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Perceived Robotic Futures

Benjamin Erin Dwyer
Worcester Polytechnic Institute

Matthew Francis Dickerman
Worcester Polytechnic Institute

PERCEIVED ROBOTIC FUTURES

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Submitted to:

Professor John Wilkes (advisor)

Professor N/A (co-advisor)

In Cooperation With

(names and titles of agency liaison)

N/A

(name of agency and division)

N/A

(typed names)	(signatures)
Michael Brauckmann	
Benjamin Dwyer	
Matthew Dickerman	
Adam Valada-Roth	

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Advisor Signature

The current report reflects a larger team effort including the two authors of this document Benjamin Dwyer and Matthew Dickerman and their team mate Adam Vadala-Roth as well as Michael Brauckmann who was doing MQP JMW-RF51, which will produce a separate report. This report is the work of Ben and Matt with substantial contributions by Michael who has shared with them portions of his larger analysis of the data set gathered by the whole team. One gets the gist and major message of the findings from this results section, but there are many more details to follow. He has also written the first draft of their methodology section. His, in the MQP, will be a bit more detailed. Adam's main contribution was to extend the study and thus the data set to two more colleges and gathering about 50-60 cases. The analysis of those data are not included in this report and will be submitted by him separately after consultation with Michael who will expand his analysis to some extent given the improved data set. Adam was assigned to address the question of degree to which the WPI and Clark Data will be likely to generalize to the student bodies of other colleges and universities.
Hence, the whole report is a work in progress at this time and this installment represents about 50% of what is will ultimately be.

Abstract

Inspired by P.W. Singer's *Wired for War*, this comparative study investigates the perceptions of students pursuing robotic, technical, and non-technical careers on the likelihood, desirability, and ethical implications of four possible scenarios unfolding for the field of robotics circa 2050. Each scenario posits a different institution driving the development of robotics and each institution takes a different stance on Isaac Asimov's three Laws of Robotics. Using these responses we investigate the concerns of students majoring in different fields about the direction the military, government, and corporations are taking robotics and if these concerns are mitigated by the ethical values of the controlling institution.

Authorship Page

Abstract	Ben Dwyer
Introduction	Ben Dwyer
Background	Ben Dwyer 90%, Matthew Dickerman 10%
Methodology	Mike Brauckmann
Results	Mike Brauckmann
Further Development	Matthew Dickerman
Conclusion	Matthew Dickerman

Contents

List of Figures

An x64 processor is screaming along at billions of cycles per second to run the XNU kernel, which is frantically working through all the POSIX-specified abstraction to create the Darwin system underlying OS X, which is in turn straining itself to run Firefox and its Gecko renderer, which creates a flash object which renders dozens of video frames every second.
Because I wanted to see a cat jump into a box and fall over.

I am God. ---Randall Munroe, XKCD

Introduction

In July 2002 (NASA), more than 6000 miles away from the computer with the jumping cat, a Pentium III microprocessor (iRobot) powers up, bringing an iRobot PackBot Scout to life. This robot is one of the first ground-based robots ever used in a war-zone. Four years later, more than five thousand robots would be deployed in Iraq and Afghanistan (Singer 61).

Ten years later, in 2012, these events would already have inspired Singer to write his book Wired for War, published in 2009, and it in turn has inspired this study. The current study of perceived futures in the field of robotics involved about 150 student respondents from WPI and Clark University in Worcester, Mass. Singer was the direct inspiration for one of the 4 scenarios for the future and three more were written assuming that the military dominated development of this field gave way to something else well before 2050, the year described in the scenarios. In the other 3 scenarios the lead institution developing the field has different social goals. The relative Likelihood and desirability of those scenarios is what is assessed by the student respondents, whose perceptions are solicited about the development of the field of robotics over a time frame representing the bulk of their expected working careers.

A robot is a machine built upon the "sense-think-act" paradigm—that is, they are man-made devices that sense their environment, process the data, and respond based on what they've perceived (Singer, 67). The PackBots deployed in Afghanistan are far from the only robots out there. iRobot also makes the Roomba, small disk-shaped vacuum cleaner robot. Predator drones armed with missiles patrol foreign skies. Industrial robots tirelessly work in the

production lines of factories across the globe. The field of robotics is developing extremely quickly.

Most of the funding for field of robotics comes from the military. Programs for developing a single robot frequently have budgets in excess of several million dollars. Some of these robots are designed as scouts, made to go into places people don't want to. Others, Foster-Miller's SWORDS platform and the predator drone, are intended to hunt down and kill humans.

This is possible because the military avoids looking at the ethical implications of the technologies they work with. As Michael Goldblatt, DARPA's defense sciences office director, puts it "You can't let the fear of the future inhibit exploring the future." In the words of another DARPA program manager, "That [considering ethics] is above my pay grade."

This document represents a preliminary report on the conduct of a study assessing the perceived influence of the funding institutions on the development of technology and its impact on society. Our survey instrument took the form of four scenarios set around 2050. Respondents will be asked to answer a brief five item questionnaire on each scenario. In each one, a different institution drives the development of the field of robotics and each institution has varying degree of compliance to Asimov's Laws--a code of robo-ethics introduced by Isaac Asimov's science fiction during the 1940's.

We intend to determine the perceived likelihood, perceived likelihood of spin-off technology, perceived desirability, and perceived likelihood of ethical concerns for each scenario. We collected about 150 student responses from aspiring experts, other technical majors, and non-technical majors. Our analysis is primarily comparative looking at the degree of consensus between the strata. The sample was collected from students in 8 classes at two colleges selected

due to the likely distributions of majors in each class, robotics majors, other technical majors at WPI and non-technical majors at a liberal arts college.

Background

As noted above, our study was inspired by P. W. Singer's book, *Wired for War*. The first section of the book covers the current robotic technologies employed by US troops in Iraq and Afghanistan. Two corporations compete building ground-based robots for deployment. On one hand, iRobot builds the small, light, highly advanced PackBot for the military while still building consumer robots. On the other, Foster-Miller builds the heavier, tougher Talon and is "a defense firm at heart (Singer 27).

While the original PackBot and Talon platforms included robotic arms, Foster-Miller's SWORDS version of the Talon is a prototype designed to carry and fire weapons. Capable of carrying anything from an M-16 to a .50-caliber machine gun to a rocket launcher, the SWORDS robots are amazingly accurate (Singer 30). iRobot is also developing a shotgun-wielding version of their PackBot.

The iRobot Corporation takes its name from Isaac Asimov's book *I, Robot*. Considering that iRobot is developing killer robots, this is association is rather peculiar. Asimov was a science fiction writer and published a series of short stories known as *I, Robot* during the late 1940's. The book describes how, over the course of a lifetime, robotics begin as simple mechanics and develop into complex entities containing "positronic brains" somewhat more like the human brain than microcontrollers. In this alternate future, all robots follow the Laws of Robotics:

1. A robot may not injure a human being, or through inaction, allow a human being to come to harm.
2. A robot must obey the orders given to it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law

With these ethical laws in place, humanity thrives in the company of these intelligent machines. Robopsychologist Dr. Susan Calvin explains that strict adherence to these laws prevents robots from performing tasks that are immoral, dangerous, or generally undesirable.

iRobot's machines clearly violate all three of Asimov's laws. The military, in fact, "explicitly wants robots that can kill, won't take orders from just any human, and don't care about their own lives. So much for Laws One, Two, and Three (Singer 432)." The people at iRobot, however, believe that Asimov would "think it's cool as hell (Singer 25)."

In 1998, Vice Admiral Arthur Cebrowski predicted that the introduction of computers and near-instant communication would produce something he called "Network Centric Warfare." He predicted that this change would be a paradigm shift called a "revolution in military affairs," or RMA. "RMAs typically involve the introduction of a new technology or organization, which in turn creates a whole new model of fighting and winning wars. A new weapon is introduced that makes obsolete all the previous best weapons (Singer, 181)." Just as the introduction of guns made highly trained knights nearly worthless, Cebrowski predicted that near-instant communication would create a similar change in warfare. Unfortunately, network-centric warfare introduced a sort of information overload, proving Cebrowski wrong. Singer predicts that robotics will be the technology that revolutionizes military affairs, "perhaps even leading to the rise and fall of global powers (Singer 204)."

