# Inventing Accuracy: p209

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2500 words

December 2, 2011

## 1 The Gyroscope and Technological Determinism

The popular notion that a new technology rises from the genius of a single inventor is false. Especially in the case of inertial guidance systems, innovation did not come solely from a single scientist, or even a group of scientists. Donald MacKenzie, author of Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance, shows that the modernization of missile guidance technology is due to the *social* efforts of the technologist rather than any unique mathematical or technical insights that they may possess[1]. The history of inertial guidance involves the complex interplay of many social and political elements. At the core of inertial guidance is the gyroscope.

Instead of relying on external sources such as radio signals or star-sightings, inertial guidance is a self-contained system[2]. After being calibrated with its initial position prior to launch, the missile's guidance system senses changes in orientation during flight through the use of a gyroscope. When a gyroscope is rotated around its sensitive axis, its spinning wheel reacts by changing orientation in a predictable way. With this property in mind, engineers mount one or more gyroscopes on a platform inside of the missile. This platform is free to rotate with respect to the missile. By detecting the twists and turns of this platform, the gyroscope can send signals to little electric motors to keep the missile

[1]MacKenzie, 27
[2]MacKenzie, 16

stable in flight[3]. To achieve the accuracy necessary to destroy targets at intercontinental ranges, missiles required gyroscopes of incredible precision to be developed.

Gyroscopes did not become the primary means of guidance solely out of merit. Most critical to the adoption and perpetuation of the gyroscope was the efforts of technologist Charles Stark Draper. Draper did not engineer the guidance system itself so much as the indispensable need for this new system[4]. MacKenzie demonstrates how inertial guidance came to be out of social and political circumstances, and how Draper rose to become the champion of this new technology, ensuring its survival for decades.

MacKenzie introduces the idea of a "Technological trajectory". It is the natural evolution of a single technology over time, with branches representing its different designs. "Technological determinism" is the notion that technology inevitably follows a predictable path, uninfluenced by culture or politics. With nuclear missiles primarily employing inertial guidance systems for decades now, it would appear as if no competing technologies ever existed. The incremental improvement of the gyroscope appears to be the natural path that guidance systems should take. This paper will examine the powerful social forces behind the development of guidance systems in nuclear missiles, and how a technologically deterministic point of view gives an incorrect perception of this technology's evolution.

## 2 The First Inertial Guidance Systems

Inertial guidance systems on ballistic missiles originated with the invention of the gyroscope. The gyroscope as a means of navigation or guidance, however, went unnoticed for years after its invention in the early 1900's until the development of the gyrocompass by German scientist Hermann Anschütz-Kaempfe in 1905[5]. Successful trials of the gyrocompass attracted a great deal of international attention, and lead to the creation of

[3] MacKenzie, 17
[4] MacKenzie, 61
[5] MacKenzie, 34

what MacKenzie calls “gyro culture”. The most important result of the sudden obsession with gyroscopes was that they became a technology of political power[6]. War planes could drastically improve their navigation through the use of the gyroscope, and naval weapon systems could be stabilized to better track their targets[7]. With such strong political interest, there was ample funding available for research and development.

Inertial guidance using gyroscopes saw its first use in a ballistic missile after Germany’s defeat in World War I[8]. This method of guidance was referred to as “black box” navigation, as it could operate without any input from its surroundings (such as from radio or the stars). Black box navigation was considered superior over other methods because it was not subject to outside influence. Radio guidance was also an option at the time, but it was feared that radio could be jammed. Germany did not pursue the gyroscope by chance. The Treaty of Versailles attempted to limit Germany’s ability to rearm itself after World War I. The effect, instead, was to focus Germany’s resources into technological innovation in order to compensate for these limitations[9]. Germany, still working within the confines of the treaty, had to develop lightweight and accurate munitions instead of simply manufacturing great quantities. The eventual result was the V-2 rocket. While it was not very accurate, it used gyroscopes for guidance and was effective in its goal: striking anywhere in Greater London[10].

Simultaneous with the development of black box inertial guidance systems in Germany was the work being done in the United States. One of the most influential individuals during this period was Charles Stark Draper. During this time, Draper was working in the MIT Instrumentation Laboratory. He had just become famous for his work on an extremely successful gyroscopic gun sight used by the Navy. His success made him a strong supporter of black box navigation using his gyroscopes[11]. The possibility of using the gyroscope was met with severe opposition, however, as it seemed like an unrealistic goal.

