drives instead of room sized magnetic tapes. (Haxel, Hedrick, & Orris, 2002)

Issues of Supply Chain Control

The Chinese Bayan Obo mine produces over half the REE in the world. Extracting these resources comes at a high environmental cost. The Chinese Society of Rare Earths says that every tonne of REE mined generates 9,600 to 12,000 cubic meters of waste gas. These gasses contain harmful chemicals such as hydrofluoric acid, sulfur dioxide, and sulfuric acid. Additionally, each tonne of mined REE produces 75 cubic meters of acidic wastewater and trace amounts of radioactive waste (NASA, 2012).

Satellite images demonstrating the surface level change from REE mining at Bayan Obo is shown in Figure 7.

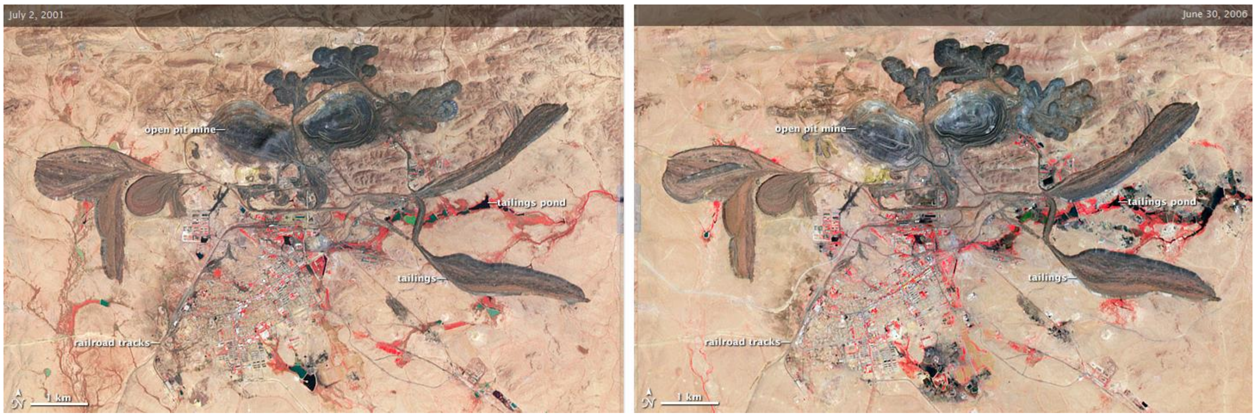


Figure 7: Satellite images of the Bayan Obo mine in 2001 and 2006 (NASA, 2012).

China currently controls 97% of the production of REE and currently has at least 1/3 of the world's known reserves. Meanwhile, commodity prices for rare earth metal have risen by at least 700% and as such, researchers are looking for new sources of these commodities. Researchers at the University of Tokyo are currently looking into extraction of REE from deep sea muds. Finding new sources will reduce the dependency of many nations on China's exports. This is meaningful because in April 2001, China placed taxes on exports of heavy and light rare earth elements of $8.90 and $4.45 per tonne respectively (CBC, 2011).

(Long, Van Gosen, Foley, & Daniel, 2010) state that it is very normal for one country to source to dominate the market for a minor metal commodity. For instance, the U.S. supplies 86% of the world's beryllium while Brazil provides 92% of the world's supply of niobium. However, placing the market power in one country creates concerns over price manipulation, labour disputes, natural disasters, and political conflicts. (Long, Van Gosen, Foley, & Daniel, 2010) For the case of REE, which are a major component for creating our favorite electronics, we are at the mercy of the Chinese government and their state owned enterprises. This is hardly a situation that Western nations find ideal. A breakdown of current REE production and REE reserves by country is provided in Figure 8.

Table 8. World production and reserves of rare earth elements minerals in 2009.

[In 2009, China produced 95 percent of world rare earth elements although it had only 36 percent of rare earth elements reserves. TREO, total metric tons of rare earth oxides]

Country	2009			
	Production		Reserves	
	TREO (metric tons)	Share (percent)	TREO (metric tons)	Share (percent)
Australia	0	0	5,400,000	5
Brazil	650	0.5	48,000	0.05
China	120,000	95	36,000,000	36
Commonweath of Independent States	2,500	2	19,000,000	19
India	2,700	2	3,100,000	3
Malaysia	380	0.3	30,000	0.03
United States	0	0	13,000,000	13
Other	0	0	22,000,000	22
Total	126,230		99,000,000	

Figure 8: REE production and reserves across the world (Long, Van Gosen, Foley, & Daniel, 2010)

However, it is important to note that China's control of the REE supply wasn't always the case and that it doesn't have to remain this way. As we can see in Figure 9, the dominant producer of REE used to be the U.S. Using basic concepts from economics, it can argued that China supplies the majority of REE to the world simply because they provide a satisfactory competitive price (which may come from low labour costs and weak environmental regulations) to their customers. In the event, that China attempts to gouge consumers on the price of REE eventually another nation will open a mine since there is a profit to be made in undercutting China. As we already saw in Figure 8, China only controls 36% of the world's known REE reserves, this means that high REE prices will entice nations to go search for new REE reserves, reopen old mines, or invent new technologies to cheaply extract known reserves. This can be compared to how oil prices recently declined and America became a major oil producer in response to the long period of record high oil prices.

