Weapons Design, Engineering Ethics, and the Duty to Inform: A Case Study on U.S. Hypersonic Missile Development

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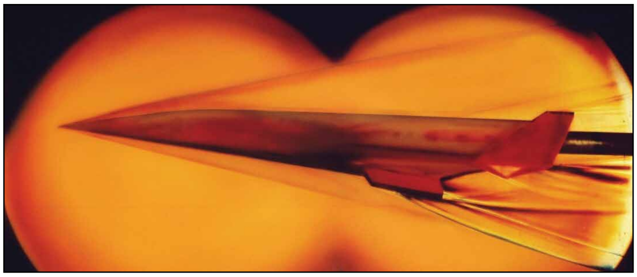
A LARGE NUMBER of engineers take part in the design of weapons technologies. In the United States, for instance, the Department of Defense (DOD) advertises itself as "one of the world's largest engineering organizations" [1]. In a 2023 survey asking U.S. engineering students which employers they most desired to work for, arms manufacturer Lockheed Martin rated first [2]. Three of its counterparts—Raytheon, Northrop Grumman, and Boeing—ranked in the top ten.



Given the grave implications of the use of the weapons technologies that these organizations design and produce—including the destruction of infrastructure, environments, and human bodies—the participation of engineers in weapons design gives rise to substantial ethical challenges. Chief among these is the tension with the obligation of engineers to avoid causing harm, a principle of nonmaleficence enshrined in most professional codes of engineering ethics [3]. The Institute of Electrical and Electronics Engineers (IEEE) Code of Ethics, for example, requires that engineers, first and foremost, "hold paramount the safety, health, and welfare of the public" [4].

A significant body of engineering ethics literature has analyzed this tension, most often through the lens of just war theory. This theory posits that the prosecution of war, via the application of weapons technologies, is ethically permissible so long as it is conducted within certain constraints (for example, without direct targeting of noncombatants) and toward certain ends (for example, to halt the victimization of oppressed populations) [5]. Most ethical analyses conclude that

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engineers can uphold their ethical obligations while developing weapons technologies only if they reasonably infer that these technologies will be used exclusively in a just manner [3], [6], [7], [8], [9], [10].

However, the ethical challenges of weapons design extend beyond this nonmaleficence obligation. Engineers are not mere producers of technology; they also hold a particular knowledge status within their societies. From this status there derives a social contract dimension of engineering ethics, where "in return for a monopoly on certain specialized knowledge and skills, not easily attainable by the general population, the profession agrees to use that knowledge and those skills to serve society" [3]. Engineers might therefore be obliged not only to refrain from unjustly harming publics, but also to inform them as to the benefits, risks, and societal implications of technologies. This duty to inform could entail direct public education or, in societies organized around principles of democratic governance, advising the policymakers who represent public interests in issues of technology development, use, and regulation.

Weapons design and the duty to inform

Much of the foundational thinking on the engineer's ethical duty to inform publics on the implications of weapons technologies arose during the Cold War, when scientists and engineers confronted their role in the development of immensely destructive nuclear weaponry, and in the ensuing nuclear arms race between the United States and the Soviet Union [11]. In 1987 civil engineers Evans and Munsey [12], considering the threat that the U.S.–Soviet nuclear standoff posed to the global populace, argued for an ethical obligation of engineers to "be critical of the technology that is their livelihood" and to not merely refrain from causing direct harm, but to "take a more active role in bringing about social change" so as to reduce global nuclear risks. This call for social activism by the engineering community prompted a lively debate in the *Journal of Professional Issues in Engineering*. Some concurred, recognizing "the significance of engineering judgments to a modern democratic society that requires a well-informed public to weave interests of the individual into the fabric of national policy" [13]. While others countered with more sanguine takes on the risks of nuclear armament, even critics agreed that engineers "should seek to educate the public" on weapons issues [14].

