Understanding Space Technologies through *Mobile Suit Gundam: Iron-Blooded Orphans*

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

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Abstract

With the growing space industry in the coming decades, space technologies will play a greater role in our lives. Moving forward, a significant human presence in space will be sought after given the resources available in space and the technologies that will spur from innovation. These technologies are nuanced and unexplored with regards to its social impacts. The anime series *Mobile Suit Gundam: Iron-Blooded Orphans* will be used to demonstrate how media can be utilized to consider potential cautions engineers must face when developing these technologies. The show depicts inequality and exploitation as a result of expansion beyond Earth, and these narratives serve as a possible future scenario that can help engineers understanding the implications of revolutionary space technologies. Cyber-human systems, space weapons, space mining, and energy-propulsion systems are examined with the STS concepts of political technologies and paradigm shift to discover multiple facets of the problem by referencing both technologies in *Iron-Blooded Orphans* and in our world.

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Introduction

Imagine you are looking out the window and you see the Earth's curvature on the pitch-black backdrop of space. You are waiting at the Earth's orbital spaceport, ready for the six-month trip to Mars. This is a business opportunity to establish new trade links for rare metals mined on Mars. It was only a century ago since humans first landed and began exploring the surface of Mars, but not long after self-sustaining habitats were being sent over in large quantities along with spaceports being constructed using asteroid capture and mining resources, as well as space laboratories established beyond low Earth orbit. This future is enabled by new propulsion, energy, and material technologies, and the space industry in 2021 is reaching the critical point in which such developments will accelerate and bring about the spacefaring future of humanity (Vidmar, 2020).

Perhaps the most exciting development in the upcoming decades will be the human arrival on Mars, as current efforts to realize this long-time fantasy have begun revving up with SpaceX and NASA researching novel space technologies aimed towards exploration (Hall, 2021). The benefits and impacts of said technologies will undoubtedly be significant upon the science and engineering community, but the effects on the social order are fuzzy, especially with regards to the long-term development of human presence on Mars. This paper demonstrates the capability of using science fiction material to ignite discourse among engineers and STS scholars on visualizing the future. In order to dissect this issue, it is crucial to first consider potential space technologies and impacts they may have. Media analysis, in which a science-fiction piece is broken down to examine aspects of technology and its connection to the narrative, is crossed with real-world space

technologies to accomplish this. This paper will utilize the anime *Mobile Suit Gundam: Iron-Blooded Orphans*, which depicts a burgeoning spacefaring society that struggles to reconcile space-age technologies with a stratified society, to achieve said media analysis. Aired between 2015-2017, the latest installment in the *Mobile Suit Gundam* series takes a grounded approach to emphasize the horrors associated with the abuse and misunderstanding of space-age technologies. With the ultimate goal of a smooth transition towards space colonization and expansion, identifying key technologies and conflicts can provide insight towards how to approach future space endeavors as a society.

Iron-Blooded Orphans will be used in conjunction with works on space exploration such as *The Case for Mars* (Zubrin, 1997) to inspect Martian colonization and its societal, political, and economic factors to understand of how to approach future space exploration efforts and establish key players that are essential to the successful development of human society beyond Earth. Two STS concepts that are applied are political technology and paradigm shift, both of which hold merit when discussing possible future technologies and political responses that play a role in developing colonies, including our understanding of the world that will shift when human presence in space is on the rise. This paper demonstrates the capability of using science fiction material to ignite discourse among engineers and STS scholars on visualizing the future. Producer Masakazu Ogawa stated in a 2015 interview that the series took place on Mars because it was not too far but just close enough for the audience to feel sympathetic, and the spectacle of a terraformed Mars is something marvelous to behold (Ogawa, 2015). *Iron-Blooded Orphans* is not a run-of-the-mill space opera featuring aliens or magical qualities, it was produced to speak to human hearts through its conflict-driven narrative fueled by powerful space technologies wielded in the wrong hands. This leads to the question, how can the use of science fiction media help understand the expansion

into space and how to reconcile the social consciousness with unfamiliar technologies while intelligently maximizing their potential for growth? Human-cyber interfaces, advanced weapons, space mining, and energy-propulsion systems will each be individually scrutinized for real-world counterparts and have the social context around them discussed.

