A Virtue Ethics Analysis of the Development and Testing of the Airbus A400M Atlas Aircraft

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By

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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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Introduction

In May of 2015, an Airbus A400M military plane crashed during a pre-delivery test flight near Seville, Spain following the failure of three of the four engines. Of the six members of the aircraft crew on the flight, four were killed and the remaining two seriously injured (Keller, 2015). Investigations led by the Spanish defense ministry agency CITAAM found that the primary cause of engine failure was a software bug which emerged during software installation onto the computers which control the engines. Following these investigations, it was accepted that the fatal crash was a result of a concatenation of isolated factors, which altogether prevented the conclusion of individual or group behavior that can be attributed as a failing. However, this deduction fails to explore the morality of Airbus' actions while developing and testing the A400M plane. To view this incident as a one-time culmination of small issues denies the chance for society to judge the improper practice of software design and testing from one of the largest aerospace defense companies in the world.

I will analyze the case of the A400M plane crash using the ethical framework of virtue ethics to judge the morality of Airbus' actions and demonstrate that the company can be held ethically responsible for the event. Virtue ethics is an ethical theory which can be used to assess the moral character of individuals or entities based on their expression or absence of desirable traits (van de Poel & Royakkers, 2011). Specifically, I will justify this claim by demonstrating Airbus' lack of two character traits deemed necessary for morally responsible engineers: commitment to quality and cooperativeness. Airbus' inability to exemplify these characteristics becomes evident throughout the development, testing, and preparation of the A400M plane for flight in coordination with the company's civil engine suppliers. To support this argument, I will cite news articles containing excerpts from the criminal court case surrounding the event,

CITAAM's report on the accident, and interviews from members of Airbus and engine supplier EPI.

Background

Airbus is a commercial aircraft manufacturer and one of the largest aeronautics and space companies in the world, producing both civil and military aircraft. The A400M Atlas aircraft is a military cargo plane produced by Airbus with the first aircraft being delivered to the French air force in 2013, years before the May 2015 crash (Bjork & Wall, 2015). The engines for the A400M plane were built and supplied by an external civil organization, Europrop International (EPI). On May 9, 2015, a pre-delivery test flight of an A400M, piloted by an Airbus Defense and Space test crew, was being conducted out of Seville Airport in Spain. During the flight, a technical fault occurred with three of the engines, forcing an emergency landing and ultimately causing the death of four of the six members of the crew. This engine failure was a result of files containing torque calibration parameters being wiped due to a software vulnerability in the installation of engine software at Airbus facilities (Kelion, 2015). The A400M model faced temporary flight restrictions following the May 2015 crash, but would later be reinstated and praised for its performance by clients such as the French air force. The crash was investigated by the Commission for the Technical Investigation of Military Aircraft Accidents (CITAAM) in Spain, whose report was used in the criminal trial which found neither Airbus nor EPI criminally liable for the crash and corresponding loss of life.

Literature Review

Many scholarly sources have examined groups of software failures such as the A400M plane crash and explored strategies to produce faultless software. However, these works do not investigate the A400M crash in detail to explore the morality of Airbus and its insufficient

design and testing practices which resulted in the accident. Marilyn Wolf (2016) examines examples of software failures including the A400M crash, presenting immediate industry-wide measures that should be taken to improve the reliability and safety of embedded software in general. These measures include: assigning responsibility to top company officers, increasing staff and improving inspections at the lower end of companies, investing in software artifacts, making reliability a top-level concern, and emphasizing the practice of "trust, but verify" (Wolf, 2016). On an industry-wide level, these practices include the improvement of established procedures for software reviews, designing foundational sets of embedded software units for public use beyond open-sourcing code, and changing the mindset of the industry to emphasize verification of software. While these guidelines would have helped address the issues which resulted in the A400M accident, the author does not provide an argument about determining how to hold companies that do not meet these standards accountable in the case of subsequent software failures.

Frank J. Furrer (2017) discusses examples of software successes and failures to determine what requirements must be met to produce software that is "error-free." Furrer outlines the following requirements to produce software successes: responsible management, established quality company culture, appropriate evolution strategy, more effective product liability for software, and good employees (Furrer, 2017). The author's ultimate argument is that the increasing dependence upon software in society must be met with greater responsibility, competence, and long-term thought from companies to avoid catastrophes. While the lack of some of these requirements correlate with the failings of Airbus, Furrer does not go into detail about how Airbus in particular failed to meet these requirements or were otherwise morally responsible for the accident.