Subsequently, the ethical duty to inform was explicitly addressed by engineering professional societies. For example, in 1991, the IEEE updated its code of ethics to include a requirement that engineers "help improve understanding of technology and its proper use," later appending a duty to inform on the "potential consequences" of use [15]. In 2018, concerned about "ethical challenges raised by the next generation of technology," the IEEE again edited this canon to specify an obligation "to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies" [16]. Two years later, this obligation was moved up in the list of duties, placing it as the second canon of the code, immediately following the nonmaleficence provision [17].

While not included in all engineering codes of ethics, the duty to inform is presently found in those of a wide range of national and international engineering societies. For example, the Association for Computing Machinery notes that engineers must uphold "a special responsibility to provide objective, credible evaluations and testimony to…users and the public" [18]. The Japanese Society of Civil Engineers obliges its members to "openly provide information and engage in public dialog," and to "make known…their findings and policy recommendations" by "sharing these with both their professional colleagues and the people" [19]. The United Kingdom's Royal Academy of Engineering and Engineering Council require that engineers "be aware of the issues that engineering and technology raise for society" and "promote public awareness and understanding of the impact and benefits of engineering" [20]. The World Federation of Engineering Organizations, representing over 100 national engineering institutions, obliges engineers to "foster the public's understanding of technical issues" [21].

While the implications of the nonmaleficence duty for weapons design have been extensively studied, relatively little attention has been paid to the role of this duty to inform. The history of weapons engineering, however, suggests that upholding it may pose a unique challenge in this field, where factors like the siloing of information due to governmental secrecy and the perceived exigencies of war create an environment uniquely conducive to the spread of misinformation. Contakes and Jashinsky [10], for instance, write of the "diverse and in hindsight dubious justifications for poison gas work" put forward by the World War I-era chemists and chemical engineers who championed the development and use of chemical weapons. Rappert [22] points to Iraqi, South African, and Soviet scientists and engineers who, motivated by "reasons of patriotism, professionalism and profit," led covert bioweapons programs, hidden from the public and in violation of international law. Beyond the mere failure to inform publics and policymakers about weapons issues, engineers might actively engage in the production of misinformation. Santos [23] warns that professional incentives can prompt a predilection among technologists for "statements in which the primary goal is to create support and enthusiasm about…emerging research areas or technologies" rather than to inform.

Neither this tendency toward the provision of technical misinformation nor the ethical obligation to abstain from it is specific to a particular nation or branch of engineering practice. Yet weapons development is typically quite national in character, focusing on specialized technologies tailored to achieve the unique military objectives of a particular state. Understanding of the interactions between engineering practice and ethics in this arena thus demands a close analysis of their manifestations in particular cases.

One case in which these dynamics appear particularly prevalent is the historical development of U.S. missile technologies—uncrewed, airborne weapons that accurately deliver conventional or nuclear explosives over long distances. Sapolsky [24], assessing the U.S. Navy's rapid development of submarine-launched missiles in the late 1950s, was surprised to find that the success of this program derived less from feats of engineering achievement than from false narratives of technical innovation, carefully crafted by missile developers to appeal to the political interests of governmental funders. He described a vast marketing effort in which "conceptual gymnastics" were employed alongside "an alchemous combination of whirling computers, brightly colored charts, and fast-talking public relations officers" to convince policymakers that these missiles could carry out whatever mission might be desired, regardless of actual technical capabilities. Sapolsky concluded that "it mattered not whether the parts of the system functioned or even existed… only that certain people for a certain period of time believed that they did." These dynamics were not confined to the Navy. U.S. Air Force historian Perry [25], in his analysis of the development of ballistic missiles, concurred, lamenting that this was "an area in which myth, legend, preconception, and misinformation are abundant…and where distinguishing between reality and illusion is no easy task."

Given this historical evidence of failings to impartially inform publics and policymakers about weapons technologies, there is a clear need for closer study of whether the ethical duty to inform is being upheld in modern weapons engineering. One emerging weapons technology particularly suited for this analysis is the hypersonic missile, currently in development by a number of nations [26]. The effects of these weapons and the implications of their deployment remain uncertain and controversial, yet, for U.S. development programs, relevant data are available on both governmental discourses and technical characteristics of weapons systems. This case is also timely, given the recent battlefield debut of these weapons in the Russo-Ukrainian War [27], [28].