Background on *Mobile Suit Gundam*: *Iron-Blooded Orphans*

Given the obscurity of the media being analyzed, an overview will be presented first. *Mobile Suit Gundam* was first introduced in 1979 as a science-fiction mecha (robot) anime and has since grown to be one of the world's largest media franchises. There exist multiple timelines within the franchise that all include recurring themes of space society, war suffering, and defining humanity. *Iron-Blooded Orphans* follows its predecessors in those narratives by introducing the audience to a colonized Mars after a great war 300 years ago between Earth and its space colonies (Mars, moons, and orbital colonies) that left Earth under a single military hegemony named Gjallarhorn. The story follows a group of orphans on Mars who rebelled against a private security company to form their own called Tekkadan, whose goal in the first season was to escort Kudelia Aina Bernstein, a representative of the Mars autonomous region, back to Earth for discussions of independence. Battles of might and deception occur as Gjallarhorn attempts to block her arrival. Season two follows Bernstein seeking financial independence for Mars through a mining operation with the protection of Tekkadan. Once again, Gjallarhorn meddles in the matter and ultimately succeeds in defeating our protagonists. However, due to internal chaos from the incident, including the exposure of corruption and rebellion amongst high-ranking officials, the Martian cities were freed from Earth's control and formed their own union, leading to greater advancements such as

the abolishment of human debris– the in universe term for child slavery in space– and removal of other toxic players in the Martian sphere (Okada, 2015).

Figure 1

Gundam IBO Poster

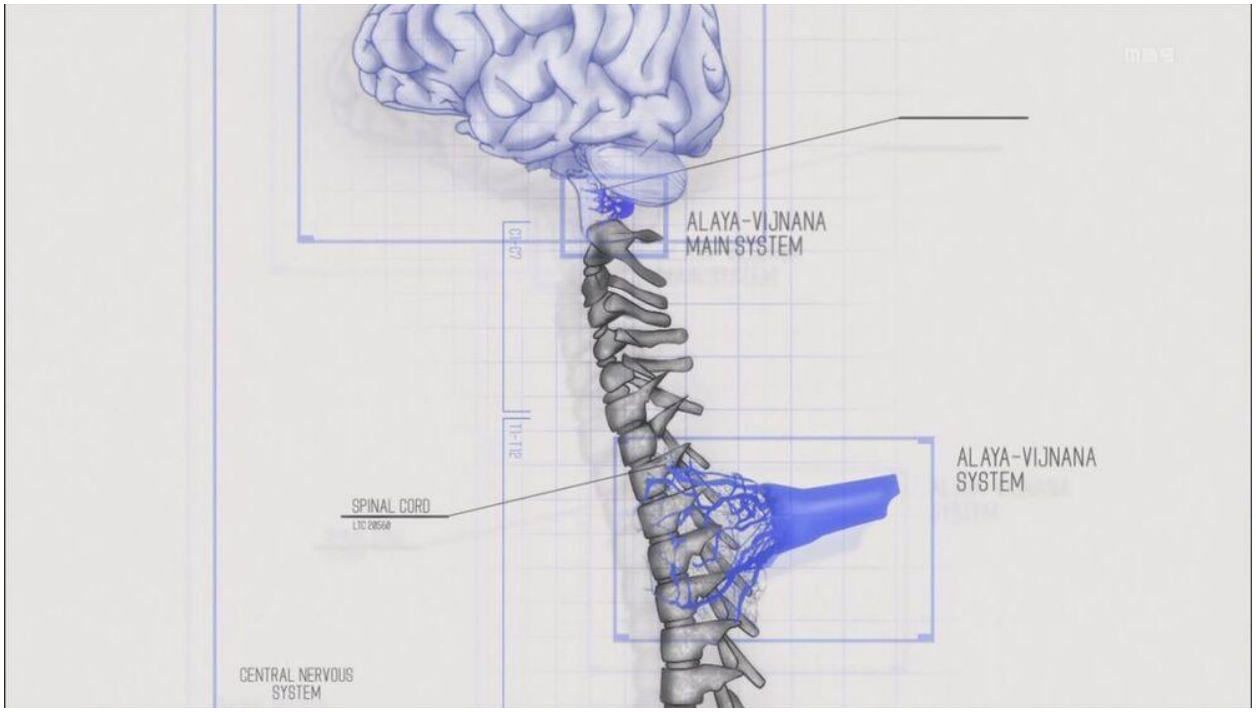
Note. [Poster for Season 1 of IBO]. (2015), from https://en.gundam.info/series/tekketsu/