These scholars focus on potential solutions to address the issue of faulty software on a company and industry-wide level, agreeing that there needs to be change to prevent further disasters. However, they fail to explore the morality of Airbus and how the company fell short from meeting the standards that they propose. Using virtue ethics, I will analyze how Airbus failed to act in accordance with virtues for morally responsible engineers to demonstrate the lack of care taken with its design and testing.

Conceptual Framework

Virtue ethics is a normative ethical theory focusing on the nature of the acting person or group. As developed by Aristotle, virtue ethics is centered around striving to live "the good life," which can be understood as achieving happiness by being a good person (van de Poel & Royakkers, 2011). To reach this optimal state, Aristotle argues that people must use reasoning to its fullest extent to act with moral virtues that exist as an equilibrium between two extremes. This means that people must seek the middle course of the extremes depending on the given situation, in which practical wisdom is used to determine what the proper equilibrium is. As a result, there is always ambiguity with the right course of actions, as the balance is determined by the corresponding unique circumstances.

Since the invention of virtue ethics, many people have distinguished virtues with which people should act. Michael Pritchard developed a list of 'Virtues for Morally Responsible Engineers' beyond the general virtues to be used in daily life (Pritchard, 2001). These virtues are listed as:

1. cooperativeness (being a good "team player")
2. willingness to compromise
3. perseverance
4. habit of documenting work thoroughly and clearly
5. commitment to objectivity
6. openness to correction (admitting mistakes, acknowledging oversight)

7. commitment to quality
8. being imaginative
9. seeing the “big picture” as well as the details of smaller domains

Figure 1: Pritchard's ‘Virtues for Morally Responsible Engineers’

Pritchard goes on to state that having all of these dispositions may not be sufficient to practice morally responsible engineering, but that lacking any of these virtues will certainly diminish from responsible engineering practice (Pritchard, 2001). Therefore, any action that displays an absence of one or more of these virtues in turn leads to irresponsible engineering practice that can be used as evidence for determining ethical responsibility. I will thus analyze the actions made by Airbus in the production, design, and testing of the A400M plane using two virtues outlined by Pritchard: commitment to quality and cooperativeness. By examining each one of these virtues, I will then determine whether or not Airbus is ethically responsible for its practices in the development of the A400M.

Analysis

Airbus particularly falls short of two virtues that are integral for morally responsible engineers: commitment to quality and cooperativeness. This judgment is determined from an analysis of several of Airbus’ actions and practices in the development of the A400M aircraft leading up to the eventual crash in May, 2015. As described by Pritchard, lacking just one of these virtues is grounds to find a subject unethical (Pritchard, 2001). The following sections consider each of these two virtues individually, providing evidence and subsequent analysis of actions that demonstrate a lack of the particular virtue.

Commitment to Quality

Airbus displayed a lack of the virtue of commitment to quality as demonstrated by its failure to address valid warnings from engine supplier EPI in association with software installation issues and insufficient safety measures. When considering a cargo aircraft flying up

to an altitude of 40,000 feet that can carry dozens of men when in operation, the quality of the plane is of utmost importance. Beyond just developing working systems, commitment to quality in the lens of virtue ethics requires an engineer to sufficiently test and verify systems, addressing identified issues to ensure safe, well-made products.

In October 2014, months before the eventual crash of 2015, EPI warned Airbus and the European Aviation Safety Agency (EASA) that issues related to software installation could cause the deletion of engine data (Hepher, 2017). Note that rather than listen to this evidence and attempt to coordinate corrective actions, Airbus instead failed to acknowledge the problem and took no significant action. When an engineer learns about a new error, especially one as critical to safety as the deletion of engine data, the morally responsible corrective action would begin with assessing the problem and identifying the root cause. Then, the problem can be directly addressed, retested, and verified to determine if a successful solution has been reached. Considering that models of this aircraft had already been delivered to customers when Airbus learned about this issue, the safety of both customers and Airbus test crews were put at risk by the company's lack of action, despite knowing that the problem was correlated with software installation.

