Robot Rhetoric: Fostering Public Understanding of The DARPA Robotics Challenge

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Abstract

In our increasingly science and technology-dependent world, science and technology communication has become an increasingly important form of writing. Industrial pollution, environmental exploitation, global warming, healthcare, and nuclear energy aren't just topics in science and technology – these are multifaceted issues that affect all of American society. Robotics is not immune to this intermingling. Drone warfare, job automation, and assistive robots in the home are all relevant to the American public for a variety of reasons. Engaging and informative writing by experts can guide the public to consider these issues as educated citizens and consumers. My project studies the skills and considerations involved in effectively describing science and technology to the public.

First, my project studied different rhetorical strategies for presenting topics in robotics to the public. I learned that, when they describe science and technology, writers have a choice in how they present their topic. Some writers boost the virtues of science and technology, some encourage the public to think about how technology could affect them, and some promote skepticism and dialogue about the uses and misuses of technology. Next, I studied contextual considerations such as audience, medium, current events, and culture that dictate how a topic is approached and what details are relevant. I also researched techniques for writing engaging prose about science and technology. These techniques included using narrative to make a topic more relatable, employing metaphors to translate abstract technical concepts, and illustrating ideas through the use of visual media.

Using this theoretical framework as a critical lens, I examined several articles about the Defense Advanced Research Projects Agency (DARPA) Robotics Challenge. This is an ongoing competition funded by the Department of Defense to improve state-of-the-art disaster-relief robots. As I read these articles, I noticed gaps in how the Challenge was being presented to the public. Articles failed to explain the historic significance of the Challenge, the technological hurdles facing participants, and the military applications of the nominally-humanitarian technology of the Challenge. In an attempt to improve coverage of the Challenge and apply the theories I studied in my literature review, I wrote a feature covering the Challenge for the Boston Globe Magazine.

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Introduction

Science and technology communication is the writing discipline concerned with presenting the work of scientists and engineers to the public. In our increasingly science and technology-dependent world, the work of science communicators is becoming more and more important. Science issues such as environmental pollution, global warming, nuclear power, and public health affect everyone in society. In the early 21st century, technological issues such as data security, government surveillance, and drone warfare have become important topics. Although these topics exist at the intersection of several disciplines and are heavily influenced by politics, understanding the science and technology concepts underlying each issue is important for grasping the full picture. Science and technology communicators have the challenge of presenting these concepts in an understandable, engaging, and contextually-aware manner.

Presenting topics in robotics to the public is a particularly interesting problem. Because the field of robotics is still relatively young when compared to other disciplines in science and technology, the public does not have very much familiarity with the topic beyond science fiction. The Defense Advanced Research Projects Agency's Robotics Challenge is a particularly interesting topic in the field of robotics communication. This is an international robotics competition funded by the Department of Defense. The stated goal of the competition is to improve the effectiveness and autonomy of disaster-relief, search-and-rescue, and hazardous material cleaning robots. Much of the coverage surrounding the event has boosted the "coolness" of the robotic technology involved in the Challenge. But the significance of the challenge has been under-emphasized. Nothing like the Challenge has ever been attempted before and the robots involved are some of the most sophisticated robots ever built. The DARPA Robotics Challenge has the potential to revolutionize robotic technology and writers are not aptly conveying this potential.

Furthermore, the potential for military adoption of Challenge technology is being under-represented. The event organizers are firm in their assurances that the competition is being held for purely humanitarian robot purposes. But, when it comes down to it, this is a military-funded competition. The improvements it might bring about for robotic technology will almost definitely be applied to future military robots. Because the competition is funded by American taxpayers, writers have a responsibility to cover this aspect of the Challenge.

I will answer these deficiencies in public understanding of the Challenge by writing my own article. In it, I hope to convey the historic, technological, and ethical components of the technology being developed for DARPA. This competition is one of the most important things to ever happen in the field of robotics, and I want to help readers understand why.

To write an engaging, educational article, I will gather the recommendations of experts in the field of science communication. Although many of them write about science communication, not technology communication, the same principles apply to topics in both fields. First, I will study the rhetorical perspectives involved in science and technology communication. The rhetorical strategy of a writer is absolutely essential as it indicates the writer's perspective of the public's relationship with science and technology. This dictates how a topic is presented. Some writers choose to boost the benefits of science and technology, others try to translate concepts to make them relevant and engaging to readers and some seek to improve critical understanding of topics. Next, I will examine contextual considerations that make a piece "fit." This includes appealing to a piece's audience by building upon their experiences and understanding, making cultural connections that make a piece relevant to history or current events, and tailoring writing to its target publication. Finally, I will compile recommendations for writing engaging non-fiction prose. These include using graphic media to make a point, using metaphors to elucidate abstract concepts, and employing narrative to make a topic more human.

Next, I will use my research as a lens to critique articles that have been written about the DARPA Robotics Challenge. Through this critique, I tried to find examples of the rhetorical frameworks, contextual advice, and writing techniques described in my research. I also tried to find ways in which writers could improve their coverage of the Challenge. These gaps informed my own article.

At the end of this project, I will not yet be an expert in the science-writing discipline. That takes a lifetime of practice. Instead, I hope to gain a theoretical understanding of the practice of presenting science and technology to the public. My article should serve as a demonstration of my understanding.

Science and Technology Communication Theory and Technique

Introduction

I want to examine what experts have written about popular science writing at three levels. First, I will examine three rhetorical stances that science and technology writers typically take. These stances define the relationships between the author, the reader, and the topic at hand. Next, I will look at intermediate considerations such as appealing to audience, contextual connections, and tailoring to a piece's target medium. These critical factors shape the tone and style of a piece, and a failure to consider them can make or break an article. Finally, I will convey writing techniques that experts use to translate science and technology in an informative, easy-to-understand manner.

Rhetorical Models of Science Communication

Science and engineering communication always involves certain rhetorical considerations. The rhetorical triangle of writers, readers, and the science topic at hand all interact in different ways depending upon the author's intent. In her 2013 book, *Communicating Popular Science; From Deficit to Democracy*, Sarah Perrault identifies two categories of writers that shape this triangle. First, she describes "boosters," authors who extol the glory of science. For boosters, success is measured by the degree to which readers' concerns and priorities line up with that of scientists (Perrault, 2013). Boosters are faithful advocates of science and technology who portray their topic in a positive light. Critics, on the other hand, seek to encourage a dialogue about science. They recognize that science is not perfect, is capable of being used for nefarious purposes, and the public should know about its costs (societal, environmental, ethical, financial, etc.) and its potential for misuse.

Boosters see their communication as filling a deficit in public understanding of science. This deficit model is an important topic in many evaluations of science communication and will come up again. On the other side are science critics who seek to encourage skepticism and critical analysis of the topics they present. They also realize that the public might have something to contribute to science. When 50% of legislation presented to congress involves science or technology, this is a valid realization (Penrose & Katz, 2010), To help the public understand topics in science and technology, they follow the contextual model, connecting science and technology to relevant societal, historical, political, and environmental factors (Perrault, 2013). Boosters might be seen as talking down to their audience, but critics seek to elevate the audience to their level of understanding and authority.

Building upon these rhetorical perspectives, Perrault identifies three paradigms of popular science/technology writing. These paradigms dictate the stance of the author and define how a topic is presented to readers. These strategies have been identified in similar terms by several notable scholars in the field (Kahlor & Stout, 2010; Gastel, 1983; Brossard & Lewenstein, 2010). The first, Public Appreciation of Science and Technology (PAST) exemplifies deficit communication. Next, Public Engagement with Science and Technology (PEST) blends the deficit model with contextual awareness. The third model, Critical Understanding of Science in Public (CUSP), seeks to elicit critical analysis of science from readers and draws heavily upon the contextual model. These perspectives are not mutually exclusive -- they exist as a continuum and writers might blend all three approaches in a single text.

PAST Model – Public Appreciation of Science and Technology

In this type of dialogue, scientific and technological advocates (boosters) share knowledge without seeking to encourage public engagement. Writers following the PAST model try to fill a perceived deficit of knowledge and understanding in the public. Rhetorician Greg Myers describes the public (according to this model's perspective) as "a blank slate of ignorance on which scientists write knowledge" (Myers, 2003). One might envision this type of science writing as a brilliant scientist talking down from his podium to the unenlightened public with no scheduled time for the masses to ask questions or offer input. This relationship between topic, writer, and audience is depicted below, in **[**Figure 1**].** This rhetorical triangle depicts how PAST writers become the filter through which the public receives science and technology. In an article advocating the PAST model, science is described as "the rational pursuit of objective truth about the world, which can only be good" (Bauer, 2000). On the other hand, Perrault argues that the deficit model fails to effectively communicate science because it does not consider the social, cultural, political, and personal contexts in which science exists. This contextual model has been suggested as an improvement over the deficit model by several scholars (Sturgis & Allum, 2004; Bauer et al., 2000; Brossard & Lewenstein, 2010; Nisbet, 2010).

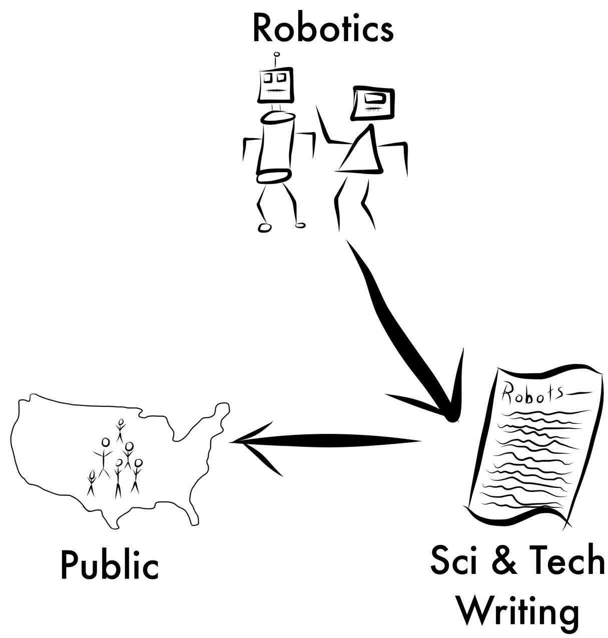

Figure 1 - In the PAST model, writers are the filter through which the public understands technology.

The deficit model also fails to consider the public's contributions to science as consumers, taxpayers, critics, and research participants. Perrault claims that PAST writing is often perceived as pontificating or irrelevant because of its failure to account for context (Perrault, 2013). Science is presented in a vacuum, without consideration of its faults and fallibility. In a 2004 analysis of public attitudes toward science titled *Science in Society: Re-evaluating the Deficit Model of Public Attitudes*, Sturgis and Allum critiqued the deficit model. They discovered that individuals who learned science without context (they defined context as the "patronage, organization and control" and politics surrounding science and scientific organizations) were less likely to understand the issues and potential for misuses in some topics in science (Sturgis & Allum, 2004).

Because of their lack of contextual and critically balanced considerations, boosters of science are capable of spreading dangerous misinformation. America's fervor for radioactive materials in the early 20th century is often cited as an example of misguided science boosting (Gastel, 1983; Endres, 2010). Writers of the era extolled the benefits of radiation and their enthusiasm and authority led the public to consume irradiated drinking water, medicine, and food. A company in Germany even produced radioactive toothpaste (Serafini, 1993). Perhaps if science journalists of this era had been less enthusiastic and more skeptical about this nascent discovery, the public wouldn't have consumed so much harmful material.