Cyber-Human Systems

One of the first technologies shown in *Iron-Blooded Orphans* is the "Alaya-Vijnana System," a term derived from the Buddhist concept of consciousness. It is a cyber-human interface in which nodes are surgically implanted into the subject's spine and enables one to operate vehicles with greater precision and control. Originally developed during the great war, the technology was designed to assist mobile suit pilots maximize their output. As an "old" and invasive technology, it was abandoned by those on Earth and instead became the default for young space dwellers who worked with compatible vehicles for mining or battle. The surgery implants were also incredibly dangerous with a high mortality rate and often not voluntary as these children were either abandoned or enslaved. Thus, this technology became associated with the disposable class of people, a standard even modern society does not have, as a means to control the lower working class. The protagonists are a band of orphans who take advantage of its power through the Gundam, a pre-war mobile suit designed to destroy other space weapons. Its immense power enables the orphans to fight their way to independence, channeling the Alaya-Vijnana System that was forcefully implanted within them towards their own dreams (Okada, 2015). Another group associated with Gjallarhorn attempted to revive the technology on Earth yielding a mobile suit piloted by an amputee integrated into the system, taking cyber-physical melding to the extreme. The cyber-physical systems in the real world already have some of the capabilities mentioned in the series, and examining its implications are essential towards preventing such abuse of power.

Figure 2

Alaya-Vijnana System Visual



Note. From Gundam IBO Episode 22

Astronaut enhancements have been studied and considered for its benefits as many physiological barriers such as lethargy, reliance on oxygen, or radiation vulnerability will reduce the effectiveness of personnel operating long-term in space. Lengthening one's life to reduce generational shifts for century-long voyages acts as another example (Harrison, 2002). According to Abney and Lin, these enhancements bring about ethical issues regarding privacy and physical dehumanization. They suggest that enhanced human beings, although practical in space environments, may reach too far into the realm of human modification and its ethical bubble (Galliott, 2015). Dealing with enhanced individuals for a society is not a novel concept or dilemma across the Gundam franchise, however a paradigm shift in the very definition of what constitutes

a human will be necessary. Can spacefaring "humans," who were modified, either biologically or cybernetically, for the purposes of surviving in space be called humans? Abney and Lin calls this existential risk as the uncertainty of moral questioning for what constitutes a human being. They also raise a more practical concern for astronaut enhancements: humans modified to better survive in space environments will provide a tactical advantage when it comes to warfare. The current bioethical framework does not deem military necessity as a reason for deploying human enhancement technologies, but they claim the emergence of space pioneers may justify such technologies, and in turn change the military landscape both on Earth and in space (Galliott, 2015).

Turning back to cyber-enhanced humans in *Iron-Blooded Orphans,* the ultimate dilemma is reconciling with a society with human modification. It is perhaps easier than it sounds, as medical intervention to improve livelihoods of disabled or chronically-ill individuals also constitute a sort of enhancement as Abney and Lin discusses. There is a line that divides therapy and enhancement, and "the key moral question would seem to be whether a medical intervention aids in human flourishing, whether or not one's genetic makeup (or physical environment on Earth or in space) would cause it to be classified as either therapy or enhancement" (Galliott, 2015). Enhanced military soldiers also complicate the issue, as the Alaya-Vijnana System provides a significant tactical advantage in battles as the neural link enables even amateur pilots to outperform veteran military pilots. A paradigm shift could subconsciously occur in which the line pushes towards enhancement normalization, towards the world portrayed in *Iron-Blooded Orphans* where cyber-human interfaces are commonplace in the public consciousness and the fundamental standard for defining humanity drastically changes.

Space Weapons

Iron-Blooded Orphans is at its core a series about warfare, and it is unsurprising that numerous space weapons were introduced in the series. Battles were primarily fought through "mobile suits," piloted bipedal robots that can operate both on land and in space, but there is little parallel that can be drawn to real life weapon systems there. Instead, kinetic space weapons will be discussed as they not only play a large part in the story's narrative, but they also have the greatest potential to enter deployment in our world.