Does the military truly understand the potential of robotics and what is the institution trying to achieve? An interview with Peter Campisano, a retired PHD Sociologist who served at the Pentagon, overseas and is associated with the Army War College, spoke with us and produced an interesting response to this question. Campisano reports that robots are thought of as weapons of precise destruction. Once, say in World War II, if an army unit took fire from a building, they could call in an air-strike and that entire grid-square would be blown up. This method was quite effective for eliminating threats but also had a fairly high human cost and involved widespread collateral damage. By the time of the Vietnam War, damage could often be limited to the building used by a sniper or machine gunner. In the first Iraq war, "Desert Storm", "smart" munitions were used to try to limit the damage to the right building and if possible the right room in the building. As technology has advanced, the military has become much more fervent about targeting threats more precisely and hopes that by using robotics they can start to spare all the civilians in the building and target the right people in the right rooms, the actual combatants. Campisano believes that robots will never replace human soldiers on the battlefield, but that they will be used to eliminate whatever threatens--and only what threatens--our soldiers. Military representatives have also announced that the Department of Defense will always keep a human "in the loop" of the kill decision, meaning that robots will not be allowed to autonomously target and fire on humans or machines operated by a human without some sort of input from an authorized person. Skeptics are quick to scoff at that claim, noting the logic of replacing costly humans with valuable machines will be to have the machines protect themselves, even from humans, and then to have fewer and fewer humans in charge or, and then just monitoring more and more robots. In short, the robotics will become more and more capable and autonomous.

Others are more skeptical and concerned about the whole ethical issue of allowing robots to kill humans as a matter of principle. The human in the loop debate gets more complicated when scenarios include multiple robots for one operator and the fast reaction time needed in a fire fight. Some, such as military robotics expert Robert Finkelstein, believe that once artificial intelligence matches human capabilities, "It could end up causing the end of humanity, or it could end war forever (Singer 415)." In short, robotics can be considered a transformational technology capable of changing all the rules, creating a "singularity" in which we can't predict what is likely to happen next due to interactive complexity. It also seems to raise existential questions about the survival of the human race or at least its continued mastery of the world. The emergence of a predator that humans cannot protect themselves against raises questions about the extinction of the race, a theme explored in the Terminator movies. The only prior technology to raise this kind of question has been nuclear power applied to war. Rod Brooks from iRobot comments that a robot takeover "will never happen. Because there won't be any of us (people) for them (robots) to take over from (Singer 417)." This is hardly a reassuring position statement.

Surely, then, it is a good idea to take a look at what futures are possible and ask how people perceive them. "We can't simply do our science and not worry about these ethical issues (Singer 424)." Thus, we developed our four scenarios, each outlining a different possible future for the field of robotics. Each "company" we posit as being the breakthrough organization, represents an institution other than the military driving the development of robotics, and each one takes a different stance on robotic ethics. We chose to adopt Asimov's three laws as our code of ethics. By gathering people's perceptions of these scenarios, we hope to see if Asimov's three laws provide some sort of implicit or explicit framework from which a code of robo-ethics could be developed. . Our study question is whether the respondents see the

scenarios as raising ethical questions in the same order that they circumvent or break more and more of Asimov's laws.

We adopt Asimov's framework with care. Asimov wrote the laws before the first transistor was developed, his positronic brains and our microprocessors share next to nothing in common. As one roboticist put it, "People ask me about whether or not our robots follow Asimov's laws. There is a simple reason [they don't]. I can't build Asimov's laws into them (Singer 432)." Furthermore, the entire premise of Asimov's short stories is that the three laws do not entirely prevent robots from behaving in undesirable ways. We have been very careful that the corporations we posit as the emerging leaders influencing the development of robotics are the ones following, or trying to follow the ethical code or not, in the case of the Military.

Methodology

The objective of this study was to assess the perceived influence of funding institutions on the development of technology and its impact on society. It is the pilot study (using student respondents) for a later Delphi study on the impact or robotics in the next 40-50 years. For this comparative study, four scenarios describing possible futures in the development of robotics technology have been developed. Each one posits a different lead institution providing the bulk of the developmental funding for the field of robotics. Our questions about the perceived importance of institutional influence shaping the field are answered indirectly by examining changes in the perceptions of those likely to be affected in different ways.

The underlying question to be addressed is whether people aspiring to enter the field of robotics and their peers aspiring to other technical and non-technical fields are equally concerned about where the field of robotics is headed, and if those concerns are mitigated by the values of the institution leading the field. This question will be unobtrusively embedded in four scenarios

concerning possible futures of robotics. Currently the vast majority of funding for research and development of robotics technology comes from the Department of Defense. In one scenario this trend was continued in the other three scenarios another institution replaced the military as the institution driving the development of the field. A survey was attached to measure the perception of robotics technology after reading each scenario. Differing reactions to the scenarios imply that it really does matter what institution is playing the lead role. If there is a consensus that it greatly matters who develops this powerful technology, the stage is set for further investigation using social methods that get beyond perceptions data. The following sections detail the development of the scenarios, and the survey, and explain the methods for distributing and collecting the instrument, and tools used for analysis of the data.

Developing the Scenarios

In order to determine students' perceptions of robotics technology being developed under different institutions four scenarios were developed. In each scenario a different institution is depicted as the leader of the field of robotics. Each institution has a different goal for the technology; to explore and take advantage of lunar resources, to aid in meeting a major global food and environmental crisis, to take advantage of eldercare opportunities in the commercial sector, and to gain an advantage on the battlefield.

Each scenario was designed to expand the current state of robotics technology for approximately 50 years, and to picture similarly advanced robotics systems. This time frame was chosen so that the scenario would represent the contribution of the current generation of students to field at the end of their careers. Each scenario then represents a perceived future of robotics under the leadership of varying institutions trying to address different real world problems. Each scenario is designed to raise ethical questions about the direction of robotics technology and its social and technical implications. Differing views on these implications between scenarios will reveal the effect

of the driving institution. Additionally, each scenario represents a different relationship to Asimov's three laws of robotics. Although they come from works of science fiction, Asimov's Laws are the best known statement in the literature on ethics in robotics and keeping the technology under social control. The institutions in control in each scenario vary in their ability to accept Asimov's laws, from complete acceptance in the lunar scenario to complete rejection in the military scenario with the others falling somewhere in between. There were concerns about the clarity, and readability of the scenarios as well as how long it would take respondents to read through all four of them. Hence, a pilot study was conducted in a single WPI class containing about 80% robotics majors in order to attain initial responses to the scenarios. Feedback from this class allowed for critiques that were grounded and set the stage for editorial adaptation of the stimulus and response items. Following this pilot study, the scenarios were also modified to avoid confusion and to shift attention to the social implication of the technology itself, downplaying the many feasibility concerns coming from the robotics majors about how such advanced technologies might be implemented.

Developing the Survey

A questionnaire was attached to each scenario in order to collect data on the direction and strength of participant reactions to the scenarios. In the end, the hope was to produce a rank order from most to least likely and most to least desirable, though ties were possible. The same indicator questions were used on each scenario to enhance comparability between scenarios and make a rank ordering possible. The questionnaire consists of five variable indicator items: one designed to assess the likelihood question; two to address the desirability of the scenario in general and as a economic and technical stimulus; two more to get at the severity of ethical issues raised by the technology. One of these ethics items left open the nature of the ethical concerns that concerned the respondent and the other picked up on the man machine relationship specifically to tie into the extensive literature about technology becoming autonomous and getting out of control.

Each response is intended to reveal a different aspect of the participant's perceptions of a possible direction in which robotics could develop and gives one an idea of what they expect to see from the technology. The analysis is simplified by treating them as alternatives, though in fact they are not mutually exclusive and in fact are likely to co-exist and interact. These four scenarios do not represent the only possibilities for robotics and the respondents actual best prediction of what will really happen is not directly assessed. Instead this is a search for consensus on the direction that the technology is most likely to move in and whether the social implication associated with most likely directions are reassuring or disquieting.

It was decided to keep the number of differing response categories to a minimum to avoid confusion and improve the appearance of the survey. Each question was worded such that it could be answered on either a likelihood or desirability scale. Four response categories were chosen so that there would be no middle ground. Hence, participants would be encouraged to think about the question enough to choose a side. The two response scales used on the questionnaire are as follows:

Unlikely	**Somewhat Unlikely**	**Somewhat Likely**	**Very Likely**
Undesirable	**Somewhat Undesirable**	**Somewhat Desirable**	**Very Desirable**

At this point a walkthrough of the five items in the order they were asked after each scenario is in order so that comments can be made about what variable the indicator is supposed to tap and what the logic was for addressing each key variable in this fashion.

How likely is it that this scenario could come about?

This question was used to support a comparison of the four scenarios to reveal which scenario's application area (space, the seas, personal service or warfare) was perceived as the most probable direction of application and hence have funds for technology development in the field. It was important to allow for ties, a forced rank ordering item was avoided.