Using recent U.S. hypersonic weapon development efforts as an illustrative case, this analysis proceeds by assessing dominant narratives about hypersonic weapon capabilities, identifying a prevalence of technical misinformation. To examine its origins, a sociotechnical analytic framework is adopted, making use of heterogeneous engineering [29] and actor–network theory (ANT) [30] as analytic tools for tracing the roles engineers have played in shaping hype narratives regarding the performance of these weapons, and thus in shaping national weapons technology policy. Engineers are shown to have played central roles in both countering and propagating hype narratives. These findings reveal a tension between ethical obligations and the practice of weapons engineering, as well as a need for further development of engineering ethics to better address the duties of engineers as creators not merely of technologies, but of technological knowledge.

The hypersonic arms race

Hypersonic weapons comprise a class of emerging weapons technologies that have garnered a great deal of technical controversy and therefore present a useful case study of ethical issues in weapons design. These missiles are named for the velocity regime in which they fly—five times the speed of sound (Mach 5) or greater. However, it is not their speed that distinguishes these weapons from more established technologies, like the ballistic missiles that many militaries have deployed for decades. Rather, hypersonic boost-glide missiles, which are the most capable and most well-developed variety of hypersonic weapons, differ from ballistic missiles primarily in terms of the trajectories they fly.

Ballistic missiles are initially launched on rocket engines, which rapidly burn fuel to accelerate to many times the speed of sound. The maximum speed achieved scales with the maximum range of the missile, with intercontinental-range systems typically reaching around Mach 20. A few minutes after launch, these engines run out of fuel, detach from the front portion of the missile, and fall back to Earth. The remainder of the missile, known as a reentry vehicle, carries an explosive warhead on an arcing flight path, illustrated in Figure 1, which generally reaches high into outer space. Because they spend most of this flight outside the atmosphere ballistic missiles avoid atmospheric drag that would slow their flight. However, they cannot take advantage of lift to glide or maneuver, outside of brief periods at the beginning and end of their trajectories.

The initial flight paths of hypersonic boost-glide missiles, also illustrated in Figure 1, are similar to those of ballistic missiles. They are launched on the same type of rocket engine and thus accelerate to similar maximum velocities. However, while ballistic missiles fly high, arcing flight paths after burning through their fuel, hypersonic boost-glide missiles instead drop back into Earth's atmosphere, then glide through the atmosphere for the remainder of the distance to their targets. The main factor distinguishing ballistic missile technologies from hypersonic missile technologies is therefore the extent to which the latter flies through the atmosphere, rather than above it.

Hypersonic weapon technologies are commonly associated with a wide range of purported advantages over ballistic missiles. The news media characterize them as a "game changer" [31]. They write that these weapons are "nearly invisible" to the early warning systems (like radar or infrared (IR) light sensors) that an adversary would use to detect and track incoming missile strikes and, even if they were detected, "unstoppable," since hypersonic weapons could speed past the defensive missiles with which an adversary might attempt to intercept them [32]. Scholars of international security tout the "unmatched speed" of these weapons [33], arguing that they "could hit over-the-horizon targets in a fraction of the time it would take existing ballistic or cruise missiles" [34], thus leaving adversaries "insufficient time…to confidently identify and confirm the nature of an incoming attack, let alone to