Though the PAST model has a few shortcomings, its focus on inspiring appreciation for science merits further discussion. Though some authors (Perrault in particular) considered PAST the least-valuable rhetorical model, some scholars argue that inspiring wonder and excitement for science and technology is a noble goal. Richard Holmes, author of *The Age of Wonder: The Romantic Generation and the Discovery of the Beauty and Terror of Science* argues in his book that wonder is one of the driving forces behind science because it inspires the heart as well as the mind. Penrose and Katz suggest that science and technology writers consider this, advocating the "deontological appeal," a rhetorical strategy which focuses on inspiring surprise, joy, and awe (Penrose & Katz, 2010). But writers should be careful to only praise technology that deserves it. Though most science communicators agree that a writer who praises the efficiency of a lethal robot would be doing the public a great disservice, some technology, like a prosthetic leg that enables patients to run again, *does* deserve appreciation.

PEST Model – Public Engagement with Science and Technology

This model improves upon the PAST model by connecting technology to the public. Science and technology writers who adhere to the PEST model realize that the public is interested in science and technology because of the benefits science and technologybring to their lives. Therefore, they believe that science should be democratized (Perrault, 2005; Brossard & Lewenstein, 2010; Gastel, 1983) PEST writers recognize that the public are participants in scientific research and technology development. They are affected by science and technology through the environment and their culture, and they might contribute as taxpayers, research participants, or consumers. As a result, PEST writers seek to encourage public involvement in the scientific process. The rhetorical triangle describing this relationship is depicted below in [Figure 2]. This represents how, in addition to helping the public to understand science and technology, writers in this model seek to connect topics with readers. While PAST writers might place science upon a pedestal and say "see how wonderful it is," a PEST follower would encourage readers to imagine how technology can affect their lives. They write about science and technology with the intent of making their topic "understandable, relevant, and engaging" to non-technical readers (Gastel, 1983).

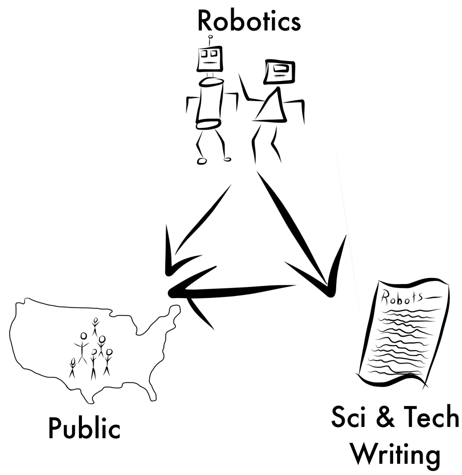

Figure 2 - In the PEST model, the public is encouraged to consider how science and technology affects them.

Science and technology translators have a noble goal in their desire to increase engagement with science and technology "to the masses." When individuals are more knowledgeable about science and technology, they are more likely to understand related topics such as global warming and the advent of robotic automation. This can lead to more effective criticism of science and technology, less alarmism about its harms, and more enthusiasm about beneficial science and technology. These are important effects in America, where (according to a survey by the National Science Board) only 63% of the public demonstrates basic scientific literacy (National Science Board). When only 58% of Americans believe climate change is a problem, the need for science communication is more urgent than ever (Frank, 2013). In our increasingly science and technology-dependent world, the public needs to be better educated about these topics.

Scholars agree that fairness is an important component of public-engaging writing. John C Besley compiled discussions on fairness in public engagement in his

2010 essay, *Focusing on Fairness in Science and Risk Communication.* In Besley's essay, he argues that "distributive, procedural, interpersonal, and informational" fairness are essential parts of science communication that seeks to foster public engagement with in the scientific process. Though he never explicitly defines his interpretation of fairness, he goes on to explain that science writers should strive to present the "full picture" of the concepts they describe (Besley, 2010). During the course of his research, he found several studies that connected fairness of science communication with citizen engagement and trust.

CUSP Model - Critical Understanding of Science in Public

Introduced by Bruce Lewenstein and further developed by Perrault, the CUSP model seeks to foster critical public discussion of science and technology issues and developments (Lewenstein, 2003). Advocates of the CUSP model believe effective science and technology writing "praises science when praise is called for, challenges it when challenges are needed, and explains it in terms that situate it in its social, cultural, and material context" (Perrault, 2013). The PAST model tends to paint science in a purely positive light, but the CUSP model recognizes that science and technology are not always purely beneficial. Evans and Durant discovered in their 1995 study titled *The relationship between knowledge and attitudes in the public understanding of science in Britain* that members of the public who truly understand science are generally "less supportive of morally contentious issues in science." This finding supports the correlation between public understanding and improved dialogue about controversial scientific and technological issues. The CUSP model also contextualizes science, believing the politics, culture, and people behind science are also important to present (Perrault, 2013; Ziman, 1991).

According to this model, writing about science should involve skepticism. CUSP writers recognize that non-scientists and non-scientific considerations should influence scientific and technological development. They believe in the democracy of science. Perrault describes CUSP writing as fulfilling the "twin duties of science communication…to inform and educate the public about science on the one hand but also to probe and criticize it on the other" (Perrault, 2013). The rhetorical triangle at the top of the next page, in [Figure 3], depicts how CUSP readers believe the public and their writing should relate to science and technology. CUSP writers believe both themselves and the public should inform the scientific process, so the arrows go both ways.

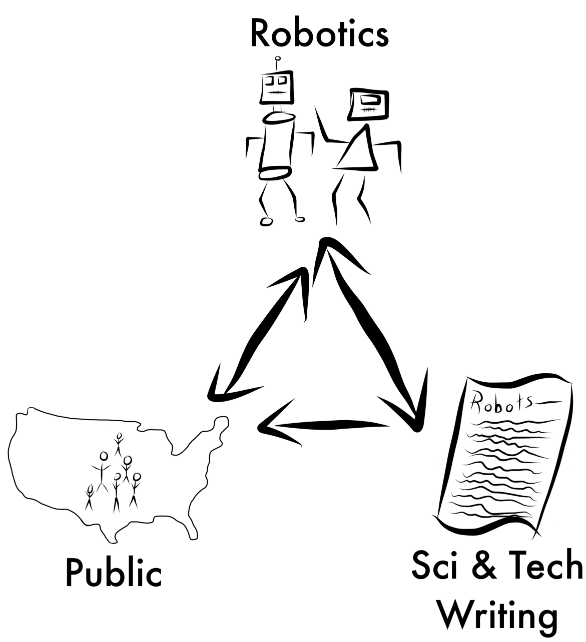

Figure 3 – This figure indicates how CUSP writers believe their writing and members of the public interact with science and technology

NPR recently published a robotics article that demonstrates the CUSP model. Titled *Can You Trust A Robot? Let's Find Out* and written by Adam Frank, it was published in NPR's *13.7* blog, which is described as "Commentary on science and society." Already, this is sounding like a promising CUSP piece. The article starts out with this paragraph:

> When they come — and they are coming — will the robots we deploy into human culture be capable of evil? Well, perhaps "evil" is too strong a word. Will they be capable of inflicting harm on human beings in ways that go beyond their programing?

This piece tries to enlighten the public about robotics safety. The author asks several rhetorical questions throughout the piece, which (though Perrault doesn't say so) I believe is an important part of CUSP writing. By asking these questions, the author lets readers consider this for themselves.

Summarizing and Synthesizing PAST, PEST, and CUSP

These three models aren't strict categories into which a piece of writing can be definitively sorted. They exist as a spectrum, and a single article might employ aspects of all three. A hypothetical article might praise the design of a vacuum-cleaning robot (PAST), demonstrate how the technology could help readers (PEST), and explain how the technology is affecting the market for maids (CUSP) all on the same page. Writers should not feel the need to stick to a single appeal. In fact, balancing appreciation where appropriate and criticism where necessary of a topic might be the most reasonable approach.

Tailoring to Context

Several considerations, tools, and strategies are used by writers when they describe science and technology. Rhetorical stance is an important factor, but there are still many more aspects to consider. Scholars of science communication place heavy emphasis on considerations of context, medium, and audience when framing a piece. Audience and the medium in which it is published dictate the tone and topic of an article. Cultural connections set the scene and tie in relevant societal, historical, and other "big-picture" considerations. The prejudices, preferences, and experiences of a piece's audience dictate how it will be received. Links to current events, political topics, and popular culture might make it particularly relevant to readers. Writers need to consider their publication holistically. In this section, I will highlight strategies from science writers about leveraging such factors to improve a piece.

Not every writer will approach these factors in the exact same way. While a freelance writer might agonize over who their target audience and medium are, a staff journalist at the New York Times knows exactly what sort of readers he's writing for. A scientist who wishes to write about her own research isn't going to pick a topic according to current events. For this reason, the following sections are not a step-by-step guide. Instead, they should be considered as an interconnected web of factors.

Cultural Environment

To make science seem relevant and appealing to readers, it is necessary to consider the environment in which it exists. A technology's cultural environment – relevant current events, historical connections, pop-culture allusions and the geographical setting all influence to its significance and relevance in the eyes of readers. The authors of *The Science Writer's Handbook* argue that considering these factors is absolutely critical. They provide the example of a science writer who waited for a gas shortage to publish a piece about how gasoline is formed (SciLance, Hayden, & Nijhuis, 2013). If it had been published on any other day, the readers of her magazine might not have felt curious about gasoline's origins. Because of its relevance at that time, the piece received a great deal of attention. Connecting science and technology to current events is called, in journalist vocabulary, a "news peg."

Dr. Barbara Gastel, author of the 1983 classic *Presenting Science to the Public,* adds onto this strategy. She defines *news stories* as an entire genre of science writing. These pieces typically feature the traditional "5 W's and an H" of journalism – who, what, when, where, why, and how. Gastel also recommends using a news peg as an introduction for lengthy articles about research. She suggests that, if a writer's piece can't be connected to any current events when it is written, they should hold onto it and wait for a relevant headline. Adding a short introduction (in journalism terms, a lead) that pegs the piece to a topic in the news will make it more relevant and receptively received by readers.

In robotics, there are several topics with which writers can connect their article's subject. Politically, the American military's aerial drones are a hot topic. Economically, automation and its effects on the job market is a huge topic. The government also invests a great deal of money and effort into robotics research and development, so financial and political connections are sometimes easy to make. Some articles, particularly ones written for local news markets, focus on the local businesses involved in a robotics topic. The headline *At robot contest, MIT team places 4th* used for a reprinting of a NYT article in the Boston Globe is an example of this (Markoff, 2013).

Because robotics is still a relatively young field, it can be hard to find a connection that will make sense and appeal to readers' interests and knowledge. Most members of the public do not own a robot and a great number of people have never seen a robot first-hand (Eurobarometer, 2013). So, to draw readers to this somewhat niche topic, many writers connect their topic to science fiction robots. Pieces about drones and military robotics often make a connection with the Terminator robots from the eponymous 1984 film. Articles about personal robots often mention Rosie the robotic maid from *The Jetsons*. Below are some recent examples of how authors have used science fiction to attract readers, make their point, or translate technology:

By Sci-Fi Standards, Newest Robots May Disappoint - John Markoff, NYT

In this article, Markoff uses the impressive capabilities of fictional robots as a contrast to the struggles of DARPA Robotics Challenge robots. This sets up explanations of the challenges of programming robots to do human-like tasks. This is a great example of using cultural connections to foster critical understanding. Markoff explains why readers' expectations are unrealistic and offers clear explanations of what state-of-the-art robots are truly capable of.