It is only of passing interest what the majority of the sample considers to be most likely. Each subgroup or sampling strata, in the stratified sample will first be considered separately in this regard. This study is designed to reveal the level of consensus between our three sample strata (robotics majors, other technical majors and non-technical (liberal arts) majors). Thus, it is the level of agreement within and between these groupings is of interest. If there is a significant consensus among these people with different academic backgrounds and literacy on the subject at hand, then a comparison can be made with desirability to determine if the perceived most likely direction of the technology is also the most desirable.

If the scenario came about, would the resulting technology be likely to spin-off many applications that significantly advance the field of robotics?

This question was developed to determine the amount of influence the technology described in scenario would have in terms of stimulating robotics and possibly other related fields. High number responses on this question are intended to indicate substantial socio economic impact potential. However, on its face it also means that the participants see this as a promising direction of technology development that will spread outside the scope of the scenario and stimulate secondary effects on society and the economy.

While expecting many spinoffs would not be enough by itself to support the notion of a coming "singularity" (a complex, interaction of explosive technological developments to the point that predicting where it is going and what effect it will have is impossible), as proposed in the literature and noted by Singer in his book *Wired for War*. Many spin off applications would be part of a singularity pattern. If robotics advances are highly transferrable to other ends, the resulting dynamic and volatile technology raises two questions of interest to this study. "Is the technology particularly likely to get out of control?" and "Does it matter who funds the development of the technology in terms of the likely benefits and risk of getting out of control?" One premise of this

study is that it matters what institution develops the technology and for what purpose. However, this is in principle an empirical question, and this assumption is what we hope to test, at least in the world of perceptions.

There are those who claim, with some justification, that technology will be applied to war whatever the grounds for its initial development and application and vice versa, ie. that military capabilities will soon be turned to other ends. The internet for example was a DARPA project aimed at robust communications capability that could survive a nuclear war when the major communication nodes were destroyed. Clearly that has not been its most significant application and it is increasingly considered a socially transformative communications medium.

At this point we are not collecting data intended to (or in principle able to) resolve this matter but are interested in the perceptions of those in the field of robotics and their peers likely to be affected by these developments about whether the who and why of robotic development matters- at least for the 50 year period which their careers will span. If all four scenarios are considered to have massive and essentially equal potential for spinoff, the sample is saying that it does not matter. However, we do not expect this to be the case, an the comparison of the military dominant scenario spinoff potential to the others will be of special interest and is expected to be revealing about whether it matters what institution is in the heavy funding driver position and what the applications objectives tend to be.

If the scenario came about, how desirable or undesirable would the resulting changes in the quality of life be?

The change in quality of life is used as a general and non-specific indicator of the effect the technology would have on the society it is introduced into. It was important to get beyond narrow efficiency and economic implications and get into disruption and displacement issues if they

concerned the respondent. A broader than economics intent had to be clear, hence "quality of life" for people. A desirable effect on the quality of life indicates that the technology improves society in some way or at least alleviates the social issue it was designed to address. Undesirable responses indicate the technology may create worse problems than it solves, upset the balance in the system, displace workers or even get out of control. The key to make room of perceptions that it does not seem likely to solve problems, or that in solving one problem it might have unintended side-effects and create even worse problems. By comparing these responses across scenarios and across the three groups in our sample we can determine if a consensus exists on the scenarios most likely to have desirable outcomes and compare them to the perceived most likely scenarios.

If the scenario came about, how desirable or undesirable would the resulting changes in the man machine relationship be?

Having two parts to the desirability question was an effort to separate out the major theme of dependency of people on machines and inversions in the man machine control relationship from the many other questions rose by the movement of automation into a robotics phase. The creation of artificial intelligence combined with advanced robotic capability might be what one could consider the risk in making these two otherwise positive trends undesirable. Having two questions which could easily be combined into a composite item was a modest recognition that this was a multidimensional variable. Similar to the quality of life question, this question is intended to measure desirability of the scenario. Whether or not it is dependence on machines to meet some basic need or the formation of a caretaker relationship, the way in which machines interact with humans is inevitably changed by the kind of advancements in robotics technology under discussion. Questions of subordination and autonomy are bound to come up and thus impact the man machine relationship that we are accustomed to seeing.

From a man -machine partnership to explore and mine the moon under surface conditions hazardous to humans, to reshaping the ecology of the seas to feed humans, to directly putting vulnerable humans under robotic care, the stakes are rising. In the end creating machines designed to hunt, ambush and kill humans raises the ultimate question of who is in control here especially if there seems to be a trend from human in the loop to increasing autonomy in these killer bots. But all along the way to this "terminator" extreme, the man machine relationship is one thing you want to watch, and the control issue it raises is the focus of Asimov's laws.

Whether the ratings on acceptability and rated desirability of the scenarios tracks with the degree to which the scenario violates Asimov's laws is one of the questions under study. Responses to this question will also be checked for consensus among Robotics majors, Technical majors, and non-technical majors. It is not clear that WPI and Clark University students will see things the same way, as they did not in the case of nuclear power during the late 1970's. This is a matter where trust and confidence in the technology and the institutions creating and managing it become increasingly important to public acceptance.

The perception of who was in charge and public confidence in that institution (be it "science", "government" or "private industry") greatly affected public attitudes toward nuclear power in the 1970's prior to the Three Mile Island (TMI) incident. At both WPI and Clark University there was high confidence in science as an institution, but only the WPI students perceived scientists to be in charge of the nuclear industry via the Nuclear Regulatory Agency. The Clark University students viewed this as a venture of the private sector, known for cost cutting in areas related to public safety. After the TMI incident in 1979 and the Chernobyl accident in 1986 the dynamics changed, in part due to the discrediting of all the organizations in charge of the technology. The nuclear establishment seemed not to have been worthy of public trust and the charges were now specific rather than by analogy.

The robotics debate is still in its pre disaster phase and analogy based perceptions of the institutions in charge are likely to be very important, hence the scenarios we designed move the lead role from government to various forms of public- private or private ventures. On the other hand there has been a very active science fiction literature raising concern about this technology development. The bulk of the nuclear power referents in science fiction tended to be fairly optimistic by comparison. That may have contributed to the public reaction of shock when the technology finally did get out of control, even before there was a disaster that massively affected the public - at Chernobyl. Now there has been a second accident at Fukushima, but nuclear power plant construction had already been halted in the USA by TMI.

So, the issues of autonomy, subordination and control, highlighted by Asimov, are the focal point of this part of the desirability variable.

If this scenario came about, how likely would it be to raise severe or challenging ethical concerns?

This item serves as a crosscheck item for the ethical concerns raised by the man machine relationship. Major ethical concerns may be indicated by the man machine relationship, but it is also possible that other values, especially an environmental ethic, and possibly issues having to do with the meaning of work from various religious perspectives, have significant bearing on reactions to the questions that robotics raises for humanity. An item that asked about the level of concern provoked by each scenario that was not specific to what those concerns were, seemed appropriate. This question is an estimate of the odds that severe ethical concerns would be raised by the technology developing for the purposes indicated under the control of the given institution in each scenario. A consensus in high ethical concerns would be a very significant “red flag” even if the respondents did not see the ethical stakes rising with each violation of one of Asimov’s laws, as we expected. Each

scenario was designed to vary in its expectance of Asimov's laws. Responses to this question will be used to determine a relationship between Asimov's laws and perceived ethical concerns. This serves as hypothetical test of Asimov's laws as ethical guidelines for robotics technology. The results of this question will also be compared with the scenarios deemed most likely to come about. In this case the two likelihood items will indicate whether the most likely scenarios are also the ones most likely to raise ethical concerns and challenges. If the current direction of the technology is deemed problematic on grounds of the emerging man machine relationship and those involved will likely be faced with ethical dilemmas, it is time to examine whether this is the direction the field or the funding agencies want to go.

The Sample

In a traditional Delphi study one would normally draw on a small panel of experts; and it would be difficult to know if they were representative of all expert opinion but the credentials of the participants would provide credibility to the result. One often has to contact many experts to get a few to participate, so the panel is probably not representative, and may actually be skewed toward the experts with the strongest opinions on the subject. However, past studies on other technical subjects (aerospace technologies) have revealed that Delphi panels and student samples tend to be in sync with one another one average, the majors difference being more moderate opinions on the part of the students, who are also more likely to respond. Hence, the difference may be that one has a better approximation of the full range of opinion among the students. An intermediate study of WPI Alumni compared to WPI students and expert panels produced about a 25% response rate, and a distribution in sync with the average student distribution.

These findings led us to have confidence that using a student sample to calibrate a new instrument and get an initial sample distribution would be meaningful and efficient. Our resources would not allow us to generate a sample large enough to statistically represent a substantial pool of

experts. The choice was a small Delphi panel or a student sample of hundreds stratified to allow us to see if the more expert students (aspiring experts) stand out from those in other courses of study. By substituting students for real experts one can get a statistically respectable sample size which is more likely to be representative of the universe of students from which it was drawn. This study is intended to set the stage for getting better data from panels of experts in the future with a more refined instrument and a better interpretive context of prior data.