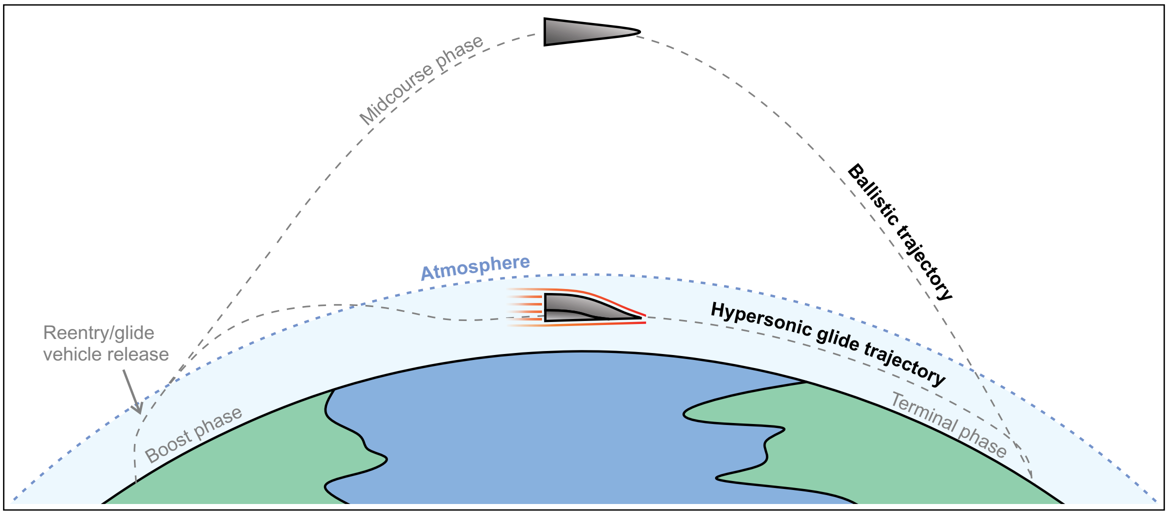

Figure 1. Representative trajectories of a ballistic missile and a hypersonic glide missile. Both are accelerated by rocket engines, but after this boost phase, a ballistic missile reentry vehicle follows a high-altitude path through outer space, while a hypersonic glide vehicle quickly reenters the atmosphere and glides to its target.

decide how to respond" [35]. U.S. defense officials warn that "there is no defense against hypersonic" [36] and predict that these weapons "will revolutionize warfare by providing the ability to strike targets more quickly" [37]. The U.S. National Academy of Sciences, a prominent advisory body to the government, writes that the speed of these weapons and the difficulty of detecting them will "greatly compress decision and response timelines" of those targeted [38].

This dominant narrative positions hypersonic weaponry as a revolutionary technology offering unparalleled capabilities in terms of flight speed, undetectability, and evasion of missile defenses. These perceptions underpin an ongoing arms race between the United States, Russia, and China to develop and deploy such weapons [39].

Technical counterarguments to hypersonic hype

If engineers are upholding their ethical obligation to inform publics and policymakers about the effects and implications of new weapons technologies, one would expect careful scrutiny by technical communities of the extraordinary claims made about hypersonic weapon performance. Indeed, a small but growing literature has sought to rigorously assess the validity of these claims, often finding them to have little or no technical basis.

In some of the earliest work scrutinizing modern U.S. hypersonic weapons development, Acton [40] and Wright [41] analyzed open source data from early 2010s flight testing of the Hypersonic Technology Vehicle-2 (HTV-2), one of the longest range and fastest hypersonic glide weapon tested by the United States. Surprisingly, Acton [40] found that this missile approached its target quite slowly relative to modern ballistic missiles since its long-term flight through the atmosphere subjected it to excessive drag that greatly reduced its flight velocity. This suggests that, counter to the claims of hypersonic weapon proponents, these missiles might be uniquely vulnerable to interception. Acton [40] thus found "reason to wonder whether boost-glide weapons could reliably penetrate the sophisticated point defenses that advanced states could use to try to defend exactly the high-value targets that [hypersonic] weapons might threaten." He also raised the possibility that intense aerothermal heating produced during hypersonic flight through the atmosphere—which ballistic missiles avoid by flying primarily through outer space—could render hypersonic systems detectable by satellites equipped with IR sensors. The United States and Russia have fielded constellations of these satellites for decades, and China is currently developing its own [42], [43], [44].

Terry and Cone [45] directly compared the performance of hypersonic weapons in nuclear warhead delivery with that of alternative technologies that could carry out the same mission, like ballistic missiles. They found that hypersonic technology "provides few advantages relative to cruise missiles or [intercontinental-range ballistic missiles] in terms of speed, range, or accuracy." In a similar comparison, Oelrich [46] concluded that "claims about the revolutionary nature of hypersonic weapons do not withstand scrutiny…Their capabilities are not new, and today most of the missions proposed for hypersonic weapons could be accomplished cheaper and with less technical risk simply by modifying existing ballistic missiles."