Back to the Future 2's Robotic Gas Station Arrives a Year Early – Fox Val Allen, TIME Magazine

This article introduces a robotic gas station by connecting it to a scene in a well-known pop movie. The sci-fi connection isn't incorporated heavily into the piece, but instead serves as a hook for the attention of readers. This shows how sci-fi can be used to attract readers. Sci-fi connections don't always help translate technology – sometimes it's more appropriate to simply draw the reader's attention.

Why 'Robocop' is good for humans – Tony Hicks, San Jose Mercury News

Tony Hicks uses the recently-released movie RoboCop to explain applications of robotic technology, why robots fascinate people, and why sci-fi robots aren't realistic representations of actual state-of-the-art robots. Using RoboCop as a hook was a great appeal because it connects to a movie that's fresh in readers' minds.

Although science fiction robots are not accurate portrayals of the technology as it exists today, they provide a foundation upon which the writer can build a reader's understanding. This foundation, though it is based in fiction, is useful because it connects technology to something with which readers are familiar.

Medium

The publication in which writing is presented dictates quite a bit about the piece. Medium defines tone, vocabulary, the level of detail, and audience (Zinsser, 1976). It also dictates the length of an article and influences the types of topics chosen (Gastel, 1983). An article written for *The New York Times* is not going to seem appropriate in *TV Guide*. When a reader picks up an issue of *TV Guide*, they're expecting the articles to be fairly easy-to-read, not too in-depth, and easily consumed in just a few minutes. A *New York Times* piece will have a more advanced vocabulary, a less casual tone, and typically will explore a topic more in-depth than a piece written for *TV Guide*. Every publication has unique requirements.

There are a variety of strategies writers can use to make sure their writing “fits” in its targeted medium. Authors of *The Science Writers Handbook*, members of SciLance (a partnership of freelance science writers), have some advice about considering medium. Freelance journalists spend more time considering this factor than most journalists because they often need to tune a specific story for multiple publications (SciLance, Hayden, & Nijhuis, 2013). So their advice is particularly valuable. First, they advise picking up an issue or two of the target publication. Nothing will offer a better feel for a publication than reading through it, they recommend. For more statistical information about the typical reader, the writers of SciLance recommend researching readership surveys for a targeted publication. These typically provide details about its audience’s age, education level, location, and may even provide metrics such as the amount of time a typical reader spends on each article (Green, 2011).

In *Presenting Science to The Public*, Gastel explains a fascinating way to determine whether an article is appropriate for its medium (Gastel, 1983). Robert Gunning’s Fog Index is an algorithm that measures the readability of a piece of writing. Originally introduced in Gunning’s *The Technique of Clear Writing* in 1952, the Fog Index determines the “grade level” of a piece of writing. The algorithm considers the average lengths of sentences and the ratio of long, complicated words to shorter words. It measures this ratio by considering the number of syllables in each word. Though this doesn't precisely measure the complexity of vocabulary, Gunning argued that it is an effective approximation. The result of the algorithm is a number reflecting the estimated "grade level" of the analyzed passage. The average ninth-grader can easily read a piece with a Fog Index of 9 and high school graduates can typically read pieces that score 12 and below.

Checking the score of an article against the typical score of its desired medium is a good way to determine whether it is appropriate. Publications tend to consistently score at the same level. For example, articles in *Ladies' Home Journal* score around 8, *Reader's Digest* lands around 10, *Time* and *Newsweek* around 11, and *The Atlantic Journal Monthly* consistently scores a 12. Almost no popular magazine rates higher than a 12 and publications in post-doctoral physics journals can score over 25. Though this is far from an end-all solution for ensuring your writing fits its medium, it can be a very useful tool for self-analysis.

Audience

No reader comes to an article in a newspaper as a blank slate. Penrose & Katz explain that an audience typically has some (even elementary or inaccurate) familiarity with an article's topic (Penrose & Katz, 2010). They might hold expectations of what the author is trying to tell or sell them. Every reader also has their own interests and expertise to which they will try to connect a topic, and perhaps they might even first-hand experience with the topic. These notions all combine into a filter through which everything they read is perceived. The father of rhetoric, Artistotle, believed tuning writing for its audience was the key to writing persuasive, engaging prose.

An audience's filter can be a blessing or a curse. With careful consideration of their audience, a writer can write in a way that appeals to potential readers. An article about research in reducing the effects of aging in a magazine primarily circulated to retirees is likely to be received positively. But an author who does not consider their audience and, for example, submits an article about the benefits of eating more red meat to a magazine for vegetarians, is doomed to fail. Penrose & Katz argue that writing should be "listener-based, not speaker-based." Writers need to tailor their topic to the audience's experiences, prejudices, and priorities. That red meat article might sound well-constructed and convincing to the author, but their article will fall on deaf and disgusted ears if it's read by vegetarians.

Translating Technology

Howard Zinsser, author of the 1976 classic non-fiction instructional book *On Writing Well*, argues that first and foremost, good non-fiction writing must be good writing. So all the old rules apply: no run-on sentences, no grammatical mistakes, ensure that everything is spelt everything correctly, etc. But writing informative, engaging prose about science requires something more. It involves a certain kind of translation. Writers need to translate the results of research and development, which might be forbiddingly abstract, technical, or complex, into prose. In this section, I will highlight strategies science writers use to make their writing both entertaining and educational.

Structure

In *On Writing Well*, Zinsser recommends that any piece about a complex topic should be structured "like a pyramid." This enables the author to build understanding from basic details to complex ideas. The most basic, obvious details come first. These are what the reader *needs* to know to understand the topic at hand. They form a foundation for the rest of the piece. As the piece progresses, more complex ideas (which typically rely upon understanding the "bottom parts" of the pyramid) are introduced. The piece should move from basic, foundational truths to a discussion of the topic's more advanced aspects. This linear sequence, aided by deduction, brings readers from unknowing to familiarity. Zinsser suggests that the crown of the pyramid should connect the piece to the rest of the world. He suggests speculating upon a topic's applicability to day-to-day life, connecting it to other current research efforts, or suggesting future applications and improvements.

When considering the structure of a piece, its introduction is perhaps the most important part. Journalists often speak of the "lede" of a piece (SciLance, Hayden, & Nijhuis, 2013). This is a short paragraph which would typically be placed in the first few pages of a newspaper and attracts readers to find the rest of the article in its appropriate section. This typically tries to make the piece relevant to readers, either by connecting it to current events, introducing a new development in science, or by introducing a new perspective of old technology. The lede can determine whether or not readers will see a piece, so this is a very important consideration when drafting an article for a newspaper.

Narrative

Science and technology is driven by people, and people always have stories. Instead of writing about science itself, many writers choose to highlight the stories of people doing science or developing technology. In *The Science Writer's Handbook*, many of the book's contributors argue that the best way to write about science is by telling a story (SciLance, Hayden, & Nijhuis, 2013). Most of the book's topics relate to writing stories about science and scientists. Michelle Nijhuis goes into detail about science-as-story in her chapter, "Sculpting the Story." Nijhuis identifies three common types of narratives in science writing. According to her, The Quest, Overcoming the Monster, and Rags to Riches are the three most common archetypes. In The Quest, a scientist toils away for some elusive result and succeeds. The narrative focuses on their trials and triumphs along the way. In Overcoming the Monster, a scientist overcomes some great difficulty in achieving their research goal. In the third most common archetype, Rags to

Riches, some scrappy scientist with limited resources is described as succeeding despite their disadvantages.

Galileo Galilei, one of the most prominent science writers in history, understood the power of narrative. In *The Dialogues*, the book in which he posited that the sun, not the Earth, was the center of the Universe, the foundation of his argument was not mathematical proofs of astronomy. Instead, his book was mostly composed of an ongoing argument about the sun's position between three good friends on a gondola in Venice. Galileo made jokes and wrote silly arguments and poems, while interspersing complex equations throughout. He also sought to present his idea to general audiences by writing in Italian instead of Latin, which was the "scientific language" of the era. Hundreds of years ago, Galileo understood the value in presenting science to the public, and decided that telling a story was the best way to accomplish this goal (Krulwich, 2012).

The popularity of science-as-story communication shows that the public eagerly consumes science when it's told in this way. Radiolab, the award winning science story podcast from NPR, is consistently among the top 3 podcasts in iTunes. Carl Sagan's *Cosmos*, which told science stories wrapped up in history, is one of the most successful documentary stories of all time. The debut of its 2014 sequel, hosted by Neil Degrasse Tyson, was watched by almost 40 million viewers worldwide (Maglio, 2014). The public craves stories, so a story with science or technology interspersed throughout is a great way to present a topic.

Many articles have used narratives to explain robots. In his 2013 article, *The Umbilical Link of Man to Robot*, New York Times staff writer John Markoff started his piece with a short narrative. The excerpt below, which serves as the hook to a rather technically in-depth article, attracts curious readers by telling a story about a robot:

> Atlas doesn't shrug. But he teeters, loses his grip, stutters and staggers.
>
> His task one afternoon is to clear a debris field. After many agonizing moments, in a set of abrupt and jerky movements, he crouches and with painstaking precision manages to grasp a two-by-four board and then drop it to his right. At the rate he is moving, completing the chore might take days.
>
> Atlas in this case is an imposing, six-foot-tall humanoid robot that evokes the bipedal "Star Wars" robot C-3PO.

This piece exemplifies anthropomorphism, which is a special kind of metaphor that involves writing about something non-human as if it is a person. Atlas is a genderless robot, but using "he" to refer to Atlas made Markoff's story more attractive. Many robotics articles include some sort of anthropomorphism. In 2003, a widely-cited human-robot interaction study led by Brian Duffy analyzed the effects of anthropomorphism on human perception of robots. The author discovered that humanlike descriptions and actions help laymen to understand the behaviors and purposes of robots. But he also found that, when the metaphor is misinterpreted or carried too far, misunderstanding arises. If a writer describes a robot's shortcomings in human terms, the reader might be led to conclude that the robot is just a "stupid human" rather than an imperfect piece of advanced technology. In this way, anthropomorphism sometimes oversimplifies complex systems (Duffy, 2003).

Metaphor

Metaphors can be powerful tools for translating science and technology. George Lakoff, author of the modern classic *Metaphors We Live By* defined a metaphor as a "cross-domain mapping in the conceptual system" (Lakoff, 1980). By this, he means that metaphors allow us to understand new ideas by relating them to concepts we already know. Lakoff asserted that a metaphor is not just a rhetorical flourish, but is instead a basic property of language and thought. He suggested that metaphors affect the ways we perceive, think, and act. They structure our understanding of events, convey emotions and attitudes, and allow us to construct elaborate concepts about public issues and events.

Michelle Nijhuis of *The Science Writer's Handbook* points out that, while scientists and engineers use mathematics to understand the natural world, most of us use metaphors instead. Abstract scientific concepts that are outside the realm of human experience can be made relatable through metaphor – think of Neils Bohr's model of the atom as a miniature solar system. Galileo was one of the first to recognize the power of these two ways of seeing the world. In a wonderful statement from his book *The Esseyer*, he suggests that math is "the logic of the universe…without which one is wandering around in a dark labyrinth." His writing was filled with brilliant mathematical proofs and illuminating metaphors like this one. Galileo died three-hundred years ago, but his metaphors are still as powerful as they were in his lifetime.