Student assessor panels were drawn from both technical and liberal arts colleges. Our Objective was to collect a stratified sample broken into three segments of Aspiring Experts: Future Experts in Robotics, Future Experts in other Technical Fields, and Future Professionals in Non-Technical Fields. The preferred approach was to sample at the level of classes rather than individual students despite the problem that would create later in assessing the randomness of the sample. As a practical matter, the adequacy of the sample would be determined by the willingness of the instructor to devote class time to the study more than the selection of classes, though both would be a factor. The classes were not randomly selected. Some were selected to maximize the chance of finding robotics majors in them, others were selected so as to represent a typical distribution of majors at the college and others were selected in the hopes that the instructor would be interested in the subject and cooperate with the study by offering class time for administration.

Classes were selected from Worcester Polytechnic Institute (WPI) and Clark University based on distribution of the students we needed and the relevance of our study to the class topic. If the course instructor agreed to participate, they were given the option of having us distribute the survey with a five minute speech, or for us to take over the class and administer the survey followed by a presentation on the project. Three robotics courses and three other technical courses were selected at WPI, and three humanities courses at Clark University. In total there were about 45 Robotics Majors from WPI, about 60 other Technical from WPI and 54 Non-Technical from Clark University, about 150 in all. The critical part of the study was getting a very high proportion of the

total pool of robotics majors and that was done in part by getting strong cooperation from one key professor and good cooperation from the instructors in two other key courses. There was a near complete failure to obtain data from a related CS course in which the instructor provided modest access but no endorsement. Hence, just over half of the RBE major data came from one key course with 98% participation. This gives us some confidence that the data in that strata are not self-selected since it is a required course and there was full participation. The other smaller courses involved were over 80% participation as well. The class data collection effort that was a bust had little to no impact on the study other than changing the definition of an "expert". In addition to majoring I robotics we were going to include CS majors taking an AI course as "experts". That is no longer the case. Data collection at Clark University was more successful since the instructors were carefully selected so as to be likely to be interested, and 75% were. Again, one was exceptionally interested and her class participated fully but another allowed class time to be used for data collection as well. If there is any self-selection in the Clark University sample it is at the level of deciding to take a course dealing with science fiction or computer science, and not at the individual level of deciding whether to fill out the questionnaire and return it. Thus the sample may not represent the whole student body, but is comparable to the kind of subset of the campus represented by the robotics majors at WPI, the most literate portion of the campus on this subject.

Where an honest effort to be representative of the campus as a whole was made was in selecting the "other technical" sample at WPI. This was an effort to go to the classes that fulfilled distribution requirements for the campus as a whole rather than to select any given major. Though first choice was the Engineering Science (ES) classes taken by most majors, the faculty members offering those courses could not make a course connection to the study and response rates were distressingly low (10-15%). As a result, we shifted to social science classes that fulfilled campus wide requirements in another way. Two Sociology classes, without much if any connection to the

study other than as the basis for a social research methods illustration, ended up providing the bulk of the subsample, with 80-90% participation rates in each class.

Though as case could be made that the kind of student who would fulfill their social science requirement with sociology rather than economics or psychology classes might differ from the typical WPI student, the likelihood of self-selection is certainly no greater than it was in the Clark University sample and less likely to be directly relevant to the subject at hand. This is our most successful effort to represent the general student population of a campus and the basis for later going to a Sociology class at Worcester State College that served a similar role for majors there when cross checking the Clark University sample with one from another non-technical college. The technical sample was cross checked by going to a computer science class at Boston University where there is no robotics major, but this class spent one week out of 14 on the subject.

Results:

Likelihood

The ANOVA test between scenarios and post-hoc Turkey test showed the Military scenario was considered significantly more likely than all other scenarios with a mean 3.2 while the rest varied between 2.45 and 2.75. An ANOVA test between the sampling strata showed no significant difference between robotics, other technical and non- technical subsamples on the likelihood of the military scenario. Hence, the Military scenario is considered most likely by all sample groups and Figure 1 shows the distribution of means across scenarios for the sample as a whole.

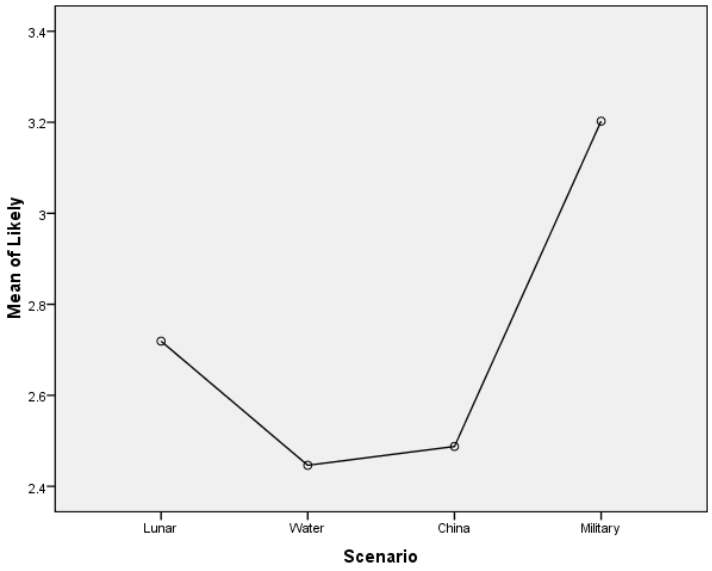


Figure 1: Distribution of averaged likelihood across all scenarios.

Significant differences did arise between strata on the Lunar and Water Scenarios. For the lunar Scenario the Tech sample was significantly different than both the Robotics majors and the Non-Tech majors from Clark University. The other majors at WPI rated the scenario less likely than the two other strata. There was no significant difference between RBE majors and Non-Tech majors. For the Waterworld Scenario the Tech and Non-Tech samples were significantly different with the Tech sample rating likelihood lower and the Non-Tech sample rating its' likelihood higher. The RBE sample bridged the gap between them and was not significantly different than either of the other strata.

Spinoff

The spinoff item did not prove to be as revealing as we hoped and should be revised in future studies using these scenarios. A variable that does not get much variance in reaction is of little use where the goal is to distinguish the reactions of different strata. However, it is still a finding that there was little perceived difference in the spinoff implications of the different areas of advance. It was on the high side in all but one case and hence, there is only one significant

difference to report. The exceptions was that the other Tech group at WPI rated the eldercare robot systems presented as being deployed initially in China as having a significantly lower spinoff potential than the other strata. The Robotics majors and Clark University non-technical majors did not see this application as having low potential for spinoff or less spinoff potential than the other application scenarios.

Since there was little yield on this item a better and probably more direct approach to the question of the likelihood of a "singularity" should be used in the future if one wants to see if one or another scenario has higher potential for this outcome. However, these data do suggest that the general perception is that this is a dynamic field with high potential for transfer of technology from one area to another and thus a volatile period of interactive change is expected no matter what is done with the technology at first.

Desirability

Initial analysis indicated that there was a correlation between the two variables used to measure desirability, the perceived changes in the man machine relationship and the perceived changes in quality of life. At this level of correlation only about 20% of the variance in one is explained by the variance in the other, so they are tapping different dimensions and are worthy of separate analysis. However, for our immediate purposes in comparing the likelihood and desirability of the different scenarios one either has to select between them or combine them. We opted for the latter as there is a good case for calculating a single composite variable. It would get at more of the dimensions of desirability and not be restricted to our primary focus on the man machine relationship, questions of dependency and control. However, we know from the equal weight on the second variable that those are being considered.

A desirability index was formed to combine these two variables by averaging each participant's response to the two questions. This allowed a direct comparison of mean between scenario and strata. An ANOVA test indicated significant differences for the overall sample in the perceived desirability of the military and lunar scenarios. However, the more interesting findings emerged when the strata were compared in a closer look at how the subsamples reacted to each scenario. It was evident that the Robotics majors at WPI did not see things the same way the majors in the other subsamples did. The RBE group stood out in two cases rating the military scenario less desirable than the majors in the other strata and the lunar scenario more desirable than did the other strata. Figure 2 and show this variation of mean between strata.