Tracy and Wright [47], [48] conducted a computational analysis of various hypersonic glide vehicles flight tested by the United States, and compared their predicted flight performance with that of ballistic missile systems. Considering common claims of reduced warhead delivery time, they found that although the low-altitude flight trajectories that hypersonic weapons follow allow them to travel shorter paths to their targets, relative to ballistic missiles, the effects of atmospheric drag would more than outweigh this benefit for most missions. Their calculations indicate that hypersonic weapons flying trajectories optimized to minimize delivery time would reach their targets no faster—and often significantly slower—than ballistic missiles flying similarly optimized trajectories.

Addressing claims that hypersonic weapons cannot be detected by existing early warning systems, Tracy and Wright [47] calculated the intensity of IR light that a glide vehicle would emit as it flew through the atmosphere at hypersonic speeds. Comparing this intensity with the known sensitivity of currently deployed space-based IR sensors, they confirmed Acton's contention [40] that these sensors could reliably detect not only the launch of a hypersonic weapon, when its rocket plume emits intense IR light, but also much of its flight, during which aerothermal heating would raise the temperature of the glider's exterior to thousands of Kelvin.

Candler and Leyva [49] and Tracy and Wright [50], using more advanced computational fluid dynamics (CFD) techniques, subsequently confirmed this finding that gliders could be detected by existing space-based sensors.

On the vulnerability of hypersonic weapons to interception by missile defenses, Tracy and Wright's calculations again supported Acton's contention that claims of hypersonic superiority are unfounded [48]. Due to the effects of atmospheric drag, hypersonic weapons lose much of their initial velocity as they approach their targets, leaving them less able to maneuver and evade an interceptor. Tracy and Wright [50] conclude that currently deployed terminal defenses, which seek to intercept a missile in the final moments of flight as it dives to its target, would be effective against state-of-the-art hypersonic weapons of the sort that the United States, Russia, and China are now developing.

Finally, Kramer et al. [51] performed further computational analysis of the use of hypersonic weapons in specific military scenarios, including conflicts between the United States and China in the South China Sea, and between the United States and Russia in Eastern Europe. As with the prior analyses, they found that hypersonic weapons would offer little advantage over existing ballistic missile technologies while costing substantially more to develop, procure, and deploy.

These technical analyses indicate that common narratives about the supposed performance and superiority of hypersonic weapons lack a technical basis, thus constituting a form of technical misinformation. The publication of these analyses over the last decade is evidence of effort on the part of technical communities to scrutinize and critique technological hype narratives, thus upholding their ethical duty to inform. However, in assessing the extent to which engineers are upholding this duty, it is not sufficient to consider only the roles they have played in scrutinizing common narratives about these weapons' effects; it is equally important to consider whether engineers, holding a privileged position with respect to the construction of technical knowledge, have played a role in the production and propagation of these false narratives.

Social construction of hype

Historical analyses of U.S. missile development programs show that engineers often play central roles in shaping unfounded hype narratives about the capabilities and implications of new missile technologies. Much of this work draws from the science and technology studies (STS) literature, which emphasizes how perceptions of the capabilities of a technology are not determined solely by its technical or material characteristics, but are also socially constructed by individuals who seek to shape these perceptions so as to promote or hinder the development, adoption, and use of that technology [52]. This process of the social construction of technological knowledge, while a necessary component of engineering work, presents opportunities in which engineers might breach their ethical duty to honestly inform others about a technology.

Consider, for instance, Spinardi's in-depth study of the U.S. Navy's submarine-launched missile development efforts [53]. He concluded that the successful development of these technologies depended less on their actual capabilities than on the extent to which those developing them were able to convince stakeholders of their advantages, whether or not those purported advantages had a technical basis. Spinardi [53] concluded that "whether [a missile] would actually perform to specification in a war situation is a moot point and not actually crucial to the success of the technology…what matters is that the technology succeeds as a network of interests." These interests can include the ability of a missile technology to carry out a specific strategic or tactical mission, but this interest in capabilities is frequently subordinated to other factors like the technological prestige accompanying the development of a new weapons technology, the capture of budgetary resources that might otherwise be directed to competing weapons projects, and the opportunities for career advancement that arise for engineers when their projects are deemed successful.