The final episode of *Iron-Blooded Orphans* displays one of the most devastating sequences, not only because we see the protagonists slaughtered on the battlefield, but because of the realistic means by which it happens. As our protagonists fend off waves of Gjallarhorn soldiers on Mars to buy time for others to escape, a Gjallarhorn commander orders a line of mobile suits to hover in orbit with a crossbow-like weapon. Upon command, the "arrows" were shot onto the battlefield from space and ultimately defeated the protagonists. This is an example of kinetic bombardment, or the use of "hypervelocity rods made out of a dense material (tungsten or depleted uranium) in orbit that could be dropped from space on terrestrial targets" (Galliott, 2015). As nuclear weapons were effectively banned from space through international treaties, more creative methods were considered by world superpowers as the militarization of space became noteworthy (Galliott, 2015). Although weaponized satellites destroying other satellites could utilize various technologies from lasers, collision, signal jamming and EMPs, mass destruction on the ground with lives at stake will certainly involve orbital bombardment technology. Even if space warfare were to break out outside of Earth's sphere, such as in the case of *Iron-Blooded Orphans's* final battle, kinetic weapons prove to be a cheap and effective method to neutralize targets as they are safe to store and deploy.

The United States government, along with the Russian and Chinese governments, has poured considerable resources into investigating various space weapon technologies (Thompson & Bowman, 2021), but the agreed upon consensus to not engage in active space warfare is due to the space debris that will result from war, and clouding low Earth orbit with more debris is not in the interest of any organization who seeks to expand further into space. As a result, while humanity remains on Earth it is unlikely space will be weaponized beyond intelligence gathering, but outside of Earth's sphere, such as perhaps disputes over Martian or lunar land, could yield in aggressive behavior politically on Earth but physically manifested in space.

Figure 3

Kinetic Bombardment Scene

Note. From Gundam IBO Episode 50

Space Mining

Space mining currently exists only as a mere concept, but in the next few decades it is safe to assume this industry will become the most profitable and revolutionary in the march towards a spacefaring society. Space mining can be broken down into planetary mining and asteroid mining, and while *Iron-Blooded Orphans* focuses upon the former, current research is already demonstrating possibilities for the latter. The Colorado School of Mines is actively expanding its space resources program to train engineers specializing in space mining despite the nonexistence of the industry. Their vision is to "pursue the study and utilization of space and planetary resources by developing technologies for prospecting, drilling, excavation and extraction, materials processing and manufacturing, and spacecraft and habitat life-support systems" (Abbud-Madrid, 2006), with active projects on sensing for planetary exploration and lunar soil excavation. NASA JPL considered asteroid capture missions which acts as the precursor towards asteroid mining (Agle, 2016), as once the asteroid is captured in orbit, mining equipment could be sent over and the resources can be reliably delivered back to Earth. An extension of space mining is space manufacturing, in which manufacturing in low-gravity or a vacuum enables protein crystal growth and improved semiconductor wafers to name a few candidates (Off-earth manufacturing, 2020). Resource management in space is on the precipice of material development as planned missions to the Moon and future Mars missions will definitely utilize both mining and manufacturing to enable self-sustaining spheres.

In *Iron-Blooded Orphans,* Mars contains vast quantities of a fictional rare resource called half-metal that is crucial for electronics and weapon systems. The political debates regarding Martian independence revolved around the deregulation of half-metal export, as the Martian colonies were treated as "third world" areas designated for resource extraction. In order to utilize

the vast resources of space, both political and social concerns must be addressed to prevent exploitation of Martian setters or lesser powers back on Earth.

An economic paradigm shift would occur in which raw material acquisition and processing industries such as metallurgy, refinery, and manufacturing will emerge as dominant forces on the global market. A single asteroid could worth up to $10,000 quadrillion dollars, potentially breaking modern monetary systems unless preemptive efforts are put in place to brace for paradigm shifts that may redefine value and scarcity. (Becker et. al., 2020). The global economy will see a reprioritization of industries as an influx of previously rare materials will boost electronic and construction industries. The information technology (IT) industry that has dominated the consumer space will be devalued as intellectual capital will flood towards the space industry and away from IT. Supply chain management, operations research, and industrial engineering are example subsets of the space industry that will see increased prioritization by educators as driven by economic incentive. Similar to the rise of Silicon Valley and its paradigm shift on human values with digitization, the rise of the space industry will be followed by its own paradigm shift.