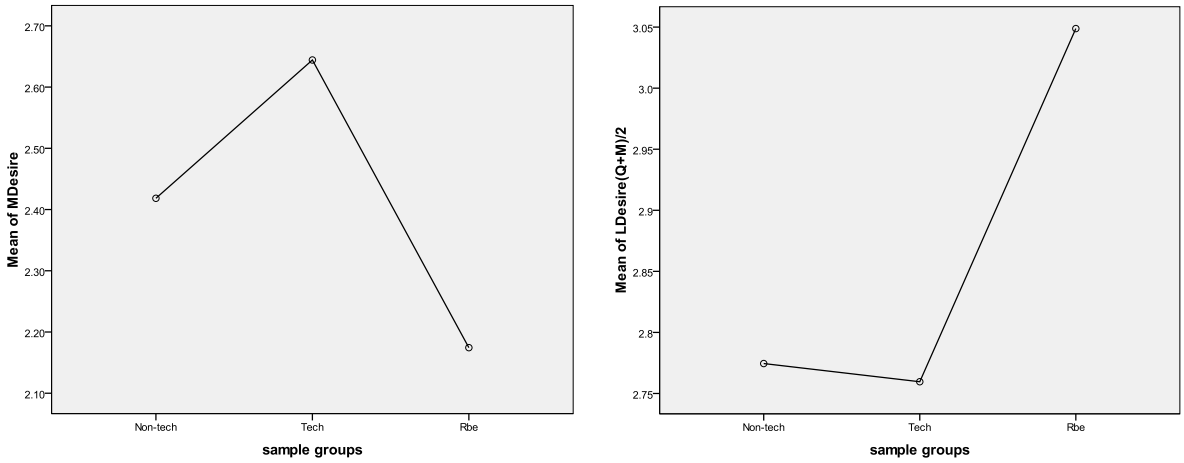


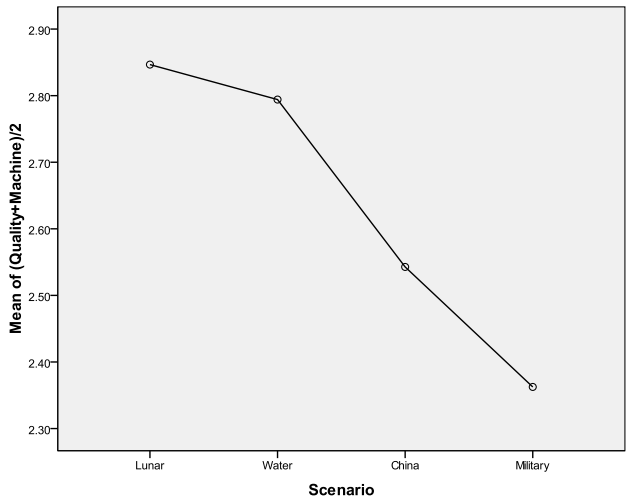
Figure 2: Variation of average desirability between strata

(Military scenario on left, Lunar scenario on right)

Actual ordering of relative desirability varied for the three study groups however the Military and Chinese eldercare scenarios were in the lower half in every strata, so there was a consensus that the lunar and Waterworld scenarios were more benign applications. The Military application had the lowest average desirability rating for both the WPI Robotic engineering majors and the Non-Tech majors at Clark University but the other Technical majors at WPI rated

the Chinese eldercare scenario as least desirable. For the robotics majors there was a significant difference between the Chinese eldercare scenario and the Military scenario. Since they barely distinguished the eldercare case from the water world case and saw them as only a bit less desirable than the lunar application. The Chinese Eldercare application was much more problematic for the students in other majors at both WPI and Clark and was rated on average as similar in desirability to the military application by both groups.

Figure 3 shows the distribution of means by scenario. The table below shows the means for each sample strata.



Mean Desirability Rateings				
	Lunar	Water	China	Military
Non-tech	2.8	2.9	2.5	2.4
Tech	2.8	2.8	2.5	2.6
RBE	3.0	2.8	2.7	2.2
total	2.8	2.8	2.5	2.4

Figure 3: Distribution of average desirability across all scenarios

The examination of the means for each scenario by the sample as a whole reveals a trend not evident in the individual subgroups. The lunar scenario emerges as the most desirable or at least benign application, due to the enthusiasm of the robotics majors at WPI. There is a consensus across the strata that Waterworld is relatively okay. The sharp disagreement between the robotics and other majors about the other two applications produces a fairly low rating for the Chinese Eldercare case, and the qualms about the military application primarily by the robotics majors pushes that into last place as the least desirable.

Given that there was a fair consensus that that scenarios was also the most likely one, an interesting problem has emerged, as we have a sense that the next generation does not think the trends in the development of that field are going in a desirable direction and the most concerned students as the aspiring robotics experts who will be the ones carrying out this program. They really want to be doing something else, like developing lunar and ocean exploration and development technology. Their peers in other fields are in general agreement.

Ethical Concerns

The mean responses to the general ethical concerns question are compared in the following table. There are some interesting similarities with the composite desirability findings. For the sample as a whole the rating of the China Eldercare scenario and the military scenario are nearly identical. The lunar scenario raises the fewest concerns, but the Waterworld scenario has moved to an intermediate position between these two extremes. However, this is overall. The rank ordering shifts depending on the stratum one is examining and the ethically charged scenarios got to their nearly tied positions in different ways. The non-technical majors from Clark University consider the China eldercare scenario more fraught with moral issues than the Military scenario.

The WPI students rank the two most controversial scenarios the other way around, but the Other technical majors at WPI see the two as about equally controversial while the WPI Robotics majors see both as more ethically concerning and also discern more of a more difference between them.

The mean ethical concerns ratings on the military scenario by the robotics majors and WPI and the Non-technical majors at Clark University are quite similar. It is the other technical

majors at WPI that are most comfortable with the Military application rating it at a level lower level of ethical implications than the Robotics majors rated the China eldercare scenario.

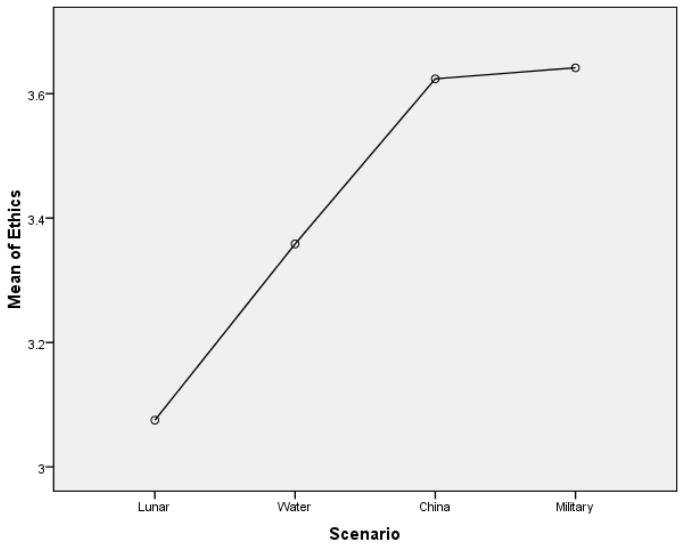
Turning to the question of statistical significance, ANOVA analysis reveals that the only significant difference between the strata was on the China eldercare scenario. Post-hoc tests show that difference to be due to the Clark Non-Technical majors who rated the China scenario far more unethical than the RBE or Tech majors at WPI did. . However, it is also important to note that it is the mean 3.82 rating from the Non-Techs at Clark contrasting with the 3.50 rating from the Other Technical majors at WPI that is statistically significant. The 3.58 mean rating of the robotics majors is not significantly different from that of the other stratum involving WPI students. On the military scenario which the Non-tech rated on average a more moderate 3.75 as the Other technical majors at WPI moved up to 3.55 one no longer has a statistically significant difference with a sample of this size. In this case the RBE majors were intermediate with a mean of 3.69. These three ratings are not significantly different at the .05 level.

In terms of ethical issues, we have a theory to test. The hypothesis involving this item was that ethical concern would rise to the degree that the scenario violated one or more of Asimov's laws of robotics. Hence, we were expecting the Military Scenario to be most fraught with ethical concerns and the China eldercare scenario which violated only one of these laws to be more acceptable. Comparison of Means showed both RBE majors and Other technical majors from WPI answered rated the scenarios in our predicted Asimovian order which is the Lunar scenario as presenting the fewest ethical concerns, then the Waterworld scenario, then the China eldercare scenario and the Military scenario with the highest. The only problem with taking this position is that the differences in the ratings of the last two by the other technical majors are so small that they are statistically tied. The same situation holds when one compares

the difference between the ratings of these two scenarios by the Non-Techs who flipped the order of the china and military scenario but considered both to have higher levels of ethical concern compared to the other group that rated them as similar. Only the robotics majors seemed to really distinguish the two and put them in the expected Asimovian order. The Non-Tech majors from Clark are interesting since they not only rated the two scenarios as similar but also flipped the order of the china and military scenarios to refute the Asimovian hypothesis explicitly.