To enroll the support of disparate actors with wide-ranging interests—military strategists, congressional appropriators, proponents of alternative technologies, and others—missile engineers took part in what Spinardi termed "heterogeneous engineering" [53]. This phrase, coined by Law [29] in the earlier STS literature, refers to the dual engineering of both a technology and the social context in which it operates. As articulated by ANTs of sociotechnical change [30], tight coupling of these social and technical factors into a mutually constitutive network can clear a path for the development of a certain technology, even in the face of resistance. For instance, when early testing of submarine-launched missiles suggested they could not match the accuracy of ground-launched variants, the Navy's developers launched a campaign to convince stakeholders that high levels of accuracy, sufficient to threaten an adversary's nuclear arsenal, would represent a destabilizing threat to the nuclear balance (e.g., the promise of mutually assured destruction) and was thus undesirable [53]. When the Navy's engineers later determined that this high level of accuracy was technically achievable, they worked to reshape military doctrine and "sell" their missiles by emphasizing the accuracy capabilities they had previously demonized. Throughout, technical aspects of these missile designs were important only insofar as they could be harnessed to enroll the support of nontechnical stakeholders.

In his historical study of the development of missile guidance, MacKenzie [54] came to similar conclusions. He found that the production of a working missile technology was not merely "a matter of engineering just metal, wires, and equations. People had to be engineered too—persuaded to suspend their doubts, induced to provide resources.… Successfully inventing the technology turned out to be heterogeneous engineering." Conversely, Law and Callon's [55] study of British military aircraft development illustrates how failure to heterogeneously engineer a social environment in which "skeptical actors could be kept in place and obliged to provide the necessary resources" can lead to the dissolution of development efforts, even for a technology that likely "would have been a military success had it actually entered service." While persuading stakeholders to support missile development might be achieved through the ethical provision of accurate information about weapon performance, it might instead be most effectively accomplished through the provision of misinformation, creating a clear potential for ethical malfeasance.

Heterogeneous engineering in hypersonic missile development

In assessing whether the engineering community has upheld its ethical duty to inform regarding hypersonic weapons technologies, it is necessary to examine the heterogeneous engineering efforts of those developing these systems and to examine whether this has involved the production or propagation of misinformation about hypersonic weapon performance. Analysis of the origins of the false claims discussed previously regarding hypersonic missile flight speed, detectability, and vulnerability to missile defenses shows that engineers played active roles in shaping these technically unfounded narratives.

Consider first the claim that hypersonic weapons fly faster than the ballistic missile technologies currently in wide use. In 2019, the commander of U.S. Strategic Command, a component of the DOD responsible for the nation's global nuclear strike capabilities, testified on the security implications of hypersonic weapons before the U.S. Senate Committee on Armed Services, which is tasked with legislative oversight of the DOD. When asked by a legislator how long it would take an adversary's hypersonic missile to strike the U.S. homeland, the commander, an engineer [56], stated that "it is a shorter period of time. The ballistic missile is roughly 30 minutes. A hypersonic weapon, depending on the design, could be half of that, depending on where it is launched from, the platform. It could be even less than that" [57].

This serves as an archetypal example of heterogeneous engineering in action. It is true that a ballistic missile launched from Russian soil and following the most energy-efficient trajectory would reach the United States in about half an hour. Yet for a hypersonic glider to reach the same target earlier, an adversary would have to launch it from much closer to the United States. The 15-minute figure cited by the commander would be accurate for a particularly fast hypersonic glider launched from, for example, Portugal; a glider launched from Russia would take much longer [47]. Clearly, a missile launched closer to its target will, all else equal, reach that target earlier than one launched from further afield. Yet by diverting a query about the specific capabilities of hypersonic weapons into an implicit discussion of the advantages of forward-basing of missiles—that is, deploying them closer to their targets—the heterogeneous engineer in this case was able to construct a narrative of hypersonic superiority. This rhetorical strategy proved successful. The claim that the capabilities of hypersonic weaponry would halve the time necessary for intercontinental warhead delivery, despite lacking any technical basis, was swiftly adopted and disseminated in media discourses [32].