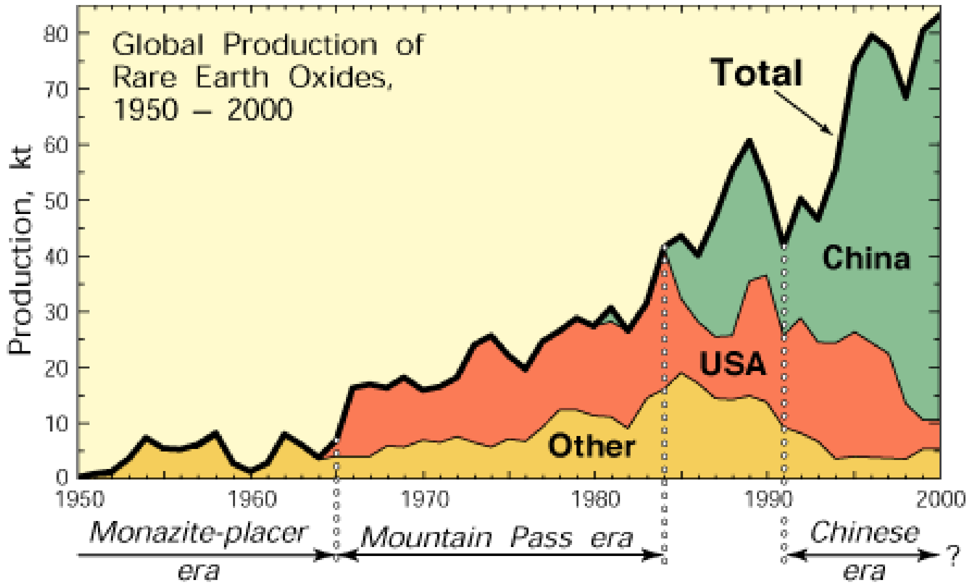


Figure 9: Historical data of REE production (Haxel, Hedrick, & Orris, 2002)

Haxel, Hedrick, & Orris (2002) warn that having the production of REE controlled by China poses a risk to national U.S. security. REE are needed for jet fighter engines, missile guidance systems, antimissile defense, satellites, and electronic countermeasures. They also warn that America is losing its status as a leader in REE research because the processing technology and applications are now centered in China and Asia. Since our project, requires and consumes REE resources we need to appreciate the value of the resource and make sure it is recycled responsibility in a modern recycling plant so that we can reduce the ecological footprint of REE mining and supplier dependencies.

Machine Vision and Mass Surveillance

Ethical Issues with Mass Surveillance

Mass Surveillance is a subject which has been discussed to a great extent both by the public and by academics, especially since Edward Snowden enlightened the world as to the extent of the National Security Agency's (NSA) global surveillance programs in 2013 (Greenslade, 2013). There are a number of ethical issues associated with mass surveillance which are brought up regularly in public discourse, and will be briefly discussed in this section. Note that many ideas in this section are sourced from the Surveillance Ethics article in the Internet Encyclopedia of Philosophy (Macnish, 2016).

The most obvious issue with mass surveillance is that of privacy. Although definitions vary, privacy is something that most would agree has an inherent value to people. It is also important for safety; for example, it would be detrimental to one's personal safety if someone with malicious intent knew everything about them. Mass surveillance directly compromises the privacy of those being monitored by constantly recording information about them. Even if the government is trustworthy (which would be a bold claim to make given how many people could be involved), information leaks can and do happen all the time due to security vulnerabilities in software.

Another ethical issue related to mass surveillance is trust. By preemptively monitoring the public, the government is implying that it does not trust the public to behave appropriately. This in turn could cause the public to distrust the government (i.e. why are you spying on me when I've done nothing wrong?).

A related issue is the loss of autonomy. This stems from the idea that if one knows that they are being watched, they will feel pressure to act in a way that is acceptable to those who are monitoring them, effectively limiting their ability to act as an individual. This also makes it near impossible to establish trustworthiness, since good behaviour may be assumed to be the result of being surveilled.

A final example of ethical issues with mass surveillance is feature creep. Even if the original intent of the surveillance is noble, it may be adapted for other purposes in the future. This could be in the form of increased functionality (more detailed monitoring) or increased use cases. The potential for such a system to be abused would be quite high.

Mass Surveillance is strongly related to the idea of technological determinism. One of the tenets of technological determinism is that the effects of technologies on society are inevitable. Mass surveillance embodies this principle in that some governments (and other organizations) are applying mass surveillance simply because the technology allows for it, without due consideration for (or at least without affording the public the opportunity to discuss) whether or not it should be used.