Since we consider testing this hypothesis important and the refutation was hanging on a slender difference, a more powerful rank order analysis procedure was used to double check the finding. In a Guttman scale one examines the way all the different respondents individually rank ordered the scenarios. This is no longer based on the mean rating form the group , but involves finding out how predictable the rating order itself is, whether the differences are large or small. The Guttmann scale effectively tells us how often we would be wrong if we tried to predict each individual's rank order using the Asimov rules hypothesis. It turns out that we would rarely be wrong. While there is some dither for the sample as a whole, relatively few Clark ratings registering large differences produced the small overall average difference in the wrong direction. For most people the response pattern is in the predicted order and even where there was divergence it involved only the order of those 2 items- ie. one error out of 4. Overall that converts to only 1/100 chances of being wrong when using Asimovian order to predict ethical order. Guttman scale procedures also reveal that there are two item groupings. The errors in order that do occur are within the lunar and water pool of items or within the China and Military pool of items. There are very few if any Waterworld and China eldercare reversals in rating. this is not surprising given the larger jump in means we had already observed, but it is

also reassuring that there is nothing like random variation in the typical pattern of ratings producing those average figures. The Asimovian hypothesis has more statistical support across the strata than seemed to be the case at first blush.



sample groups	Lunar	Water	China	Military
Non-tech				
Mean	3.21	3.39	3.82	3.75
Std. Deviation	.848	.874	.432	.483
Tech				
Mean	3.08	3.34	3.50	3.55
Std. Deviation	1.082	.919	.939	.845
Rbe				
Mean	3.00	3.33	3.58	3.69
Std. Deviation	.883	.969	.852	.780
Total				
Mean	3.10	3.35	3.64	3.66
Std. Deviation	.945	.913	.775	.719

Figure 4: Distribution of average ethical concerns across all scenarios

Further Development

Although the results of this study have provided us with tremendous insight into the field of robotics, we have recognized that the scope of our research could be dramatically improved upon. The data presented in this project represents the opinions and viewpoints of students of various academic backgrounds who attend colleges in the Worcester, Massachusetts area. To provide further validity to our study, additional students from other colleges should be asked to take our survey. With the results from these additionally selected college students, we could compare our findings to see if there is congruence in opinions, or if perceptions vary from region

to region. At the time of writing, data is currently being extracted from students from Boston University and Worcester State University. This new data will provide us with a more diverse sample and expand the scope of this study. Furthermore, it would be beneficial to collect data from college students from other regions of the United States if possible. If research of this kind were to be performed in more regions of the United States, we could search for any trends in perceptions based on regional or cultural differences. It is possible that some regions of the United States may have college students who are more receptive to robotic technologies than others. If this were the case, further investigation could be conducted to attempt to discover why differences in perceptions vary from region to region. By surveying college students from all across the United States, our study would be able to provide an incredible amount of insight into the development of robotic technologies throughout the next decade.

The research presented in this paper could even be further expanded upon by conducting similar research in other countries. Research of this scope could provide us with a global opinion on the perceptions of robots in the upcoming decade. By collecting data from college students across the globe, we would be able to make tremendous inferences into how countries as a whole tend to think about robotic technologies. If a global consensus in opinions were to emerge, this would be an astounding discovery. An equally astounding discovery would be uncovering strong differences in opinions from country to country. Once the statistical analysis of this research had been completed, further investigation could be conducted to find why college students of a country answered the survey the way they did. The information accumulated from a study of this scope has tremendous value to the robotics industry. Robotics corporations would be able to find regions of the world where their technology is perceived as most desired or most beneficial to humanity.

All data collected in this study came from college students. The goal of our research was to gather the perceptions of these students to acquire an understanding of how robotic technology might develop throughout the coming decade. The college students' age group was particularly important for this study because it will most likely be their generation who influences the development of new robotic technologies the most. Our robotic expert sample is expected to become the engineers pushing the development of robotic technologies, the other technical sample is expected to oversee robotic projects and assuming managerial roles, and the liberal arts sample is expected to shape and mold public opinion. Other age groups, such as elementary school students, high school students, middle aged citizens, and elderly citizens might also provide profound insight to the development of the field of robotics. Collecting data from these various age groups would further advance this study and show how perceptions either differ or stay the same depending on age. Research of this kind would be used to uncover developing trends in beliefs in robotic technologies across various age groups with different generational experiences.

Another dimension that our survey did not incorporate was religious preference. It is very possible, however, that participants of our survey who share similar religious beliefs also share similar opinions on various robotic technologies. If our current study were to be augmented by taking into account religious beliefs, we might discover interesting relationships between religious preferences and the level of ethical concerns with our robotic scenarios.

Another envisioned improvement to our study is to collect data from active duty and retired military officers. It is possible that military officers, the men and women who are actually prepared to put themselves in harm's way during times of war, have vastly different beliefs when it comes to robotic technologies, especially those used in warfare. By collecting data from those

who serve, profound insight might be acquired pertaining to robotic warfare and the social-ethical concerns that are associated with it. Similarly, if provided with the opportunity, it would be extremely beneficial to our study to collect data from true experts such as those from DARPA or the Office of Naval Research. The data collected from these professionals would be of interest for it could be compared to our sample of aspiring to be experts students. The data collected from true experts would also hold sociological weight considering that these are the men and women who developed military robots that are capable of killing other combatant.

Conclusion

The results obtained from this study have provided profound insight to the perceptions of college students in the Worcester, Massachusetts area. One of the most interesting aspects of our research is that regardless of academic preference or background, our participants answered 16 out of the 20 survey questions with consensus. This find indicates that human perceptions on robotic technologies are for the most part universal. It is also interesting to note the cases where our strata had differing opinions. In the Military scenario, WPI RBE majors marked the desirability notably lower than the other strata. This is an interesting discovery in itself. The future engineers who are likely to be designing robots capable of killing humans in fact perceive the technology itself as undesirable for mankind. Another variance in perception discovered from our data analysis was that WPI RBE students viewed the Lunar scenario, where robots were used to mine resources from the moon was more desirable for mankind.

Another important discovery was that Asimov's fictitious laws that were written in the mid nineteen hundreds actually hold much weight in the perceptions of humans on robotic ethics. Our data analysis revealed that both the desirability and ethical concerns accurately

represented the degree of which Asimov's laws were followed in the four scenarios. The Lunar scenario had the highest rating for quality of life and lowest rating for ethical concerns while the Military scenario produced results with the lowest rating for quality of life and highest rating for ethical concerns.

The data analysis has provided very interesting findings in the Military scenario. This scenario was designed with current funding patterns in mind. If our scenario is accurate, it will be very likely that the future will involve the robotic technologies depicted in the Military scenario. After analyzing the data we discovered that our participants by far and large believe the military scenario to be the most likely scenario to become reality. What is even more interesting is that there is tremendous consensus across all strata that advanced military robotics does not improve the quality of life and raises incredible ethical concerns. It is also important to note that during a conversation with a robotics class at WPI, students seemed to indicate that a majority of ethical concerns arise from military robots that kill rather than those that merely accumulate data or scout terrain.

In all scenarios we discovered that students believed the technologies envisioned would have tremendous spin-off technologies. The field of robotics is rapidly expanding and it is interesting to note that technological discoveries used in one application may very well serve useful in a myriad of other applications. It is very possible that the next technological revolution will stem from the field of robotics engineering.

In the beginning of this project we sought to find out if the funding patterns mattered when it came to the development of robotic technologies. After analyzing the data we found our answer: yes it does. In fact each scenario was perceived to have completely different results in the perceptions of college students. With this in mind, we believe that studies like this are

important to help guide the development of robotics engineering so that it can improve the quality of life for humans while also reduce the amount of ethical concerns. By continuing to do research such as this, the field of robotics engineering will be guided by moral values and careful thought.

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APPENDIX A: The Survey Instrument

Perceived Robotic Futures Survey

Michael Brauckmann
Benjamin Dwyer
Matthew Dickerman
Adam Vadala-Roth

with

Professor John Wilkes

Please indicate:

Major(s) _____

Have your read Wired for War by P.W. Singer?	Yes	No
Are You Familiar with Asimov's Laws of Robotics?	Yes	No

NASA Races to Mine Lunar Resources and Surpasses U.S. Military in Robotic Technology

In 2030 various nations began to compete for valuable resources on the moon. NASA contracted LunaCorp, a promising start-up, to develop technology for a lunar extraction industry. LunaCorp specialized in advanced robotics and telecommunications and has been competing against Europe's ArianeSpace, Russia's Energya, and China's Great Wall Corporation. Lunacorp's vision has always been to use semi-autonomous robots to mine the lunar surface and to support a small number of on-site human operators, thus maintaining the majority of the human workforce Earth-side. This has allowed for a safer working environment and has saved the expense of setting up a large lunar colony. By 2050 LunaCorp's mission control center in Massachusetts supported 950 operators working in three shifts, overseeing 50 people and 300 robots operating on the moon. Today in 2069, LunaCorp is expanding their mining operation by building more small colonies across the lunar surface. These new colonies will eventually allow LunaCorp to harvest resources from an area the size of North America—half the surface of the moon.