As space mining efforts will be highly profitable, regulatory efforts and rigorously defined space laws are required to maintain peace and resolve conflicts. To prevent or minimize the weaponization of space, parties must resolve claim disputes on celestial objects before attempting to extract their resources. If human settlements were established for the purposes of space mining, the terms must be well defined and adhered to. Seemingly negligible oversights could cascade into system wide failures, as Space mining in its inception will be particularly vulnerable due to the technical hurdles, economic impacts, and political disputes. To prevent the exploitation demonstrated in *Iron-Blooded Orphans,* pioneers seeking to realize space mining technologies

must acknowledge these other angles and take preemptive action rather than blindly celebrating the technical achievement and piling fortune.

Energy and Propulsion

One of the greatest limitations for space travel, and in extension the ability to maintain a sizable presence in space, is energy. The energy grid infrastructure on Earth has taken over a century to develop and refine to achieve the vast coverage and reliability experienced today. Current ground-based power plants consist of fossil fuel, green energy sources such as solar and wind, and nuclear energy. For space systems, solar and nuclear technology are dominant as their mass to power generation ratios allow lightweight energy infrastructure to power the entire space system. However, there are still significant limitations, such as the unreliability associated with solar panel coverage and maximum wattage output of RTGs, or nuclear batteries such as the one currently on the Perseverance rover (Wanjek, 2020). If larger settlements were to be considered, a sustainable energy grid independent from Earth's resources is a requirement.

Closely related to energy is propulsion, or the source of thrust generation to propel a spacecraft. Propulsion is commonly the most well-known space system as the spectacle of rocket launches are captured through plumes of smoke and blazing trail left behind from the boosters. Once outside of Earth's atmosphere, however, chemical rockets prove to be inferior due to their low specific impulse. Electric propulsion is favored in space as its mass-to-ISP ratio allows less onboard mass to be dedicated to propulsion. However, there are many more potential technologies that can provide both high thrust and ISP while satisfying the low mass criterion. According to Robert Zubrin in *The Case for Mars*, there are many potential propulsion solutions beyond what technologies are presently available. Zubrin identifies solar sails, magnetic sails, and fusion as

realistic propulsion methods for interplanetary travel, with more improbable solutions such as antimatter fuel and warp drives (Wanjek, 2020). Both solar and magnetic sails utilize century-old principles harnessing moving particles to generate thrust with a sail. Solar sails were seriously considered at NASA JPL in the 1970s, but the proposal fell through due to funding. Magsails require a high temperature superconducting cable to generate a thrust-producing magnetic field from solar wind, but the technology is not there yet despite advancing at a fast pace (Zubrin, 1997). Nuclear fission based propulsion is currently being investigated by NASA, either nuclear thermal or nuclear electric will likely enable interplanetary travel in the upcoming decades (Foust, 2019).

Despite NASA's efforts, nuclear fission propulsion is unsustainable as enriched uranium or plutonium serve as fuel sources. Both these heavy elements are naturally rare in the universe, and unless uranium-rich asteroids are found, the sustainability of this technology will be the primary hurdle to maintaining a significant presence in space. The most revolutionary yet viable solution is fusion technology, especially ones that utilize helium-3 as fuel which can be mined from regolith (Zubrin 2019). Zurbin proposes a system in which helium-3 mining will take place on the moon to sell back on Earth, as helium-3 cannot be mined on Earth, to fuel further economic incentive to develop fusion technology for advanced space systems. He claims the failure to develop fusion technology thus far was "an artifact of the mistaken priorities of the ladies and gentlemen in Washington, DC, and similar places who have been controlling scientific research and development for the past few decades" (Zubrin 2019). He believes the rise of SpaceX and the private space sector will provide the opportunities for entrepreneurs to capitalize on the market of space. As future space colonies or outposts will need to survive independent of Earth, relying upon traditional fission or nuclear decay will not be sufficient, nor could sole reliance upon solar panels,

thus fusion technology — a technology that is still viewed as too science fiction for serious consideration — is the way forward towards energy in space.