How Machine Vision Facilitates Automated Mass Surveillance

Mass surveillance with human operators has a significant flaw: there is a huge volume of incoming data to be analyzed. Not only would hiring humans to do such analysis be extremely expensive (as well as a security hazard), but humans have limited attention spans, and it is quite feasible that important details would be missed by a human operator. Of course if an incident occurs one could always re-watch security camera footage, but one of the primary functions of mass surveillance is pre-emptive monitoring. This issue can be largely resolved with machine vision techniques.

Machine vision, although a relatively new field, is already proving to be quite powerful. For example, Google's Photos app allows one to search for people, places or things in their photo gallery without the use of metadata tags, instead using machine vision to automatically detect the object of interest in the photo (Google, 2016). Similar technology can and has been used in security cameras to automatically detect certain patterns, such as counting people passing through an area. One could imagine other applications as well, such as recognizing the faces of wanted criminals.

The use of this technology for surveillance would make the system much more efficient since human error would no longer be as much of an issue, and higher volumes of data could be processed at once. Some governments are already seeing the potential of this technology. For example, in the UK, the country with the most closed-circuit television (CCTV) cameras in the world, machine vision technology is already being adapted for surveillance purposes (Mounsey, 2011). Although this technology is great news for the governments and companies that use it, it is not so good for those being monitored as it makes it even harder to "escape" being monitored.

Conclusions and Recommendations

Lithium and lithium-ion batteries are now a fundamental part of our technology. We must work towards a sustainable future in which we recycle the lithium-ion batteries and the e-waste that usually comes with it in such a manner that doesn't exploit marginalized groups to squeeze a little bit of profit. It is evident from the research that this can be best obtained through government legislation on the national and international level. The best incentives to recycle are financial and legal penalties and when a major world economy adopts a higher and more sustainable standard, market forces are often required to adapt to their consumer needs. The USA, EU, and China have the ability and responsibility to be world leaders in resource and e-waste recycling. If they do it, it is likely that many others will follow. The reserves of economically minable resources on our planet are finite and the environmental impacts of "bad" recycling are terrible so we must adopt cradle-to-grave plans for our electronics.

Furthermore, electronics such as our project require and consume REE resources. We need to better appreciate the value of the resource and make sure it is recycled responsibility in a modern recycling plant so that we can reduce the ecological footprint of REE mining and supplier dependencies. The balance of power in the REE market belongs to Chinese producers and their control and influence are so strong that Western economies may want to divest from them and seek other, less polluting, sources of REE. This can be achieved through new mines or through efficient recycling.

Finally, mass surveillance is primarily a social issue; any sort of technological solution (such as using public phones instead of a personal phone, or disabling GPS on one's cell phone to make them harder to track precisely) would result in an arms race between the public and the government and not address the root cause. Machine vision techniques are a symptom of this already happening, as they provide cheaper and more complete surveillance with security camera footage. Surveillance programs represent a trade-off between security and privacy, and so it is essential that the public is involved with deciding where on that spectrum they wish to lie. Thus far they have not, as the extent of NSA surveillance, shown to the public by Snowden, was a shock to everyone.

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Appendix A

E-Waste by the Ton in 2010 – Was it Trashed or Recycled (According to the EPA)

Products	Total disposed**	Trashed	Recycled	Recycling Rate
	tons	tons	tons	%
Computers	423,000	255,000	168,000	40%
Monitors	595,000	401,000	194,000	33%
Hard copy devices	290,000	193,000	97,000	33%
Keyboards and Mice	67,800	61,400	6,460	10%
Televisions	1,040	864,000	181,000	17%
Mobile devices	19,500	17,200	2,240	11%
TV peripherals*	Not included	Not included	Not included	Not included
Total (in tons)	2,440,000	1,790,000	649,000	27%

E-Waste by the UNIT in 2010 – Was it Trashed or Recycled
(Same report as above, but reported in UNITs, not by TONS)

Products	Total disposed**	Trashed	Recycled	Recycling Rate
	Units	Units	Units	%
Computers	51,900,000	31,300,000	20,600,000	40%
Monitors	35,800,000	24,100,000	11,700,000	33%
Hard copy devices	33,600,000	22,400,000	11,200,000	33%
Keyboards and Mice	82,200,000	74,400,000	7,830,000	10%
Televisions	28,500,000	23,600,000	4,940,000	17%
Mobile devices	152,000,000	135,000,000	17,400,000	11%
TV peripherals*	Not included	Not included	Not included	Not included
Total (in units_	384,000,000	310,000,000	73,700,000	19%

<u>What's included here?</u>
Computer products include CPUs, desktops and portables.
Hard copy devices are printers, digital copiers, scanners, multi-functions and faxes.
Mobile devices are cell phones, personal digital assistants (PDAs), smartphones, and pagers
*Study did not include a large category of e-waste: TV peripherals, such as VCRs, DVD players, DVRs, cable/satellite receivers, converter boxes, game consoles.

**"Disposed" means going into trash or recycling. These totals don't include products that are no longer used, but which are still stored in homes and offices.

Source: EPA [1]