It was also reported that technicians would not be warned prior to take-off that there were any issues present in this situation. According to the A400M's design at the time of the crash, the first warning that pilots would receive about the engine data issue would not appear until after the plane had reached 120 meters in the air (Hepher, 2015). In the case of this unique problem, a baseline ethical commitment to quality would require that any issues with engine data would at least display a warning to technicians or pilots before take off. Refraining from taking this

minimal action puts the safety of the pilots and passengers of the aircraft at risk and demonstrates an immediate failure in commitment to quality.

The production of the A400M model plane was plagued with problems throughout its design process in addition to the software installation issue which caused the crash. Within the context of production and delivery delays spanning upwards of four years, the first plane of this model delivered to Germany reportedly contained 875 construction errors or malfunctions (Agence France-Presse, 2015). With the pressure of being behind schedule and over budget, Airbus demonstrates a consistent lack of quality control where problems are overlooked or outright ignored. This points to a failure to properly test and verify the quality of its products to ensure that they work as expected and with safety carefully considered. Continuing to deliver these aircraft to stakeholders with knowledge of hundreds of issues within the model illustrates an indifference to the potentially catastrophic loss of life that occurs with plane crashes and a failure to have a commitment to quality within the framework of virtue ethics.

As I have shown that Airbus has failed to demonstrate the virtue of commitment to quality within the lens of virtue ethics, opposing viewpoints must be addressed. Some might think that Airbus cannot be held morally responsible for the May 2015 crash because it was a result of a culmination of factors including improper installation by individual technicians and poor pilot response. However, this point of view fails to consider that a greater commitment to quality from Airbus would have prevented the accident outright. During the flight, the pilots were reportedly ordered by controllers to stay at 1,500 feet in altitude after the engines were frozen at maximum speed (Hepher, 2017). To follow this order, the pilots reduced thrust, which then locked the engines to idle and caused the crash. CITAAM investigators determined that the pilots of the aircraft had not been trained to expect the situation and that the A400M's

troubleshooting system was inadequate in aiding them. Furthermore, CITAAM found that "The mitigation measures derived from that (problem) report were not sufficient" in regards to the October 2014 report by EPI that there were potential defects with improper software installation (Hepher, 2017).

This suggests that even though the software installation technicians or pilots may have been able to conduct their respective jobs better, Airbus was aware of the software installation problem despite there being no occurrence during previous flights. By locating and addressing the issue beforehand or implementing a more robust alert system taking place before liftoff, the software installers or pilots would not have needed to act with perfection to prevent the accident. Simply because there was a culmination of errors that resulted in the crash does not mean that Airbus should not have committed more time to ensuring the quality of the A400M model.

Cooperativeness

Airbus displayed a shortage of the virtue of cooperativeness as seen through its strained relationship with its engine supplier, EPI. In the industry of engineering, it is essential that cooperation is fully embraced within a company but also when coordinating with regulatory groups or partners. Proper cooperative engineering entails honesty, communication, acceptance of wrongdoing, and a mutual desire to work together to successfully develop a safe, effective product. When working directly with another organization to develop a new plane, seamless cooperativeness is integral to ensuring that the aircraft is completely safe to fly. Failure to coordinate efforts successfully with all parties involved can in turn lead to substantial loss of life for both testers and customers.

To understand the failure of Airbus to practice the virtue of cooperativeness, further background on the relationship between Airbus and EPI must be included. Airbus was

developing the A400M aircraft as a military cargo plane with European civil certification, providing these planes to various clientele worldwide. EPI, a pan-European consortium, was making and providing the engines used on the A400M model. Due to the aircraft's hybrid civil and military nature, there existed regulatory confusion as to who was responsible for installing the software for the computers of the engines (Hepher, 2017). EPI argued that it had authority to install the software of the engines under civil rules, whereas Airbus argued that it should install the software itself due to authority under military rules. Airbus would even go on to claim that the software design did not meet its specifications, which was denied by EPI. As previously discussed, EPI did also warn Airbus of the potential file deletion in certain cases of the engine software installation, but Airbus decided to keep installing the software themselves. After the crash, CITAAM determined in its investigation that Airbus was actually correct in installing the software itself since it operates in military installations (El Confidencial, 2018). The combination of these events ensued a rift between the two companies which manifested publicly in the criminal lawsuit following the crash due to the software bug being located within the process of installing the software onto the engines.