LunaCorp's highly flexible, modular robotic fleet consists of four classes of robots: miners that collect oxygen, iron, titanium, silicon, and helium from the regolith found near the base; hunter-gatherers that seek out rarer and more valuable gas and mineral resources like hydrogen, aluminum, chromium, platinum, and calcium; worker bots that aid in the construction of bases and shelters for human operators and transport liquid oxygen for delivery to low earth orbit; and an assembly robot, carefully monitored from Earth, that functions as a "queen bee," using materials gathered by other robots to manufacture new robots. Only highly sophisticated electronics need be imported from Earth. LunaCorp is using this current setup as a stepping-stone to create increasingly autonomous robots. The goal is for one operator to control several units simultaneously, thereby increasing the size of the lunar robotic fleet and freeing up the Earth-side workforce to focus on further research and development.

If a company could be said to have a patron saint, LunaCorp's would be Isaac Asimov. LunaCorp researches exactly how to implement his three laws# regarding human/computer interaction. This is particularly necessary for the companion robots that live in close proximity to humans, operating greenhouses and completing routine tasks on the lunar base. This is also crucial for the training robots used by students on the lunar base: each class gets one robot that they learn how to operate. Preparations are also afoot for the inevitable meeting between robots from different nation's corporations. These robots eventually will compete for resources and might conflict, inadvertently preventing one another from completing their missions.

How likely is it that this scenario could come about?

Unlikely Somewhat Unlikely Somewhat Likely Very Likely

If the scenario came about, would the resulting technology be likely to spin-off many applications that significantly advance the field of robotics?

Unlikely Somewhat Unlikely Somewhat Likely Very Likely

If the scenario came about, how desirable or undesirable would the resulting changes in the quality of life be?

Undesirable Somewhat Undesirable Somewhat Desirable Very Desirable

If the scenario came about, how desirable or undesirable would the resulting change in the man machine relationship be?

Undesirable Somewhat Undesirable Somewhat Desirable Very Desirable

If this scenario came about, how likely would it be to raise severe or challenging ethical concerns?

Unlikely Somewhat Unlikely Somewhat Likely Very Likely

Please comment on the scenario. (if you had any trouble with the questions above, please note it here as well)

Aquatic Robots Avert Food Crisis

In 2030, ongoing climate change has drastically reduced agricultural production. The United States faces unprecedented food shortages and people have turned to the government in search of a solution. The government enlists the help of several corporations with different approaches to regaining lost productivity. One corporation, Atlantis, believes they can harvest resources from the sea—a delicate ecosystem still thriving with life. In an effort to minimize negative impact on this fragile environment, Atlantis rejects traditionally destructive seine net dragging techniques and searches for a more sustainable method of harvesting protein.

Atlantis specializes in the development of underwater robotics. They want to build robots that will farm and harvest fish and kelp without substantially depleting the ocean's resources. By 2040, Atlantis launches their first major prototypes, a herder-farmer shark bio-mimic and a kelp farmer-gatherer robot. Unlike normal sea-creatures, these robots use electrical power from floating charging stations located near operating areas, allowing these robots to harvest plant life and farm schools of fish solely for human consumption, effectively placing humans at the top of the oceanic food chain.

The year is now 2050, and Atlantis' shark-bots swarm through the seas, herding millions of fish while more specialized robots manage other important food sources. Together, they function almost as a new species, harvesting an enormous amount of resources to feed the human population. The shark robots find schools of fish and adopt them, leading them to areas where they will thrive. These autonomous herder robots protect their schools from predators and harvest weak and aging fish for human consumption. Farmer robots watch over vast regions of kelp forest, cultivating and harvesting them as human demand necessitates. These farmer robots also need to ensure the safety of creatures living in and relying on these forests for food and shelter so as not to further disturb the balance of the larger ecosystem.

These robots are now essential suppliers of food and resources, thus Atlantis ensures that their robots follow the technicalities of Asimov's three laws# in order to ensure the safety and well-being of the human population. Despite this, some people have noticed that while certain aquatic species thrive, many others suffer. Most experts agree that the balance of the ocean's ecosystem is inevitably going to shift toward species valued by mankind. This is far better than disproportionally depleting the food and biomass resources. If all goes well, conservation and herding will result in a somewhat less diverse but healthy balanced oceanic biosphere.

How likely is it that this scenario could come about?

Unlikely Somewhat Unlikely Somewhat Likely Very Likely

If the scenario came about, would the resulting technology be likely to spin-off many applications that significantly advance the field of robotics?

Unlikely Somewhat Unlikely Somewhat Likely Very Likely

If the scenario came about, how desirable or undesirable would the resulting changes in the quality of life be?

Undesirable Somewhat Undesirable Somewhat Desirable Very Desirable

If the scenario came about, how desirable or undesirable would the resulting change in the man machine relationship be?

Undesirable Somewhat Undesirable Somewhat Desirable Very Desirable

If this scenario came about, how likely would it be to raise severe or challenging ethical concerns?

Unlikely Somewhat Unlikely Somewhat Likely Very Likely

Please comment on the scenario. (if you had any trouble with the questions above, please note it here as well)

Robotic Care-takers Bridge Gap Between Humans and Machines

In 1978, China introduced a law that limited families to only one child in order to slow population growth. This law placed unprecedented stresses on Chinese youth, forcing them to choose between professional achievement and familial values. In years prior, siblings shared the responsibility of tending their aging parents while pursuing their professional ambitions. Without siblings, youths would work diligently to obtain suitable careers in the field of science or technology, and would later relocate to cities. This left the aging parents languishing at home without care—a great dishonor in Chinese society. On the other hand, those who stayed to care for their parents dishonored themselves by failing to supply money or gain prestige.

In 2015, a group of Chinese college graduates began to work on a robotic solution to the problem. Within a few years, they founded Ant Farm, a corporation that developed robotic surrogates designed to assist aging parents. These care-taker robots completed simple house-hold tasks like sweeping floors and washing dishes, but their primary function was to notify the youth when their parents needed extra help. These robots followed Asimov's laws# quite strictly, obeying orders and acting as simple aids to elders.

In the current year, 2052, Auntie, the successor of Ant Farm, has grown tremendously. Robot surrogates have become extremely popular, allowing children to leave home and pursue college and professional careers without dishonoring themselves by neglecting their parents. Thousands of young people in China have entrusted the care of their elders to these robots. The robots themselves are now almost entirely autonomous. Humanoid in form, they help seniors clean house, cook meals, and maintain their lifestyle without the need of human care-takers. The robots can even assist seniors as they age and need to be bathed and constantly watched over. The young owners of the robots can check in and view status updates on their parents, but trust the robot to observe changes and notify them if their condition deteriorates. Meanwhile, the elders want more direct control over the robots—some hoping to continue to run farms and shops with their robotic assistants.

Demand is rising for robot care-takers with the ability to watch over parents after they have developed dementia and cannot be trusted to issue meaningful orders. The robots' artificial intelligence software is substantially enhanced, differentiating between commands that are harmless and should be followed and commands that may endanger human life and should be ignored.

In order to expand its business to foreign lands, Auntie plans to market a line of nanny-robots to Americans. These robots will have the most advanced artificial intelligence to date, providing a safer and more capable alternative to human baby-sitters. These nannies, like their elder-care predecessors in China, feed, bathe, and watch over their charges. However, these robots are not servants. Instead, these nannies take a position of authority over their charge, insisting when they sleep and eat. These robots, then, bend Asimov's third law even further by "exercising judgment," specifically disregarding wishes and even disobeying commands from human beings in their care.

How likely is it that this scenario could come about?

Unlikely Somewhat Unlikely Somewhat Likely Very Likely

If the scenario came about, would the resulting technology be likely to spin-off many applications that significantly advance the field of robotics?

Unlikely Somewhat Unlikely Somewhat Likely Very Likely

If the scenario came about, how desirable or undesirable would the resulting changes in the quality of life be?

Undesirable Somewhat Undesirable Somewhat Desirable Very Desirable

If the scenario came about, how desirable or undesirable would the resulting change in the man machine relationship be?

Undesirable Somewhat Undesirable Somewhat Desirable Very Desirable

If this scenario came about, how likely would it be to raise severe or challenging ethical concerns?