The field of robotics is particularly fertile for metaphorical relations because of the connections that can be made between robots and living things. Some aspects of robotics beg to be described by metaphors. Anthropomorphism is a great example of a specific type of metaphor. A mobile robot that pauses to survey its environment isn't "processing data from sensors" – it's "looking around." A robot with a depleted battery can be described as "exhausted." In an article about the advent of industrial automation, an author asked the question "At what point does that chainsaw replace Paul Bunyan?" (Markoff, 2012) The concept of a million humans losing their jobs due to robotics is hard to grasp, but the possibility of a folk hero being made obsolete by modern technology paints a vivid mental picture. But on the other hand, this metaphor greatly simplifies a vast problem, and is an example of how anthropomorphism and metaphor can sometimes misconstrue an idea.

Graphics

Diagrams and visual media are integral aspects of science and technology communication. Images make abstract concepts tangible. Colorful, attractive, interesting images can add new life to descriptions of science and technology. In an essay about science communication, Jean Trumbo argues that visual representations of science are absolutely necessary for creating bridges of understanding between scientists and laypeople (Trumbo, 1999). Entire novels have been written about the effective use of imagery in communicating ideas and this sort of visual theory is beyond the scope of this project. For a thorough evaluation of the effective use of imagery in the transmission of ideas, there are few more trusted sources than Donald Broadbent's *Perception and Communication* (1958).

When writing about science, it's important to not misuse images. Penrose and Katz warn about including too much detail in graphic media, and advise against using media that is not specifically relevant to the topic at hand (Penrose & Katz, 2010). Unnecessarily detailed images can backfire by overwhelming readers and making the topic at hand less clear. Gastel reaffirms this warning, suggesting that graphics be kept as "simple and familiar" as possible (Gastel, 1983). She offers the example of a writer who chose to use an x-ray of a heart to describe a specific type of heart failure. The x-ray was impossible for a layperson to interpret, and Gastel offers a diagram of a heart that would have been significantly clearer.

Vocabulary

Word choice influences understanding. In *Selling Science*, author Dorothy Nelkin illustrates how journalists convey certain beliefs about their topic through their vocabulary (1987). She uses the example of how journalists described the Three Mile Island nuclear meltdown as either an "accident" or an "incident." The former suggests human error while the latter is more neutral. At a time when information about the cause of the meltdown was sparse, journalists painted a picture with their vocabulary.

DARPA Robotics Challenge Case Studies

In this section, I will analyze a few robotics articles to see what rhetorical models (PEST, PAST, CUSP) they follow, what sorts of audiences and topics they cater to, and what messages writers try to convey. I do not intend the pieces I examine in this section to be representative of all robotics journalism -- taking a look at everything written about robotics in just a single year would be a monumental undertaking. Instead, I endeavored to find a few articles about a single topic, the DARPA Robotics Challenge (DRC) held in December 2013, that exemplify the perspectives and strategies presented in the previous section.

The DARPA Robotics Challenge is a competition funded by the US government's Defense Advanced Research Projects Agency. The challenge was created after DARPA program manager Gill Pratt, a roboticist at Olin College in Massachusetts, saw robots fail to meaningfully contribute to cleanup efforts at the Fukushima-Daiichi disaster zone. Even state-of-the-art disaster-relief robots had significant difficulty accessing the inner areas that most needed attention. Most of the robots were miniature vehicles like iRobot's PackBot. Although these robots were great for surveying certain parts of the area, their treaded wheels were incapable of crossing chaotic hallways in the facility and their solitary arms were incapable of opening doors for the robot.

Dr. Pratt hypothesized that robots with a more humanlike form factor would be able to more effectively operate in human-designed environments like Fukushima. So, for the Challenge, six teams of roboticists were supplied with million-dollar humanoid ATLAS robots, shown below in [Figure 4]. Using their robots, they were to complete several tasks that would simulate the scene of a disaster zone. Some teams chose to build their own robots, but the primary challenge was in programming software that could handle complex environments with minimal guidance from human operators. The winning team of the competition would take home a two million dollar prize and would certainly have no trouble finding employment at the world's most notable robotics companies and universities.

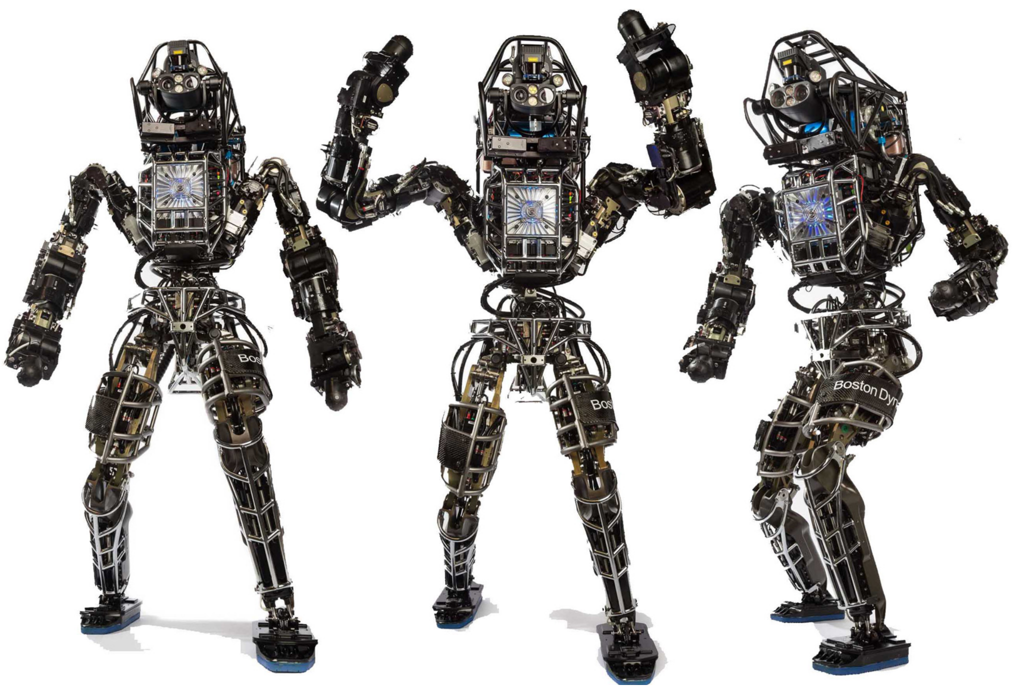

Figure 4 - Boston Dynamics's ATLAS Robot, the star competitor of the DARPA Robotics Challenge

I chose to study the DARPA Robotics Challenge because I think it is currently one of the most significant stories in robotics. Last time DARPA held a competition (the 2005 Grand Challenge), autonomous driving technology underwent a revolution. I think this technological metamorphosis is going to happen again. This time, the beneficiaries will be robots that work in complex environments, like homes, disaster zones, and other environments beyond the lab. Robotic manipulation – the technical term for any robotic task where the robot's arm touches or holds something – is at a tipping point. Decades of research are just waiting to be implemented into robust, “real world”-ready robots, and the DRC is likely to be the instigator of that change.

This revolution will have tremendous technological, commercial, and societal implications. With DRC technology, robots might finally be ready to assist around the home by doing dishes, picking up the dirty clothes on the floors of teenagers’ bedrooms, and walking the dog. Google has already expressed significant interest in the DRC by acquiring SCHAFT and Boston Dynamics, the developers of the most successful robots in the first round of field trials. After seeing Google’s success in developing the Grand Challenge’s autonomous driving technology (Google acquired the winning technology and team from Stanford after their autonomous vehicle drove 150 miles), it’s reasonable to speculate that DRC technology might be commercially available within a decade or so.

But the technology is also ripe for misuse. A robot that can walk through a chaotic environment, hold objects like a human, and work with minimal input from its operator is quite an asset on the battlefield. And, after all, let’s not forget what the D in DARPA stands for. DARPA is primarily a military organization. Though they’re responsible for wonderful creations such as the Internet and GPS, they’re also responsible for countless lethal technologies. I believe this is a significant aspect of the DRC. Writers who wish to foster critical understanding of the technology involved should present this aspect of the DRC.

All of these components make the Challenge an extremely interesting topic to study. There are so many factors at play – humanitarian intentions, commercial viability, cutting-edge technology, less-than-benign applications, and the thrill of competition –

that it should be extremely fertile ground for my own article. But first, I wanted to know what other writers said about the Challenge.

Boston Globe – It's Not Easy Getting Robots to Act Human

In this Boston Globe Business section piece, Scott Kirsner spotlights the Massachusetts Institute of Technology team competing in the DRC. Kirsner focuses on the difficulty of the tasks involved in the challenge and the effects this challenge might have on the robotics industry. Though it seems slightly out-of-place in the business section of the Globe, the author tailored the article to his audience by focusing on the companies and universities that support the challenge. Readers of the business section are more interested in these aspects of the DRC, and Kirsner does a great job of writing an article for them.

Kirsner employs metaphor to explain the challenge's significance, describing it as "the NFL Playoffs for the world's most sophisticated robots." He goes on to explain the inspiration for the challenge, the Fukushima disaster. With quotes from an MIT professor, he makes a connection between the challenges faced in a disaster zone and the competition's tasks. Kirsner only touches upon the difficulty of the competition, probably reasoning that technical analyses of each task is beyond the scope of his article. Instead, he finishes the article by describing business applications and iRobot's technical contributions to the competition. By focusing on Boston-area businesses like Boston Dynamics and iRobot, he keeps his business-oriented readers interested until the very end. Kirsner finishes the article by making a connection between the DRC and the early days of the Internet. He suggests that DRC enables robots to enter "homes, hospitals, public spaces, and workplaces" without much detail about *how* the competition enables this. This is a great example of the PEST model – Kirsner teaches how the public will *engage* with science and technology without helping them to *understand* it.

Although this article is informative and relevant to its reader's interests, I believe Kirsner could have been more in-depth about the significance of the DRC. He doesn't justify the DRC, neglecting to explain *why* the robots deployed at Fukushima were not effective. He spends even less time explaining why the DRC tasks are challenging. Readers are left knowing that the DRC is a big deal, but might be left asking why. For this reason, I believe this article largely follows the PAST model. After reading this piece, readers gain some appreciation for the advances that might result from this challenge, but have little understanding of the implications, challenges, and applications. The author also never discusses the potential uses on battlefields – the fact that this competition is Pentagon-funded is mentioned as an aside in parenthesis. Omissions like these constrain the reader's understanding of the DRC.

Popular Mechanics – Escape from the Lab

This Popular Mechanics essay by Joe Pappalardo is an example of how writing can be tailored to its audience. Pappalardo's writing presents the engineering challenges faced by roboticists participating in the DRC to technology-curious readers. Because he can assume that the audience of Popular Mechanics is interested in engineering and semi-literate in basic relevant concepts, the author goes into great detail explaining several technical aspects of the competition, such as inverse kinematics and force-feedback sensors in grippers. His description of the differences between Boston Dynamics's ATLAS and rock-star Japanese roboticist Hirochika Inoue's SCHAFT leaves readers not simply knowing that SCHAFT won the competition, but understanding *why* SCHAFT won. Even his description of the problem answered by DRC, the difficulties faced by robots at the Fukushima disaster zone, is very descriptive and detail-oriented. Pappalardo's writing inspires appreciation and enthusiasm for the robots of the DRC and for this reason his essay is exemplary of the PAST rhetorical stance.