Fusion based propulsion, despite its obscurity, is a proposed and recently revitalized field that can revolutionize space travel to match the spectacle and travel times of science fiction works like *Iron-Blooded Orphans*. According to Zubrin, it could reduce Martian travel time to "time-scale of weeks instead of months, travel to Jupiter and Saturn possible in months instead of years, and travel to other solar systems on time scales of decades instead of millennia" (Zubrin, 1997). He argues that steam technology made its way to ships, nuclear fission technology made its way to submarines, why would fusion-powered spacecraft be out of the question? In 2019, Congress secured $125 Million to develop nuclear thermal propulsion technology, signaling a revived interest in its potential after initial studies conducted during the Space Shuttle Era (Cain, 2020). As any application of fusion technology remains decades away, humankind's first travels to Mars will likely not resemble science fiction with traditional chemical and electric propulsion.

Iron-Blooded Orphans introduced a fictional power source called Ahab reactors that are capable of both power generation and propulsion much like fusion energy, but it is also capable of artificial gravity and communications jamming. Due to its power, Ahab reactors were monopolized by Gjallarhorn to prevent outside groups from obtaining them. Zubrin's proposed trade dependence for helium-3 parallels half-metal trade in *Iron-Blooded Orphans* as the rare Martian mineral is a key material for shielding components in Ahab reactors. Both technologies require space mining outposts and sustainable trade to operate successfully. Although a perfect real-world counterpart does not exist, the political implications of fusion energy and propulsion are evident regardless. If a miracle breakthrough in power generation were to occur, the necessary resources to build and sustain such a system will be fought over, and if such resources were only abundant

in space, the issues of both space mining and space warfare will enter the conversation as well. As both these two are reliant upon energy technologies, energy technologies prove to be the key to unlock spacefaring and securing space outposts.

Fusion technology as it applies to space will be highly political and even classified in the first few decades of its deployment. It will likely follow the path of current hypersonic research, in which political and military pressure from China and Russia drove the United States to reinvigorate its hypersonic research programs (AIAA, 2021). In this AIAA seminar, the Department of Defense and industry leaders spoke at length about the sensitivity of these technologies and their struggle to balance national security with the advancement of science, as many published works could not be made public. As a result, hypersonic research limits the utilization of intellectual capital as foreign nationals are barred from accessing such material.

Once fusion technology has solidified itself as the primary space-based energy and propulsion system (or nuclear fission based propulsion), it will enter a similar state in which its potential will be held back by national security and politics, leading to a less inclusive and more politically charged space society not unlike the world of *Iron-Blooded Orphans.* The political hegemony of Gjallarhorn and its monopolization of Ahab reactor manufacturing could reflect what the United States looks like if fusion technology were to be deployed here first, leading to further political imbalances and new waves of manifest destiny aimed towards space. The complex political landscape depicted in *Iron-Blooded Orphan* thus serves as a warning as to how the most revolutionary of technologies must be handled with utmost responsibility to prevent destabilization of the global ecosystem.

Conclusion

Mobile Suit Gundam: Iron-Blooded Orphans presents a snapshot of a potential spacefaring society by exploring social and political conflicts through space technologies such as cyber-human systems, human-cyber interfaces, advanced weapons, space mining, and energy-propulsion systems. By examining the problematic elements with each technology through the lens of paradigm shift and political technology STS theories and cross referencing with real-world technologies or pioneering efforts, social, political, and economic vulnerabilities are identified. These vulnerabilities include ethical concerns for human modification, political concern for weapon and energy systems, and sustainable social and economic development of space colonies or outposts. Science fiction media as demonstrated by *Iron-Blooded Orphans* can be helpful towards understanding complex social issues as narrative driven content is often less polarizing and more engaging to ignite discourse around the topic. For engineers, science fiction is often a source of inspiration to achieve new heights. Incorporating commentary narratives help engineers become aware of critical problems associated with a technology; sometimes it is not a technical error that leads to failure, but political or economic pressures. In such a case space engineers must reevaluate sponsor, stakeholder, and security needs to successfully develop and deploy nuanced space technologies.

Future engineers should consider these factors rather than be blinded by the potential of any given technology, as it is tempting to publish and describe one's own work emphasizing the game changing potential and not the problematic angle. By educating the public and policymakers alike, these technologies can be successfully integrated to usher in the spacefaring society on display in *Iron-Blooded Orphans* or any other. With careful planning and hyperawareness for its cascading effects, the world of strife depicted in the show can be avoided.

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