Unlikely Somewhat Unlikely Somewhat Likely Very Likely

Please comment on the scenario. (if you had any trouble with the questions above, please note it here as well)

Robotic Warriors Revolutionize Military and Reduce Loss of Human Life

In 1998, Vice Admiral Arthur Cebrowski, president of the Naval War College, predicted that the military would undergo a massive paradigm shift as computing advanced. Throughout history new technology has been introduced to the battlefield. Many of these technologies, such as the bow and arrow, and later gunpowder, have revolutionized warfare. When the U.S. military introduced robots to the battlefield in 2001, it quickly became apparent that this technology would again revolutionize military affairs. These first robots disarmed improvised explosive devices quite well and soon soldiers began to use them in ways well beyond what designers intended. Soldiers could send a robot with a Claymore attached to it around a corner—if the robot encountered resistance, soldiers could simply detonate the land mine. Soldiers developed emotional connections to the robots that repeatedly saved their lives, even going so far as to demand that their damaged robot be rebuilt rather than replaced. When the military realized how dramatically these simple robots had changed the battlefield, it invested heavily in the development of further robotic technologies.

By 2010, drones worth millions of dollars flew high above battlefields, keeping watch over troops, convoys, and bases. These unmanned aerial vehicles were under real-time human control, allowing an operator thousands of miles away to sit comfortably and observe anything the drone could see. Armed with missiles, these drones were even capable of finding and destroying hostile targets. At this time, all the robots on the battlefield required a human operator. Having only a few autonomous functions, these machines significantly changed battlefield tactics. They could collect information from anywhere and present it to their operators, significantly advancing battlefield awareness.

Now the year is 2052. The majority of human military personnel no longer need be deployed overseas. Instead, they go to work in office buildings, sit in cubicles, and command robotic battalions. These operators no longer need to undergo physically arduous training or endure harsh environmental conditions. Only a few personnel are stationed near war zones in order to maintain and repair robots. Surveillance squadrons survey the world, providing commanders with statistics, videos, and computer simulations of battles. Generals develop strategies and commanders in cubicles guide the robotic foot-soldiers, pack animals, heavy artillery, aircraft, and submarines. Since the lives of troops are no longer at risk, robotic troops can afford to exercise more discretion than their human predecessors. They can wait to be fired upon before firing, ensuring that targets are actually hostile. Stronger, faster, and more powerful than any human, these robots can use non-lethal force in the face of lethal force and take hostages.

The military considers Asimov's laws# short-sighted and ill-advised. Military robots cannot follow the first law because they are killing machines, executing their commander's orders without question or hesitation. They cannot follow the second law, for they obey only their commanders—completely incapable of responding to pleas for honorable terms of surrender. The robots must break the third law as well, first by entering a war zone, and again by taking enemy fire rather than fleeing. The military claims they break Asimov's "fictional" laws in order to better safeguard the freedom of people throughout the world.

How likely is it that this scenario could come about?

Unlikely Somewhat Unlikely Somewhat Likely Very Likely

If the scenario came about, would the resulting technology be likely to spin-off many applications that significantly advance the field of robotics?

Unlikely Somewhat Unlikely Somewhat Likely Very Likely

If the scenario came about, how desirable or undesirable would the resulting changes in the quality of life be?

Undesirable Somewhat Undesirable Somewhat Desirable Very Desirable

If the scenario came about, how desirable or undesirable would the resulting change in the man machine relationship be?

Undesirable Somewhat Undesirable Somewhat Desirable Very Desirable

If this scenario came about, how likely would it be to raise severe or challenging ethical concerns?

Unlikely Somewhat Unlikely Somewhat Likely Very Likely

Please comment on the scenario. (if you had any trouble with the questions above, please note it here as well)

APPENDIX B: Statement of Research Methods

Perceived Futures of Robotics
Statement of Research Methods

Robotic technology is developing at an alarming rate. The use of robots in society has been steadily increasing over the last decade. These technologies could revolutionize several areas of society, such as industrial production, environmental protection, domestic relations, and military affairs. At this stage it is important to understand the direction the technology is headed and what implications it might have on society. Most of the robotics research is performed by contractors and grantees funded by military agencies. Does it matter who funds the development of robotic technology? The following proposal attempts to answer this question indirectly by seeing whether it is perceived to matter by those most likely to be affected. This question will be unobtrusively embedded in four scenarios concerning possible futures of robotics. In one of them the military remains the lead institution driving the development of the field. In the other three scenarios another institution displaces the military as the most important actor shaping the field.

The underlying question to be addressed is whether people aspiring to enter the field of robotics[1] and their peers aspiring to other technical and non-technical fields are equally concerned about where the field of robotics is headed. Differing reactions to the scenarios imply that it really does matter what institution is playing the lead role. If there is a consensus that it greatly matters who develops this powerful technology, the stage is set for further investigation using social methods that get beyond perceptions data.

[1] At WPI there exists a robotics major, but this is highly unusual. At other colleges, we will ask students majoring in computer science, mechanical engineering, and electrical engineering to rate the likelihood of their pursuing a career in robotics.

The current pilot study will involve student assessor panels which will be drawn from different colleges (both technical and liberal arts colleges), and the preferred approach will be to sample at the level of classes rather than individual students. Should the instructors of strategically selected (required) courses not cooperate in sufficient numbers, we will draw a stratified random sample of sophomores, juniors, and seniors from public listings of students in different majors. The survey will compare the views of students in robotics/computer science and computer engineering programs and students in unrelated technical and non-technical fields. We will be sampling three robotics courses and three other technical (computer science, mechanical engineering, and electrical engineering) courses from Worcester Polytechnic Institute, three humanities courses from a college such as Clark University, three to six technical and three humanities courses from a college such as University of Massachusetts Amherst, totaling 9 to 12 technical courses and six humanities courses.

Assuming class sizes of 20-30 students, we will have sample sizes of approximately 180-360 aspiring technical experts and 120-180 humanities students. We will examine the results comparatively and assess relative levels of consensus and concern.

APPENDIX C: Model Draft of Letter Sent to Instructors

Professor **ZZZ**,

We are requesting your cooperation in distributing an IRB-approved survey to your class, **YYY**, in order to collect crucial data for our Interactive Qualifying Project.

The purpose of this IQP is to determine what students' perceptions are about the future of robotics and how institutional funding patterns will affect the future of the field.

In order to analyze any trends in perceptions, we have decided to accumulate data by polling three groups of students: robotics majors, other technical majors, and non-technical majors. We believe your course, **YYY**, will provide a substantial amount of data for our **XXX** group.

For this study, the desired sample size in each sample strata is 60-90. By polling your course, we are hoping to accumulate a third to a half of the **XXX** group sample size.

Attached is the survey we will be using for this study. We will be able to provide you with the necessary amount of copies for your class.

We have several options for distributing our survey to your class:

1) At the beginning or end of your class, we can come in and give a brief presentation of our study and pass out the survey.
2) We can administer the survey and lead a class discussion on a day that you are unable to come into class. This method may prove to be effective if you feel that our study is relevant to your course.
3) You can pass out the survey at the beginning or end of your class and ask for students to return it to you on a later date. We will then collect all surveys that were returned to you. This method could be used as an indicator of class participation if you so choose.

4) Any other method that you believe would best fit the schedule of your course is also acceptable.

For further information, please contact our IQP advisor, Professor John Wilkes (jmwilkes@wpi.edu).

Your cooperation is crucial for the success of our study and would be greatly appreciated.

We are eager and excited to hear back from you.

Respectfully,

Michael Brauckmann

Matthew Dickerman

Benjamin Dwyer

Adam Vadala-Roth

APPENDIX D: 5 Minute Pitch to Classes

Good Morning, our names are ___ and we are distributing this survey concerning perceived futures of robotics. As engineers, we tend to spend our time crunching numbers and trying to implement our ideas. All too frequently, we lose sight of the bigger picture in the excitement of new technology. This study is an effort to forecast the future of robotics and its social implications.

This study was inspired by Singer's *Wired for War*. In *Wired for War*, Singer describes robotics as it is currently funded by the military and raises some interesting questions about the direction the technology is taking society. In our survey we have produced not one, but four different scenarios outlining possible directions for the future of robotics. Our scenarios are written as science-fiction in the sense that they explore a reasonable extrapolation of current trends in technological growth. Please try not to worry about exactly how the technologies themselves are realized. The implications of technology are far more important than technologies themselves.

By studying the implications of technology, we develop an understanding of what direction technology is taking our society. Rather than blindly developing technology, we can support technologies that you believe may benefit humanity. All of the scenarios are set within the timeframe of your careers-- the next 35 or so years. If we can predict the effects of technology, we all can affect what direction it will take us.