[6] MacKenzie, 37
[7] Payne, 68
[8] MacKenzie, 44.
[9] MacKenzie, 44
[10] MacKenzie, 57
[11] MacKenzie, 64.

Even Einstein stated that "the effects of linear acceleration inside the box were indistinguishable from the effects of [Earth's] gravitational field", making black box navigation impossible[12].

With his incredible social leverage, Draper was able to dismiss his critics just on the promise that he would deliver a working solution in the future. The best example of this was his victory over George Gamow. Not only was Gamow an eminent physicist, but he was also a member of the Guidance and Control Panel of the Air Force Scientific Advisory Board. He directly opposed Draper's black box research and claimed that "the military was wasting money on something that fundamentally couldn't be done"[13]. Draper, however, was also on the Scientific Advisory Board of the Air Force. More importantly, he had the prestige of a professorship at MIT and was considered a down-to-earth, outgoing individual by high-ranking military colleagues of his. To silence Gamow, he arranged a major, classified conference to discuss black box navigation and its future. Draper invited his critic, Gamow, and all of the Air Force-funded groups also working on black box navigation to this conference. On the day of the conference, Gamow did not show up. Despite Draper having clearly stacked the conference against Gamow, his absence was taken as acceptance that he was wrong, and the military went forward with its funding for Draper's project[14].

Draper's word alone was enough to silence his critics and, with extensive funding, he delivered on his promise of an inertial, black box navigation system. With great credibility backing his every claim now, Draper continued to engineer the need for inertial guidance systems[15]. MacKenzie presents technologists such as Draper not as miraculous creators, but as careful manipulators. Indeed, individuals such as Draper created the needs simultaneously with the means to satisfy them. Even in the face of competing technology such as stellar navigation, Draper was able to use his incredible social influ-

[12]MacKenzie, 67
[13]MacKenzie, 68
[14]MacKenzie, 72.
[15]MacKenzie, 85.

ence to be sure that those technologies never received sufficient funding[16] and thus were never pursued. It is in this way that we can see how technological determinism did not naturally steer guidance systems towards the inevitable improvement of the gyroscope. Rather, it was primarily the work of an influential individual pursuing his goal. Competing technologies such as stellar navigation weren't necessarily inferior, but without enough resources, they could not be properly researched. The technological trajectory of guidance systems would seem, then, to only include one branch: inertial guidance. With no competing guidance technologies, the accuracy of inertial guidance systems became a major factor in American nuclear strategy, even reshaping its military organizations.

# 3 The "Missile Revolution"

By November of 1963, the United States arsenal had amassed around 1,000 intercontinental ballistic missiles and 600 submarine-launched missiles[17]. No fewer than 170 American weapons were aimed at Moscow alone[18]. To understand how this came to be, it is important to first explore the creation of the ballistic missile followed by the choice of its guidance system. Combined with the social and political environment at the time, the engineered need for a ballistic missile is what lead the United States to amass such an overwhelming quantity of nuclear arms.

It was agreed upon by the political elite in the United States after World War II that a significant, ideological threat to the United States existed in the Soviet Union[19]. Strategies for dealing with that threat differed greatly among the different branches of the military. The Air Force for example, with a significant investment in bombers, pushed for the development of more advanced aircraft and the cruise missile[20]. The cruise missile traveled more like an airplane than the ballistic missile, and the Air Force distinguished

[16]MacKenzie, 76.
[17]MacKenzie, 95.
[18]MacKenzie, 404
[19]MacKenzie, 98.
[20]MacKenzie, 101.

itself from other branches of the military with its planes. Its interest in the cruise missile disappeared quickly after reports were released detailing the Soviet Union's growing nuclear arsenal of intercontinental ballistic missiles(ICBM)[21]. Later it was revealed that the statistics presented in these reports greatly exaggerated the "missile gap" between the Soviet Union and the United States. The "missile gap" was the notion that the Soviet Union had many more missiles than the United States, making them a superior force. Real or not, the need to close this "missile gap" played an important role in the United States choosing to develop ICBM's. The funding for cruise missiles (originally an alternative technology to ICBM's) was dropped immediately in light of this new threat, as was the funding for new bombers. In the event of a nuclear war, it was theorized that ICBM's could strike faster than a conventional bomber, and the missiles could be housed in silos fortified to withstand a nuclear attack.