Because Pappalardo took the rhetorical stance of a technology booster, he doesn't explore the implications of the DRC in-depth. When he mentions that Google purchased SCHAFT and Boston Dynamics, he doesn't speculate about their goals. He hardly even mentions the fact that DARPA is a military organization and never speculates about battlefield applications of DRC technology. At the end of the article, instead of making firm speculations about the effects this competition will have on the industry, he makes wistful statements about how this event might be the start of something very important. Readers are left excited, but their enthusiasm doesn't have much substance. Without some critical understanding of the real-world significance and applications, the excitement Pappalardo's piece conveys seems short-lasting. I believe this demonstrates how the PAST model can do a better job of inspiring appreciation when it's combined with the detailed analysis offered by the CUSP model.

Aeon Magazine – The Robots are Coming

Aeon "is an online magazine of ideas and culture" founded in 2012 in the UK. They have developed a reputation for high-quality "longform" content on the web, choosing to ignore internet trends for shorter and easy-to-consume content. They focus on five themes: world views, nature & cosmos, being human, living together, and altered states. This robotics article fits within the "Nature & Cosmos" section, which focuses on cutting-edge scientists, explorers, and industry observers. Since its launch, Aeon has been recognized for asking “the big questions” and many web content aggregators have praised the depth of its articles (Pando, BoingBoing). Aeon does not publish any details about its readership.

This article attempts to convey true understanding of the DRC. The author, Michael Belfiore, puts the DRC in its historic, technological, and economic contexts through a detailed analysis of the companies, individuals, and robots involved with the challenge. Telling the story through the eyes of an individual reporter at the Miami Homestead Speedway (where the DRC trials were held) gives the public a human-eye view of the competition, and makes the article more engaging.

Belfiore utilizes many of the strategies I discovered in my research. Right in the first paragraph of the article, he makes a connection between the DRC’s robots and sci-fi robots like C3PO and Terminator. He uses these familiar characters to build understanding of the DRC’s competitors. Throughout the article, he uses metaphors and anthropomorphism to describe ATLAS’s shortcomings, like in this sentence: “But for all its apparent capacity for work and even mayhem, it was a baby, barely aware of the world and how to move about within it.” He puts the contest within its historical context by explaining the history of DARPA, the failures of disaster relief robots at Fukushima, and the DARPA Grand Challenge, which jumpstarted autonomous car technology. Using the Internet, GPS, stealth airplanes, and the DARPA Grand Challenge as examples of DARPA’s technological investments, Belfiore effectively conveys the potential the DRC carries to advance the field of robotics. He appeals to the PEST model by showing the real-world applications of DRC technology. Humanoid robots in the home and in disaster zones both seem like very real possibilities thanks to Belfiore’s descriptions.

When discussing the long-term outcomes of the DRC, Belfiore only sparsely explains one particular aspect. He discusses Google's purchases of Boston Dynamics and SCHAFT, and spends a bit of time making connections with Google's other robotics venture, the driverless car (which, he points out, was developed after Google purchased one of the competitors at DARPA's 2005 Grand Challenge). But Belfiore spends only a paragraph explaining the potential for military applications. In this paragraph, Belfiore includes a quote from a fellow spectator, Mark Gubrud from the International Committee on Robot Arms Control, pointing out DARPA's role as a defense organization. Gubrud suggests that, beyond robots that do dull, dirty, and dangerous jobs, DARPA must be holding the event to develop robot soldiers. Belfiore remarks in his essay "Boy, what a killjoy. He's probably right, though. Very likely, C3PO and Terminator are equally destined to be part of our future." Before encountering this spectator, it seems like Belfiore accepted the DARPA program manager's insistence that DRC robots are intended for purely humanitarian purposes. There's no other mention of this possibility beyond this paragraph. I believe his article should have spent more time discussing this aspect of the DRC. To truly "critically understand" the DRC, the public should be informed of the potential misuses of science and technology. Besides this, Belfiore's article does an exemplary job of applying the CUSP model.

The New York Times – By Sci-Fi Standards, Newest Robots May Disappoint

Published in the New York Times's science section by John Markoff, this piece explains the difficulty of the DRC by making connections to science fiction robots. Markoff is known for his writing about robots – his 2013 piece describing industrial automation, “Skilled Work, Without the Worker” won him a Pullitzer Prize. This piece, which is a bit less in-depth than his prize-winning article, nevertheless shows Markoff’s skillful translation of cutting-edge robotics. This piece doesn’t match the detail of Markoff’s previous robotics articles but does a great job of reporting the facts of the competition. He explains some of the tasks, the teams, and makes the connection to DARPA’s 2005 Grand Challenge. Readers are left with an appreciation of the technology involved and its potential for growth.

But Markoff neglects to explain the context of the competition. He leaves out details such as its disaster-relief inspiration, Google’s potential commercialization of DRC technology, and the real-world applications of DRC technology. For this reason, this article is an example of the PAST model. Without context or an explanation of the competition’s potential beyond the realm of engineering, the public is left without an understanding of *why* the DRC is important.

Science and Technology Communication Practice: Writing About the DARPA Robotics Challenge

Introduction

The DARPA Robotics Challenge is currently one of the most significant stories in robotics. With eleven million dollars of robots distributed to 6 teams, thirty-four million dollars in prize money at stake, many of the world's leading robotics companies, universities, and institutions participating with some of the most sophisticated robots ever built, it's easy to see why (DARPA, 2012). But these are surface level details. The real significance is in the technology. Nothing like the DARPA challenge has ever taken place. Nobody has ever provided roboticists with such an advanced challenge and the tools and incentives to conquer it.

Coverage of the DRC typically presents the challenge, outlines the tasks, talks about the robots, and that's it. Hardly any articles explain the **significance** of the technology, explain how it could improve commercial robots, and introduce the history of robots like ATLAS. An article might discuss the technological advances that will result from the DRC, the applications to disaster zones, or the prospects of businesses that are involved in the challenge. But not one of the 20-30 pieces I read tied all of these perspectives together into a cohesive explanation of the challenge's significance. In my article, I'd like to enlighten readers about the importance of the DRC by examining all of these aspects.

To help readers understand why the DRC is important, I'll start by explaining why this is such a challenge for roboticists and why it's so significant for the field. I'll start the article with a brief history lesson, introducing the origins of the DRC by starting with DARPA's early interest in robotic elephants, and move onto the DARPA Grand Challenge which jump-started autonomous driving technology. I'll next establish the stakes of the DRC by explaining how we might see similar improvements in robotic manipulation.

Very few pieces about the DRC effectively convey the military possibilities of DRC technology. If it's brought up at all, the fact that this is a Department of Defense-funded competition is only mentioned as an aside. Only one NPR piece really goes into the military uses of DRC robots. Since taxpayers are paying the bill for the DRC through Defense Department funding for DARPA, I believe it's important that writers remind the public what the D in DARPA stands for. Though the event organizers claim the DRC is purely intended to foster advances in humanitarian technology, these capabilities are also useful on a battlefield. If a writer describing the DRC really wants their readers to understand the full picture, they should point out that DARPA is a military organization and explore ATLAS's capacity for completing non-humanitarian missions.

To present all of these ideas, I'll combine the results of my literature review of science communication rhetoric into a CUSP-heavy article that also includes PAST and PEST appeals. I'll apply PAST by explaining the advanced technology involved, the historical implications, and the novelty of the challenge. I'll show PEST by explaining how these robots can save lives at disaster zones and how they might be commercialized to help out around the house. Finally, I'll apply the CUSP model by helping the public to understand the commercial, military, and humanitarian benefits of the technology. I'll also explain the major players in the DRC and who's paying the bills, so that the public can understand the bigger picture. The CUSP aspect of my article is the most important because I think it's where the greatest gap exists in prior coverage of the DRC.

I will also incorporate the other recommendations for science communication that I uncovered during my research. I'll translate the technological difficulties of the DRC through narratives, anthropomorphism of ATLAS, and other metaphors. My piece is targeted for the Boston Globe magazine, so I'll try to make connections to local audiences. This is a medium-sized, primarily-local weekly magazine that focuses on issues and topics relevant to Boston-area audiences. Since so many companies, universities, and individuals involved in the DRC are also near Boston (Boston Dynamics, iRobot, WPI, MIT, and Olin College), these connections should be easy to make. My article's scope is larger than a discussion of these individual institutions, but referring to them sporadically throughout the article will make my writing relevant to its readers.

These are some of the guiding questions I'll try to address in my article. I won't necessarily answer all of these completely, but I want to touch on each of them:

Why does the DRC matter?

How could DRC technology affect me?

Who are the major players in the DRC?

Who pays for this technology?

Who will benefit from it?

Throughout the article, I'll connect my writing to my research through italicized notes. To read the article without annotations, look in [**Appendix A]**.

The DARPA Robotics Challenge: The hottest front line in the robot revolution

Robots have always been important to the US Government's Defense Advanced Research Projects Agency (DARPA). In the 1960s, soldiers in Vietnam reported seeing elephants alongside enemy troops carrying war supplies up steep hills and across terrain that traditional vehicles could not traverse.

Inspired by these reports, DARPA engineers set out to build a gas-powered mechanical elephant that could carry supplies for US troops. But when he heard their idea, the agency's director quickly shut down the project, fearing it would attract public ridicule.

Nevertheless, 50 years later, DARPA-funded BigDog, a pony-sized four-legged automaton capable of carrying three-hundred pounds up hills and across rivers, began field trials.

Figure 5 - A fully-loaded BigDog, built by Waltham-based Boston Dynamics and funded by DARPA, takes a walk outdoors

This interesting anecdote serves as the "lede" for my story. Journalists use appealing ledes to attract the attention of readers. This also serves a few "public understanding" purposes. First, introduces DARPA as a military project organization. This is important for the point I want to make about military applications of ATLAS. Next, it highlights the results DARPA has delivered in the past. This gives the DRC credibility, and when I ask "What's next?" readers are inspired to imagine something significant. It also gives an example of a piece of state-of-the-art robotic technology with connections to DRC through Boston Dynamics. Finally, this connection to Boston makes the piece relevant to Boston-area readers early on (the rest of the piece diverges from these connections, but if readers are "hooked" early on, this is okay).

DARPA has invested heavily into robotics over the past two decades. Ten years ago, DARPA created The Grand Challenge. Hoping to improve autonomous driving technology through healthy competition, DARPA offered a two million dollar prize to the first team of roboticists who could program a car to drive a pre-determined route across the desert without crashing or breaking down.

I wanted to make a connection to the Google car early in my article. This was for several reasons. First, readers are probably familiar with the Google car, thanks to the widespread press coverage around it. Driving is something most people experience on a daily basis, so this example shows a PEST rhetorical appeal. It also fills out the context *for the DRC by explaining an analogous competition. The incredible results of the past DRC tells readers what to expect and why the 2013 DRC is significant.*

In 2004, the first year of the competition, the winning vehicle drove only 7 miles before getting stuck on a large rock. The following year, 22 cars surpassed that record and five vehicles completed the entire 150-mile course. Five years later, the winning team (now employed by Google) achieved another milestone: 100,000 miles without an accident. Before the Grand Challenge, autonomous driving was an unsolved problem in the field of robotics, but now the Google car is being developed for consumers.