Similar social dynamics are apparent in the origins of the common narrative that these weapons cannot be detected by the early warning satellites used to detect incoming missiles. Speaking in 2018 to a trade group representing arms manufacturers, the U.S. Undersecretary of Defense for Research and Engineering, an aerospace engineer [58], argued that the United States would need to deploy new satellites to detect a hypersonic strike because these weapons "are 10 to 20 times dimmer than what the United States normally tracks by satellites in geostationary orbit" [59], [60]. Again, this statement is an obfuscation.

Missile early warning satellites typically watch for the IR light given off by rocket engines as they accelerate ballistic missiles in the early stages of their flight [61]. Because hypersonic glide weapons are launched on the same type of rocket engine used for ballistic missiles, the launch of a hypersonic weapon would be detected by currently deployed sensors. After this boost phase, when the rocket engine detaches and falls back to Earth, it is true that a glider would emit IR light at roughly one-tenth the intensity of a rocket exhaust plume. Thus, if one were to consider only this stage of flight, the undersecretary's statement would be technically correct. However, the relevant figure for comparison with the IR emission of a glider is not the emission of a rocket exhaust plume; rather, it is the sensitivity of the space-based sensor. Modeling of hypersonic missile flight indicates that a glider would emit well above the sensitivity threshold of currently deployed sensors under most flight conditions, rendering these weapons detectable [47], [49], [50]. The substitution of this relevant benchmark by an arbitrary comparison with rocket exhaust plume IR emission is another example of heterogeneous engineering of a narrative that casts hypersonic weapons as a revolutionary technology. As was the case with claims about the purported speed advantage of hypersonic weapons, this claim that early warning systems cannot see hypersonic weapons was subsequently propagated by the news media [62].

Finally, consider the claim that missile defenses are useless against hypersonic weapons due to their high speed and ability to outmaneuver interceptors. Testifying about the hypersonic weapon threat before the U.S. Senate Committee on Armed Services in 2018, the U.S. Undersecretary of Defense for Research and Engineering unequivocally warned that "we do not have defenses against those systems" [63]. He further predicted that the United States would not develop the technology to intercept a hypersonic weapon until the mid-2020s [64].

It is true that the defenses currently deployed by the United States are not specifically designed to intercept hypersonic weapons. However, computational modeling indicates that because hypersonic weapons rapidly decelerate while gliding through the atmosphere, they would approach their targets relatively slowly and would therefore be uniquely vulnerable to terminal defenses, which intercept missiles in their final moments of flight [48]. Developments in the Russo-Ukrainian War have confirmed this. In 2023, Ukrainian forces successfully intercepted a series of Russian maneuvering, hypersonic-speed missiles [65], [66]. They did so using U.S.-supplied Patriot Advanced Capability-3 (PAC-3) missiles, which were developed over a decade ago and are widely deployed by the United States and several of its allies [67]. Again, it is clear in the case of hypersonic missile defense that the statements of engineers advising U.S. policymakers failed to accurately reflect the technical basis for hypersonic weapon performance, being instead constructed so as to promote narratives of hypersonic superiority.

Clearly, engineers engaged in the study of hypersonic weaponry have a mixed record in upholding their ethical duty to inform. While some have subjected claims about the performance of these weapons to technical scrutiny, others have actively participated in the production and spread of misinformation about these technologies. While the use of heterogeneous engineering to promote the development of a preferred technology to policymakers is common in the weapons development arena, it nevertheless constitutes a breach of engineering ethics: what Keohane et al. [68] describe as "manipulation—seeking to ensure a certain response by the audience—that depends on deception, involving either intentional misstatements or the presentation of deliberately incomplete information in a biased way."