The United States hoped to prevent an attack on its soil through the threat of "mutually assured destruction". It was hoped that this threat of retaliation would deter a preemptive strike by the Soviet Union. It was not a question of whether the United States needed ICBM's now, but rather which branch of its military would get to own them[22].

Two popular technologies were being developed for the guidance of the ICBM: radio and inertial. In an effort to promote the development of his gyroscope technology, Charles Stark Draper had established a graduate program at MIT. This graduate program produced powerful members of what MacKenzie refers to as the "guidance mafia."[23] Despite radio guidance being regarded as more accurate than inertial, the guidance mafia suggested that accuracy was not, in fact, an important quality of missile guidance[24]. The nuclear strategy at the time was to deliver a single, preemptive blow to the Soviet Union in the event of a war, so accuracy was not very important in that case. Radio guidance, then, was eliminated in favor of Draper's inertial guidance. This would make the history of guidance systems appear to follow the natural evolution of the inertial systems already

[21] MacKenzie, 112.
[22] MacKenzie, 96.
[23] MacKenzie, 118.
[24] MacKenzie, 122.

in place.

Missiles in the United States were not being built during this time out of any universal need agreed upon by the branches of the military. The Navy, seeing this new technology, built its own missiles because it felt it had to have some to remain a relevant force in the military[25]. With the exaggerated threat of the Soviet Union's rapidly growing, massive arsenal, the United States invested in technologies that would keep its quantity of missiles greater in hopes that numbers alone could deter the threat of war[26]. Nuclear strategy, then, became a rationalization of the quantity and type of missiles produced, rather than a guide[27].

## 4 "Technological Trajectory"

Conventional wisdom, MacKenzie states, sees the incremental improvement of technology as a natural process that follows a "technological trajectory"[28]. Technological change, however, is not a self-sustaining process that follows a natural path. To understand technological change, the social circumstances in which the change occurred must be understood. The trajectory of a particular technology is actually a self-fulfilling prophecy, especially in the market of inertial guidance[29]. Technologists, seeking to continue their craft, continue to engineer a need for their technology. In the case of Charles Stark Draper, he sold the promise (and need) of increased accuracy even before he was sure that he could provide it. This strategy ensured that his projects remained heavily funded regardless of whether they were better than the competitors'.

The notion of "technological determinism" is the most pervasive and paralyzing determinism[30]. During the era in which nuclear weapons were being produced in vast quantities, advances were described by their inventors simply as the "modernization" of

[25]MacKenzie, 162.
[26]MacKenzie, 162.
[27]MacKenzie, 163.
[28]MacKenzie, 166.
[29]MacKenzie, 168.
[30]MacKenzie, 384.

the United States arsenal. The introduction of a new weapon presented as "modernization" makes it seem as if the weapon came about naturally as a result of technological progress[31]. The general public assumes from this that "modernization" is an unstoppable force. It is in the face of this force, then, that we feel helpless, or "paralyzed" to stop it[32].

This is not the truth, however. It has been shown that the "black box" for navigation was not a sudden insight. Its development involved many people over several decades. Its supporters had to prove that it was not only possible, but that the alternatives (bombers) were not preferable. Proponents of black box, inertial guidance systems had to work hard to not only promote their own technology, but eliminate competitors'. "Modernization", then, was just a cycle of self-fulfilling prophecies made by individuals such as Charles Stark Draper. Their promises of innovation provided them the funding to pursue their goals without competition. So while it appears that the natural path for guidance systems was the incremental improvement of the gyroscope, it was actually the hard work of a few, influential individuals making sure that their technology was the only one in use.

Technological determinism inclines the general public to passivity[33]. Coupled with a sense of political determinism, a belief that the world of government can not be altered as well, leaves people feeling hopeless to affect change. There are, however, many divisions in the political world. The politicians and the technologists involved in the development of our nuclear arsenal regard their jobs as remarkably ordinary, despite the extraordinary products they are making[34]. As long as the further improvement of our nuclear arms appears to be a natural phenomenon, I do not believe that it will ever cease.

[31] MacKenzie, 383.
[32] MacKenzie, 385.
[33] MacKenzie, 395.
[34] MacKenzie, 403.

# References

[1] Donald MacKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance*. The MIT Press, Massachusetts, 1990.

[2] Craig M. Payne, *Principles of Naval Weapon Systems*. Naval Institute Press, Maryland, 2006.