Figure 6 - Left: the winner of the 2005 DARPA Grand Challenge. Right: The same technology 9 years later with Google's branding

What's the next big thing in robotics?

Marc Raibert is building the answers to that question. In 1980, Raibert founded Carnegie-Mellon's Leg Lab. A few years later, Raibert demonstrated his first walking robot. Actually, it hopped more than it walked, but the "3D One-Leg Hopper" took the first steps towards the development of robots that could balance and walk like humans. In the 30 years since that first demonstration, Raibert has become a bit of a legend in the field of robotics, starting MIT's Leg Lab in 1986 and Boston Dynamics in 1992.

A piece of advice many science journalists offered was to write about the people involved in science. Anecdotes about the triumphs of a brilliant individual and his team are far more interesting than descriptions of the results of a faceless lab or company. The "took the first steps towards…" is a silly little reference to the fact that we're talking about walking robots. Zinsser said good science writing should be good writing, so I tried to include clever little tricks like this throughout the piece.

Boston Dynamics builds some of the most advanced robots ever imagined. Their robots are unique in that they are inspired by biological systems, They have legs and arms and walk like humans or four-legged animals. As far as we know, the robotic elephant isn't in the works. But what Raibert and his team have accomplished in the last 30 years is nothing short of incredible.

One descendant of Raibert's hopper, Cheetah, has four legs and can run 35 miles per hour over rough terrain. AlphaDog, BigDog's big brother, carries up to four-hundred pounds up inclines of up to 45 degrees. Another creation, called ATLAS, is five and a half feet tall, stands on two legs, and can use "his" two arms to (hypothetically) do many of the things a human can do.

Except he can't.

In fact, he often has trouble simply staying upright. When describing ATLAS, DARPA program manager Gill Pratt likened the million-dollar automaton to a newborn, saying "a 1-year-old child can barely walk, a 1-year-old child falls down a lot [...] this is where we are right now."

I anthropomorphize Boston Dynamics' creations with this family metaphor. Raibert and his team don't breed robots, but it makes sense to think of the different iterations as family members and the improvements as new generations. The quote from Gill Pratt is really great, so I'll keep referring to it throughout the piece. It not only helps readers understand ATLAS's shortcomings, but it also explains his potential for growth.

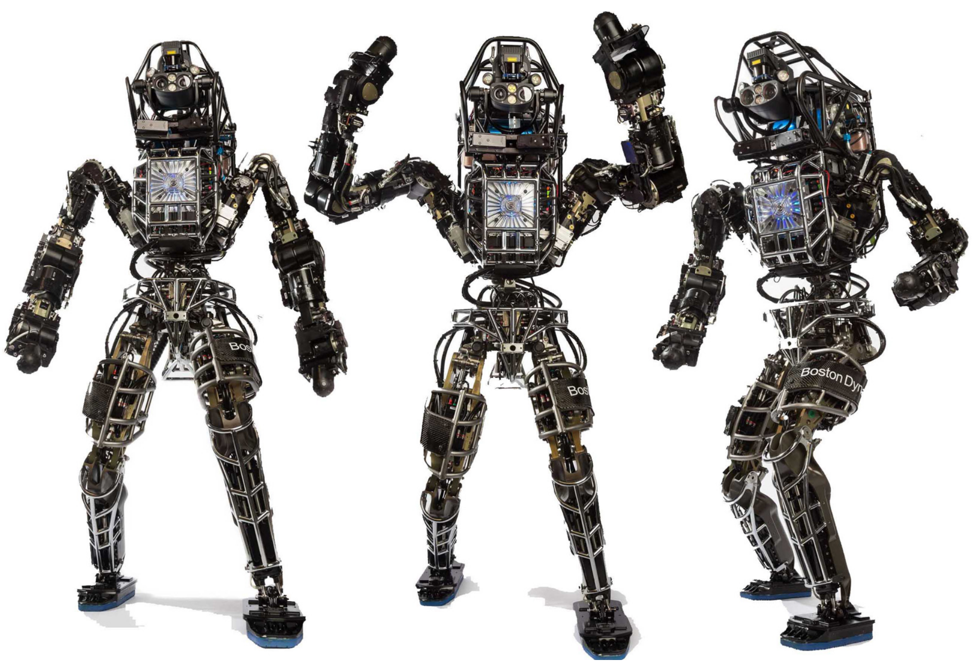

Figure 7 - Boston Dynamics' ATLAS, the star competitor at the DARPA Robotics Challenge

Mechanically, ATLAS is capable. But he isn't a very smart robot. The software that drives his pneumatically-actuated arms and legs isn't finished. He has trouble balancing, walking, grabbing things, and doing all of the things you might expect a humanoid robot to be able to do. To put it simply, his body has outpaced his brain. The field of robotic manipulation – programming a robot to interact with the world using its arms – is well-established for factory and laboratory robots. But robots (like ATLAS) that autonomously interact with "the real world" beyond the controlled settings of factories and labs are not yet field-proven.

With "he isn't a very smart robot" I anthropomorphize ATLAS to subtly explain the technical difficulties of the DRC. Of course, ATLAS is neither smart nor dumb and he doesn't have a brain, he's a computer. But readers might not understand a sentence like "the algorithms driving his arms are insufficiently complex." The human metaphor makes a lot more sense.

But Dr. Pratt thinks robots are ready to go out into the world. So in 2012, as a program manager at DARPA, he challenged roboticists to program a computer-simulated robot to perform complex tasks in a simulated disaster zone. The six teams with the most successful simulations received real ATLAS robots. For the second round of the competition, which was held in December, they needed to write software that would enable the real ATLAS to complete the same tasks in the physical world. Some teams chose to build their own robots, some of which are shown above. $10 million in winnings are at stake. This time, they're calling it the DARPA Robotics Challenge, but it promises to be just as grand as their last competition.

Figure 8 - iRobot PackBots survey damage at Fukushima-Daiichi. Source: Tokyo Electric Power Company

DARPA Robotics Challenge

Robots have been widely used in combat zones, vehicle checkpoints, search-and-rescue missions, and disaster zones since iRobot deployed the PackBot for the first time at Ground Zero in 2001. Since then, they've saved hundreds of lives by disarming IEDS in Iraq and Afghanistan, searching suspicious packages at the Boston Marathon bombings, and surveying damage at the Fukushima-Daiichi nuclear meltdown.

But they can't do everything a person can do. Contemporary disaster-relief and military robots are small, remote-controlled wheeled or treaded machines, with software only complex enough to perform some driving autonomously. When complex tasks are involved or the environment is too chaotic for a wheeled robot to traverse, humans are still the most capable option.

In my first iteration of my article, I used general examples in the second sentence, saying "They've saved countless lives by disarming explosives, searching suspicious areas, and replacing humans in some other dangerous tasks." While editing, I chose to replace these with these concrete examples of how robots have been deployed. By providing settings and clearly-defined tasks, I convey the real applications of robots. The picture further reinforces the real-world utility of robots. When I say "humans are still the most capable option," I'm setting up Gill Pratt's idea that humanoid robots are the answer. Readers will be more likely to understand his reasoning with this example.

This point was proven when robots were deployed at the Fukushima-Daiichi disaster zone in 2011. As plant engineers watched roboticists wheel through the plant with their remotely-operated mechanical proxies, it quickly became evident that even the most complex robots available would not be able to replace human plant workers. When doors needed opening, switches needed flicking, buttons needed pressing, or valves needed adjusting, the robots simply weren't up to the task. Precise or complex maneuvers such as these were simply not possible with the robots on hand. Furthermore, radiation disrupted radio links with the robots and ruined the circuitry of some of the less hardy automatons.

Figure 9 – An iRobot Warrior, used for hazardous waste clean-up, search-and-rescue, and explosive ordnance disposal missions in Iraq and Afghanistan, drives across the grounds of Fukushima-Daiichi. Warrior is one of several robots that wasn't quite up to the challenge of saving Fukushima. Source: Tokyo Electric Power Company.

After DARPA director Gill Pratt saw robots fail to effectively assist cleanup efforts at the Fukushima-Daiichi meltdown, he knew disaster-relief robots needed significant improvements. Pratt thought robots like ATLAS would be a better option than wheeled robots because a robot that looks like a human could more closely match the capabilities of a human. So Pratt designed the DARPA Robotics Challenge, a competition in which robots would perform complex tasks in a simulated disaster zone.

At the DRC Trials held in Miami in December, sixteen teams from all around the world (though six teams received ATLASes, ten more chose to build their own robots) converged to demonstrate what they had taught their robots over the previous six months.

Between extended pauses to survey the task ahead of them, their robots completed tasks that, just a few years prior, no robots had done. Robots like these – the majority of which were "humanoid" machines with two arms, two legs, and human-like gaits – had, for the most part, never accomplished much outside of a lab. But here they were, climbing ladders, operating power tools, cleaning paths of debris, even driving a small vehicle.

Figure 10 - In this shot, an ATLAS belonging to Worcester Polytechnic Institute begins the driving task. Source: DARPA

Some writers called the event the robot Olympics. But it's probably more accurate to call it a robot day care. This shouldn't underplay the significance of the event, but anyone expecting Olympian agility or poise from the mechanical competitors of the Challenge would be sorely disappointed. The robots are mechanically advanced but, in terms of software, they were practically infants. None of them even so much as took a step without an umbilical power source and fall-restricting support rope.

With "robot day care" and "practically infants," I use metaphor and refer to Gill Pratt's analogy that ATLAS is a two-year-old which was included earlier in the article.

Nevertheless, many of the world' leaders in technology watched as the robots stumbled around for a weekend. Though the robots at Miami Speedway in December were slow and careful, astute observers knew the robots would not stay this way. Like the robotic vehicles of the first round of DARPA's 2005 Grand Challenge, these robots were just taking baby steps. At the next round of the competition, scheduled for June 2015, they knew they could expect extraordinary improvements. Rumors suggest that the support ropes will be eliminated and robots will have to operate entirely autonomously. With no tethers to protect the robots from falling or human operators to assist their movements, the stakes will be significantly higher.

Here, I employ narrative to make the competition seem more "real". By referring to the scenery and the spectators at the DRC trials, I'm making the competition seem more concrete than an abstract description would make it sound. Readers can imagine technology and military bigwigs watching the competition. From this, I transition into a bigger-picture explanation of DRC possibilities. I also maintain the ATLAS-as-child metaphor, this time to suggest his potential for growth.

If DARPA is successful in their championing of humanoid robots, what will be the implications? Disaster relief, search-and-rescue, and hazardous material cleanup robots will almost certainly be the first successful commercial iterations of DRC technology. But we're likely to see the technology show up in some additional areas, too.

Don't forget what the D in DARPA stands for – the DRC is a Department of Defense-funded competition. These $1 million robots weren't built by a humanitarian organization – they're military technology. And the military is very interested in developing robots for more and more battlefield situations. In fact, General Robert Cole announced at an Army symposium in January that robots might replace up to 25% of American combat soldiers by 2030.

In the preceding paragraph, I start transitioning into more of a critical analysis of the implications of DRC technology. With real-life examples and clear prose throughout, I've conveyed understanding. Here, that understanding transitions to the dialogue-based model of CUSP, rather than the deficit model of merely presenting the technology.