Roles of academics and professional societies

One potential corrective to this prevalence of misinformation is to incorporate in policy advising processes technical input from those less incentivized to promote a given technology and thus better equipped to uphold their ethical duties as unbiased informers. Traditionally, academics have often carried out this role [69]. However, the history of missile development again reveals the vulnerability of this community to ethical malfeasance. Sapolsky's study of U.S. submarine-launched missile programs, for instance, revealed a strategy by which "any scientist who had a question on the technical plans was… asked if he would be willing to contribute to the program by working on a research problem in a relevant area of technology" with U.S. Navy funding, such that "scientists were co-opted to protect the program from potential criticism" [24].

This process of the enrolment of outsiders as proponents of a technology is apparent in U.S. hypersonic weapons development. Oelrich [70], observing the puzzling fact that "reports on hypersonic weapons generally range from kid-glove treatment to cheer-leading," attributes this in part to a process of co-option. He argues that "virtually anyone in the United States who has a solid technical understanding of hypersonic aerodynamics is working for the Defense Department, one of the national laboratories, a contractor working for Defense, or is a university researcher supported at least in part by Defense Department grants," such that "the funding realities tend to create enthusiasts rather than skeptics."

Statements from academics working on hypersonic missile development bear out Oelrich's conclusions. The primary institution by which the DOD funds university work on hypersonic weapons development, the University Consortium for Applied Hypersonics (UCAH), counts among its members 113 universities [71]. UCAH faculty have advanced narratives of hypersonic superiority in the news media. This includes the claim that "it will significantly decrease response time if one of these weapons is fired" [72], and that the adoption of hypersonic weaponry would result in "decreased detection time" and a missile that "is more difficult to intercept" [73]. These statements propagate the false narrative that hypersonic weapons are uniquely fast, undetectable, and invulnerable to defenses.

If the academy fails in this respect, professional societies might better provide unbiased advice on matters of weapons technologies. For example, the American Physical Society (APS) regularly issues reports on the capabilities and societal implications of weapons technologies through its Forum on Physics and Society [74]. An APS study of the 1980s U.S. Strategic Defense Initiative (SDI), for instance, contributed to a broad consensus that many aspects of this proposal to develop a large-scale missile defense system were, despite the claims of proponents, technically infeasible [11]. This is not solely a U.S. phenomenon; the German Physical Society (DPG), for example, features a Working Group on Physics and Disarmament and defines in its charter a duty to "provide technical advice to legislative and administrative bodies" [75]. While most engineering professional societies lack policy-focused bodies of this scope, they might do well to mimic physics societies in this respect.

Challenges of ethical weapons development

Weapons development, a common application of engineering, is ethically treacherous. Among the ethical challenges confronted by the weapons engineer is the need to objectively inform publics and policymakers on the capabilities and implications of weapons technologies, even those the engineer seeks to promote. A study of ongoing U.S. hypersonic missile development efforts suggests frequent failings of engineers to uphold this ethical duty to inform.

While this analysis focuses on a particular case of weapons technology development, prior work reports a similar role of technologists in the construction of hype narratives in fields as diverse as biotechnology [76], [77], [78], [79], nanotechnology [77], [80], and information technology [81]. The obstacles that these narratives pose to effective technology governance, wherein "policy communities can become uncritically enrolled into unreasonable expectations of future potential…occasionally at great costs to those for whom they have duties of responsibility," also align with those observed in the hypersonic weapon case. Thus, the conclusions of the present work appear to be generalizable to a broad swath of engineering practice.

Failures to uphold the engineers' duty to inform can hinder the ability of publics and representatives to properly oversee their government's development and use of technologies. For weapons technologies, these ethical failings further pose a threat to human life and security. The use of missiles that are less accurate than believed to be by military planners, for instance, might result in unanticipated collateral damage or inadvertent escalation of a conflict were they to miss their targets by larger-than-expected margins. Because effective war planning requires detailed knowledge of weapons effects, misinformation could also degrade a nation's capacity to defend its national interests. If global security and the principles of democratic governance are to be upheld in a world of increasing technical complexity and risk, engineers must better adhere to the principles of engineering ethics and better equip publics and policymakers to confront the technological challenges of the future. ■

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