Note that rather than working with EPI and relevant government authorities to determine who was responsible for installing the software, Airbus decided to do so themselves. Evaluating this absence of communication and inability to collaborate with its partner through virtue ethics illustrates a failure to act with the virtue of cooperativeness. By working together effectively with its partner, Airbus may have fixed the software defect or addressed improper installation techniques that could have been related to the deletion of key files. To determine who was responsible for installing the software for the engines, the proper action would have been to contact relevant authorities to evaluate who had jurisdiction over the installation when the initial

issue arose. When alerted to the issue associated with inadequate software installation by EPI, this measure of contacting authorities would have been an especially effective way to help repair the diminishing relationship of the companies and restore cooperativeness to address the problem. Instead, Airbus continued to install the software themselves without consulting with EPI as to how to address the problem or to validate proper installation techniques. Despite the fact that Airbus was confirmed to have proper jurisdiction over the software installation in the investigation of the accident by CITAAM, Airbus can be held morally responsible for the May 2015 crash using the framework of virtue ethics as illustrated through a lack of the virtue of cooperativeness. A more collaborative effort between Airbus, EPI, and relevant government agencies would have resulted in improved software installation techniques, identification and mitigation of the software defect, better testing, and improved relationships between the involved parties that may have prevented the accident from taking place.

Conclusion

As a result of the analysis of the practices leading up to the May 2015 A400M plane crash, Airbus' actions display a consistent lack of the virtues of commitment to quality and cooperativeness within the ethical framework of virtue ethics. While no individual engineer, technician, pilot, or quality tester is entirely guilty of causing the accident, Airbus as a whole can thus be held ethically responsible under the lens of virtue ethics despite not being held legally liable. This ethical evaluation of Airbus serves as a critical reminder that adherence to virtues for morally responsible engineering is paramount for maintaining reliable and safe products, especially in the context of cargo aircraft capable of transporting dozens of people. This analysis contributes to the broader discourse on responsible engineering practices in software and aerospace engineering. By adding to this discourse, a greater emphasis may be placed on the

importance of holding companies morally accountable for their actions while learning from their mistakes as ethical engineers. This, in turn, can be instrumental in preventing future disasters and fostering a culture of responsible engineering that may promote a safer future as technology continues to spread throughout society.

References

Agence France-Presse. (2015, May 10). *Black boxes of crashed A400M plane found, aircraft grounded*. Defense News. https://www.defensenews.com/global/europe/2015/05/10/black-boxes-of-crashed-a400m-plane-found-aircraft-grounded/

Bjork, C., & Wall, R. (2015, May 9). *Airbus A400M transport plane crashes in Spain*. The Wall Street Journal. https://www.wsj.com/articles/airbus-a400m-transport-plane-crashes-in-spain-1431177546

El Confidencial. (2018, April 9). *Judge drops criminal case on A400m crash but points to Airbus and EPI*. Defense-Aerospace. https://www.defense-aerospace.com/judge-drops-criminal-case-on-a400m-crash-but-points-to-airbus-and-epi/

Furrer, F. Software. *Computer Science Spectrum*, 40, 264–269 (2017). https://doi-org.proxy1.library.virginia.edu/10.1007/s00287-016-0973-6

Hepher, T. (2015, June 9). *Exclusive: A400M probe focuses on impact of accidental data wipe*. Reuters. https://www.reuters.com/article/us-airbus-a400m-idUSKBN0OP2AS20150609

Hepher, T. (2017, November 8). *Airbus knew of software vulnerability before A400M crash*. Reuters. https://www.reuters.com/article/idUSKBN1D81BG/

Kelion, L. (2015, June 10). *Fatal A400M crash linked to data-wipe mistake*. BBC News. https://www.bbc.com/news/technology-33078767

Keller, G. (2015, June 3). *3 out of 4 four engines on the crashed Airbus military plane were "power frozen."* Business Insider.

https://www.businessinsider.com/3-out-of-4-four-engines-on-the-crashed-airbus-military-plane-were-power-frozen-2015-6

Pritchard, M. (2001). Responsible engineering: The importance of character and imagination. *Science and Engineering Ethics*, 7(3), 391-402. https://doi.org/10.1007/s11948-001-0061-3

van de Poel, I., & Royakkers, L. (2011). *Ethics, technology, and engineering: An introduction*. Hoboken, NJ: Blackwell Publishing Ltd.

Wolf, M. (2016). Embedded software in crisis. *Computer*, 49(1), 88–90. https://doi.org/10.1109/mc.2016.18