Although DRC organizers are vigilant in their reassurances that the competition is purely intended for humanitarian purposes, DARPA's mission says otherwise. Documentation that DARPA submitted to the Department of Defense's Tactical Technology Office stated that proposals to participate in the DRC will be evaluated, in part, based on their capacity to contribute to DARPA's mission. The document goes on to explain that DARPA's mission is "to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their application."

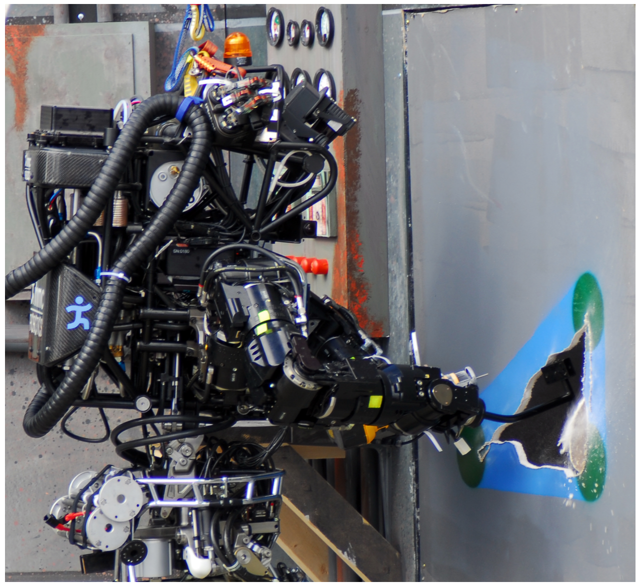

Figure 11 - ATLAS uses a power tool to breach a locked door.

So there's at least some interest in applying DRC technology to robotic soldiers. And this shouldn't be hard to do. The tools and software being developed for the DRC can be used on the battlefield just as easily as they can be used for humanitarian missions. In short, search-and-rescue robots also serve quite well as seek-and-destroy robots. For example, in one task, robots picked up a power tool, pointed it at a target, and drilled a hole in the door to reach the knob on the other side. It's not hard to imagine how the ability to hold and operate a power tool translates to using a sidearm. In fact, many of the challenges can be reframed in a similar manner. At the end of the day, no matter how smart they seem, robots are tools. Their operators get to decide whether they're used for humanitarian or military purposes.

Here, I use a specific example (the robot drilling a target) to help readers ***critically understand*** *exactly how the DRC translates to military technology. The graphic further clarifies this connection.*

So it's heartening to hear DRC officials affirm that the technology is purely intended for disaster relief missions. But the "D" in DARPA *does* stand for defense. And the forty-five million dollars DARPA plans to invest into the challenge (35 million for prizes, 10.5 million for the six ATLASes distributed to teams) didn't come from a humanitarian organization – these funds came from the Defense Department.

Knowing who paid for the DRC is an important component of understanding the challenge. The public paid for this, after all, so they should know exactly what avenue their money took.

But all this concern for ATLAS-as-soldier might be unnecessary now that Google has absorbed Boston Dynamics. Boston Dynamics's primary customers have always been DARPA and the US military. But Google executives went on record to say that, while existing contracts will continue to be honored, they have no intention to pursue further deals with the military. Instead, Andy Rubin, the former director of Google's Android mobile operating system and present chief of the company's robotics initiative, plans to incorporate Boston Dynamics's technology into his mysterious self-described "moonshot" robot project(s). Nobody knows what to expect from these efforts. But after seeing Google's succeed with its incubation of Grand Challenge technology, it's reasonable to expect something equally amazing.

Will Google-branded ATLASes do your your dishes in the near future? It's possible. The algorithms developed for the DARPA Robotics Challenge are just as capable of picking up your teenager's dirty room as they are of cleaning up radioactive waste (and some parents might argue that the two tasks are one and the same).

Will Google-branded ATLASes help relief efforts at a major disaster in the near future? Almost certainly. After the next round of the competition is over, ATLAS and his friends will likely be mature enough to really make a difference in such scenarios. Of course, we'll learn more from the next disaster and this will inform the next generation of ATLASes, but the potential is already here.

Could robots like ATLAS wearing Army fatigues assist in America's next major conflict? It's hard to tell, but it's certainly possible. If the Defense Department has their way, it's very likely.

I wanted to end the article with a few rhetorical questions that convey the uncertain future of DRC tech. I don't claim to have the answers – nobody but DARPA does. But with these questions, I get readers thinking.

One thing is certain: the robots are coming. And, to draw that one-year-old analogy out just a bit further, nobody's going to be able to stop their maturation.

Conclusion

This project taught me a great deal about science and technology communication, non-fiction writing in general, and how robots are presented to the public. I learned the rhetorical considerations that model how writers believe the public should receive science and technology. I learned how to attune a topic for its audience. Finally, I studied some of the techniques authors use to write engaging nonfictional prose. Through my research, I learned that writing about science and technology is a vast field, encompassing a multitude of topics in journalism, rhetoric, social science, and politics.

Writing an article about the DARPA Robotics Challenge allowed me to practice the theories and recommendations uncovered in my research. But my research didn't prepare me for a couple of aspects of the article. I first learned how difficult it is to end a piece. Because it's the last thing the reader hears, the conclusion of an article really says a lot about the point the author is trying to convey. My article tried to present so many ideas that I struggled to find the right topic on which to end. I also realized copyright is a major concern when including graphic media, something I hadn't encountered during my research. Because I was not able to get authorization to use the copyrighted media in my article, I learned about fair use. A fair use defense for the graphics used in my article is included in **[Appendix B]**. Legal issues affect many professions and I learned science writing is not immune to its influence.

If I had more time to work on this project, I would have liked to further investigate the journalistic process. One aspect of this process that my research didn't really cover is the actual finding of facts. Discovering topics, interviewing researchers and technologists, and fact-checking are all very important parts of science writing "in the real world." In my writing, I assumed this component was taken care of, so I focused on the conveyance of this information to the public. But information gathering is an essential first step.

The ability to present research and inventions is an essential skill for scientists and technologists. Inventors need to be able to pitch their gadget to potential investors. Once their start-up has funding, they need to be able to market their work to the public. Scientists must be able to explain their research to potential backers, whether they are department leaders, trustees of a university, or congressional representatives. Engineers need to be able to communicate their work to managers who might not be familiar with technical terms. This project has been an incredibly educational introduction to the considerations and skills involved in this type of communication. I've established a solid foundation of skills which I plan to build upon for the rest of my life.

Appendices

Appendix A – My article sans annotations

Robots have always been important to the US Government's Defense Advanced Research Projects Agency (DARPA). In the 1960s, soldiers in Vietnam reported seeing elephants alongside enemy troops carrying war supplies up steep hills and across terrain that traditional vehicles could not traverse.

Inspired by these reports, DARPA engineers set out to build a gas-powered mechanical elephant that could carry supplies for US troops. But when he heard their idea, the agency's director quickly shut down the project, fearing it would attract public ridicule.

Nevertheless, 50 years later, DARPA-funded BigDog, a pony-sized four-legged automaton capable of carrying three-hundred pounds up hills and across rivers, began field trials.

Figure 12 - A fully-loaded BigDog, built by Waltham-based Boston Dynamics and funded by DARPA, takes a walk outdoors

DARPA has invested heavily into robotics over the past two decades. Ten years ago, DARPA created The Grand Challenge. Hoping to improve autonomous driving technology through healthy competition, DARPA offered a two million dollar prize to the first team of roboticists who could program a car to drive a pre-determined route across the desert without crashing or breaking down.

In 2004, the first year of the competition, the winning vehicle drove only 7 miles before getting stuck on a large rock. The following year, 22 cars surpassed that record and five vehicles completed the entire 150-mile course. Five years later, the winning team (now employed by Google) achieved another milestone: 100,000 miles without an accident. Before the Grand Challenge, autonomous driving was an unsolved problem in the field of robotics, but now the Google car is being developed for consumers.

Figure 13 - Left: the winner of the 2005 DARPA Grand Challenge. Right: The same technology 9 years later with Google's branding

What's the next big thing in robotics?

Marc Raibert is building the answers to that question. In 1980, Raibert founded Carnegie-Mellon's Leg Lab. A few years later, Raibert demonstrated his first walking robot. Actually, it hopped more than it walked, but the "3D One-Leg Hopper" took the first steps towards the development of robots that could balance and walk like humans. In the 30 years since that first demonstration, Raibert has become a bit of a legend in the field of robotics, starting MIT's Leg Lab in 1986 and Boston Dynamics in 1992.

Boston Dynamics builds some of the most advanced robots ever imagined. Their robots are unique in that they are inspired by biological systems, They have legs and arms and walk like humans or four-legged animals. As far as we know, the robotic elephant isn't in the works. But what Raibert and his team have accomplished in the last 30 years is nothing short of incredible.

One descendant of Raibert's hopper, Cheetah, has four legs and can run 35 miles per hour over rough terrain. AlphaDog, BigDog's big brother, carries up to four-hundred pounds up inclines of up to 45 degrees. Another creation, called ATLAS, is five and a half feet tall, stands on two legs, and can use "his" two arms to (hypothetically) do many of the things a human can do.

Except he can't.

In fact, he often has trouble simply staying upright. When describing ATLAS, DARPA program manager Gill Pratt likened the million-dollar automaton to a newborn, saying "a 1-year-old child can barely walk, a 1-year-old child falls down a lot [...] this is where we are right now."

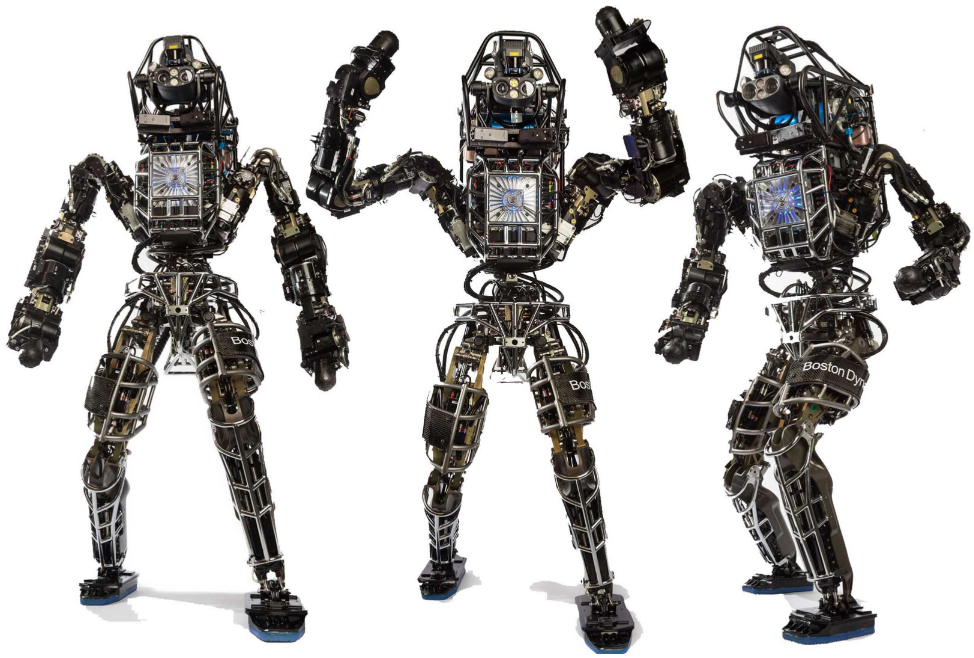

Figure 14 - Boston Dynamics' ATLAS, the star competitor at the DARPA Robotics Challenge

Mechanically, ATLAS is capable. But he isn't a very smart robot. The software that drives his pneumatically-actuated arms and legs isn't finished. He has trouble balancing, walking, grabbing things, and doing all of the things you might expect a humanoid robot to be able to do. To put it simply, his body has outpaced his brain. The field of robotic manipulation – programming a robot to interact with the world using its arms – is well-established for factory and laboratory robots. But robots (like ATLAS) that autonomously interact with "the real world" beyond the controlled settings of factories and labs are not yet field-proven.

But Dr. Pratt thinks robots are ready to go out into the world. So in 2012, as a program manager at DARPA, he challenged roboticists to program a computer-simulated robot to perform complex tasks in a simulated disaster zone. The six teams with the most successful simulations received real ATLAS robots. For the second round of the competition, which was held in December, they needed to write software that would enable the real ATLAS to complete the same tasks in the physical world. Some teams chose to build their own robots, some of which are shown above. $10 million in winnings are at stake. This time, they're calling it the DARPA Robotics Challenge, but it promises to be just as grand as their last competition.

Figure 15 - iRobot PackBots survey damage at Fukushima-Daiichi. Source: Tokyo Electric Power Company

DARPA Robotics Challenge

Robots have been widely used in combat zones, vehicle checkpoints, search-and-rescue missions, and disaster zones since iRobot deployed the PackBot for the first time at Ground Zero in 2001. Since then, they've saved hundreds of lives by disarming IEDS in Iraq and Afghanistan, searching suspicious packages at the Boston Marathon bombings, and surveying damage at the Fukushima-Daiichi nuclear meltdown.

But they can't do everything a person can do. Contemporary disaster-relief and military robots are small, remote-controlled wheeled or treaded machines, with software only complex enough to perform some driving autonomously. When complex tasks are involved or the environment is too chaotic for a wheeled robot to traverse, humans are still the most capable option.

This point was proven when robots were deployed at the Fukushima-Daiichi disaster zone in 2011. As plant engineers watched roboticists wheel through the plant with their remotely-operated mechanical proxies, it quickly became evident that even the most complex robots available would not be able to replace human plant workers. When doors needed opening, switches needed flicking, buttons needed pressing, or valves needed adjusting, the robots simply weren't up to the task. Precise or complex maneuvers such as these were simply not possible with the robots on hand. Furthermore, radiation disrupted radio links with the robots and ruined the circuitry of some of the less hardy automatons.

Figure 16 – An iRobot Warrior, used for hazardous waste clean-up, search-and-rescue, and explosive ordnance disposal missions in Iraq and Afghanistan, drives across the grounds of Fukushima-Daiichi. Warrior is one of several robots that wasn't quite up to the challenge of saving Fukushima. Source: Tokyo Electric Power Company.

After DARPA director Gill Pratt saw robots fail to effectively assist cleanup efforts at the Fukushima-Daiichi meltdown, he knew disaster-relief robots needed significant improvements. Pratt thought robots like ATLAS would be a better option than wheeled robots because a robot that looks like a human could more closely match the capabilities of a human. So Pratt designed the DARPA Robotics Challenge, a competition in which robots would perform complex tasks in a simulated disaster zone.

At the DRC Trials held in Miami in December, sixteen teams from all around the world (though six teams received ATLASes, ten more chose to build their own robots) converged to demonstrate what they had taught their robots over the previous six months.

Between extended pauses to survey the task ahead of them, their robots completed tasks that, just a few years prior, no robots had done. Robots like these – the majority of which were "humanoid" machines with two arms, two legs, and human-like gaits – had, for the most part, never accomplished much outside of a lab. But here they were, climbing ladders, operating power tools, cleaning paths of debris, even driving a small vehicle.

Figure 17 - In this shot, an ATLAS belonging to Worcester Polytechnic Institute begins the driving task. Source: DARPA

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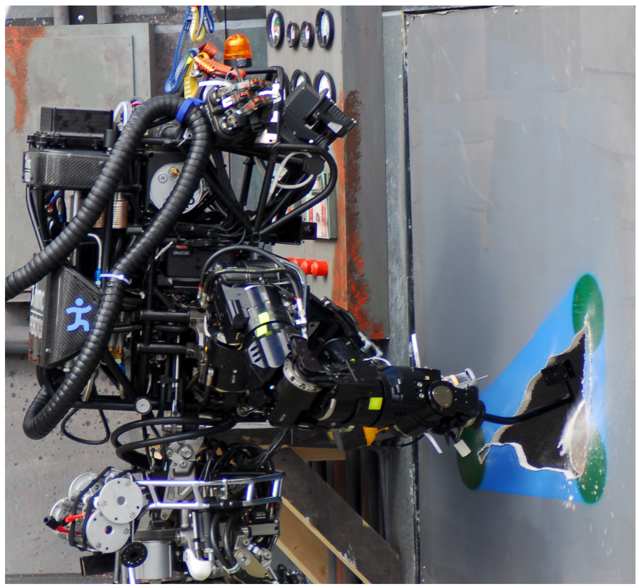

Figure 18 - ATLAS uses a power tool to breach a locked door.

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Could robots like ATLAS wearing Army fatigues assist in America's next major conflict? It's hard to tell, but it's certainly possible. If the Defense Department has their way, it's very likely.

One thing is certain: the robots are coming. And nobody can slow their maturation.

Appendix B – Fair Use Documentation for my Article

I reached out to the sources of all of the images used in my article for permissions, but did not receive answers in time for the publication of this work. To defend my use of these images, I'm including this explanation of how my usage qualifies as "fair use." I believe my usage of graphic media from Boston Dynamics, Schaft, and Tokyo Electric Power Company qualifies as **transformative**. To prove this point, I will address the four factor fair use test. These four factors are:

1 – What is the character of the use?

2 – What is the nature of the work to be used?

3 – How much of the work will you use?

4 – What effect would this use have on the market for the original or for permissions if the use were widespread?

Factor 1 - Character

My project fits under the following categories:

- Criticism
- Commentary
- Newsreporting
- Nonprofit
- Educational

Because of the critical, commentary, and newsporting aspects of my work, it can be considered **transformative** and distinct from the original usages of the graphic media

I used. The nonprofit and educational nature of my work adds weight to my **transformative fair use claim.**

Factor 2 – Nature

The media I used in my article is both **factual** and **published**, tipping the balance in favor of fair use.

Factor 3 – Usage

I have only used two graphics from Boston Dynamics, one image from Schaft, and two images from Tokyo Electric Power Company. Because I only used images where it was necessary to prove my point, this usage can be considered **an appropriate amount for a transformative purpose**.

Factor 4 – Widespread usage

This is the hardest factor to answer. Predicting the effects of widespread usage is difficult. But the images I used have already been used widely in the media, so I posit that my usage of these images, even if my article becomes widely-consumed, will **not** affect the market for the originals or for permissions.

Works Cited

Aristotle. *Rhetoric*. Ed. Edward Meredith Cope and John Edwin Sandys. Cambridge: Cambridge UP, 2010. Print.

Bauer, Martin W., Kristina Petkova, and Pepka Boyadjieva. "Public knowledge of and attitudes to science: Alternative measures that may end the “science war”." *Science, technology & human values* 25.1 (2000): 30-51.

Belfiore, Michael. "The Robots Are Coming." *Aeon Magazine*. Aeon Media Ltd., 12 Mar. 2014. Web. 4 Apr. 2014.

Besley, John C. "Public engagement and the impact of fairness perceptions on decision favorability and acceptance." *Science Communication* 32.2 (2010): 256-280.

Doc. No. DARPA-BAA-12-39 (2012). Print.

Duffy, Brian R. "Anthropomorphism and the social robot." Robotics and autonomous systems 42.3 (2003): 177-190.

Evans, Geoffrey, and John Durant. "The relationship between knowledge and attitudes in the public understanding of science in Britain." *Public Understanding of Science* 4.1 (1995): 57-74.

"Fair Use of Copyrighted Materials." *UT Copyright Crash Course*. University of Texas, n.d. Web. 26 Apr. 2014.

Kahlor, LeeAnn, and Patricia A. Stout. *Communicating Science: New Agendas in Communication*. New York: Routledge, 2009. Print.

Kirsner, Scott. "It’s Not Easy Getting Robots to Act Human." Editorial. *The Boston Globe* 15 Dec. 2013: n. pag. *BostonGlobe.com*. The Boston Globe, 15 Dec. 2013. Web. 26 Mar. 2014.

Serafini, Anthony. "RA Millikan and the Maturity of American Science." *Legends in Their Own Time*. Springer US, 1993. 79-98.

Gastel, Barbara. *Presenting Science to the Public*. Philadelphia: ISI, 1983. Print.

Green, Andrew. "Understanding magazine audiences." WARC, 2011. Web. 15 Jan. 2014.

Gunning, Robert. "The fog index after twenty years." *Journal of Business Communication* 6.2 (1969): 3-13.

Krulwich, Robert. "Tell Me A Story." 2008 Commencement. CA, Pasadena. 7 Jan. 2014. Speech.

Lakoff, George. "The contemporary theory of metaphor." Metaphor and thought 2 (1993): 202-251.

Maglio, Tony. "Fox's 'Cosmos' Watched by 8.5 Million Across 10 Networks." MSN TV. MSN, 10 Mar. 2014. Web. 18 Mar. 2014.

Markoff, John. "By Sci-Fi Standards, Newest Robots May Disappoint." *The New York Times*. The New York Times, 20 Dec. 2013. Web. 14 Mar. 2014.

Markoff, John. "The Umbilical Link of Man to Robot." The New York Times. The New York Times, 21 Oct. 2013. Web. 1 Mar. 2014.

Myers, G. “Discourse Studies of Scientific Popularization: Questioning the Boundaries’, *Discourse Studies*, 2003.

Nelkin, Dorothy. *Selling Science: How the Press Covers Science and Technology*. New York: W.H. Freeman, 1987. Print.

Penrose, Ann M., and Steven B. Katz. *Writing in the Sciences: Exploring Conventions of Scientific Discourse*. New York: Pearson Longman, 2010. Print.

Perrault, Sarah. *Communicating Popular Science: From Deficit to Democracy*. New York: Palgrave-Macmillan, 2013. Print.

"Public Attitudes Towards Robots." *Eurobarometer* 382 (2012): 4-15. Print.

Serafini, Anthony. *The epic history of biology*. Plenum, 1993.

Sturgis, Patrick, and Nick Allum. "Science in society: re-evaluating the deficit model of public attitudes." *Public understanding of science* 13.1 (2004): 55-74.

Treise, Debbie, and Michael F. Weigold. "Advancing Science Communication A Survey of Science Communicators." Science Communication 23.3 (2002): 310-322.

Trumbo, Jean. "Visual literacy and science communication." *Science Communication* 20.4 (1999): 409-425.

Van Allen, Fox. "Back to the Future 2's Robotic Gas Station Arrives a Year Early." *Techlicious*. Time Magazine, 26 Jan. 2014. Web. 18 Feb. 2014.

Ziman, John. "Public understanding of science." *Science, Technology & Human Values* 16.1 (1991): 99-105.

Zinsser, William Knowlton. *On Writing Well: The Classic Guide to Writing Nonfiction*. New York: HarperCollins, 1976. Print.