Prospectus

Designing a Sustainable Aircraft to Address the Aviation Industry Emissions Problem
(Technical Topic)

Analysis of Geoengineering Solutions and Effectiveness to Combat Climate Change
(STS Topic)

A Thesis Prospectus
In STS 4500
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Bachelor of Science in Aerospace Engineering

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:

Although it may seem like a dystopian science fiction concept, geoengineering – which can be defined as human alteration of the climate – is already an active driving factor in changing our planet's climate. Specifically, runoff pollution, chemicals, and combustion reactions from the Industrial Revolution and modern eras have drastically contributed to greenhouse gas emissions and global warming. According to NASA (2020), warmer ocean temperatures provide more energy for storms, causing them to be larger and stronger. When a superstorm of this size hits land, far more catastrophic flooding can occur, contributing to increased waterborne diseases (NASA Science Editorial Team, 2020). The heavy storm damage can also adversely impact human health physically and mentally, leading to socioeconomic problems such as financial burdens and depression (National Institute of Environmental Health Sciences, n.d.). To address the overarching problem that climate change poses to humanity and this planet, I will analyze potential benefits and problems that can come from climate change countering geoengineering solutions, as well as focus my technical research on addressing emissions produced by the aviation industry with my technical team.

Technical Problem:

The aviation industry contributes over 2.5% of all global carbon dioxide emissions, and the rapidly growing industry doesn't seem to be slowing down (Ritchie, 2024). Although greener technologies – such as hybrid electric engines and sustainable aviation fuels – help reduce pollution, the majority of all aircraft still use combustion-based engines. These engines, like the classic propeller on a private Cesna or a turbofan engine on a commercial airliner, all need to burn some type of fuel to produce power and thrust. Although most of the exhaust is water vapor, there are still plenty of harmful chemicals emitted from the combustion process. One group of these chemicals is nitrogen oxides (NOx). Nitrogen oxides not only produce harmful tropospheric (ground level) ozone, but they are also greenhouse gases that damage stratospheric (normal) ozone levels and produce acid rain (Lee et al., 2021). In addition to nitrogen oxides, combustion reactions produce harmful unburned chemicals, such as carbon monoxide, that are detrimental to human health. Combustion engines also leave behind warm vortex contrails that trap heat from the sun and contribute to rising surface temperatures (Lee et al. 2021).

To combat this growing problem, my team and I will be designing and building a fully sustainable, combustion free aircraft. Specifically, we are designing and building a high-endurance solar-powered drone that would be able to fly for days on end and only land to change equipment for different missions or to complete an inspection. This type of aircraft was selected over the more common commercial passenger aircraft due to current limitations in solar panel and battery technology, which wouldn't provide enough power for a large payload weight and fast velocity aircraft.

Although solar power is one of the leading green energy sources, Responsible Research and Innovation (RRI) analysis could bring up some questions on the future of solar power. As a background, Responsible Research and Innovation programs raise "normative, and future-oriented issues" that allow scientists and engineers to think about future consequences of the technology designed (Bijker, 2017). Using this method to analyze the future of solar power reveals that solar panels often have toxic metals, such as Lead and Cadmium, being used in semiconductor layers (US EPA, 2021). In addition to its end-of-life dangers, mining for resources for solar panels involve the use of heavy machinery that oftentimes tear up natural land

and ecosystems, and produce greenhouse emissions of their own. These additional issues could be topics of research and analysis for future projects.

STS Problem:

Geoengineering solutions are revolutionary ideas that have been proposed to counter the rapidly shifting effects of climate change. However, they are still relatively new and the long term effects have not been clearly studied yet. As a background, geoengineering as a climate solution is the intentional alteration of our climate and atmosphere in an attempt to reverse the effects of climate change and global warming. Currently, the two different methods of geoengineering are Carbon Dioxide Removal (CDR) and Solar Radiation Management (SRM). CDR focuses on removing the carbon dioxide greenhouse gas from the atmosphere, while SRM focuses on reducing the amount of solar radiation that gets absorbed on the surface of the Earth (Royal Society of London, 2009). Of the two methods, CDR has been researched and tested more, and has already been incorporated in some factories to capture the carbon dioxide and convert it into calcium carbonate cements (Gadikota, 2021). From Gadikota's research, "ex situ carbon mineralization" is a "thermodynamically downhill" method for carbon capture, meaning that this method requires little to no energy to recapture the carbon emissions from factories. On the contrary, SRM is still extremely experimental due to the associated stigma of reflecting sunlight back into space, seeding clouds by spraying chemicals, and with the concept of disrupting the natural flow of moisture in the atmosphere (Nicholson, 2020). One SRM solution is cloud seeding, which is spraying nucleation chemicals in the atmosphere to allow moisture to collect and clouds to form. However, some of the chemicals used, such as sulfur dioxide, are harmful to the environment and can break down stratospheric ozone (Crutzen, 2006). Kuhl

(2022), also argues that although cloud seeding could be a geoengineering solution to water shortages, there can be severe ethical impacts if this practice is misused (Kuhl, 2022). Since cloud seeding produces clouds by drawing moisture from the atmosphere, the people downwind of the cloud seeding users could experience droughts due to the moisture being used up prematurely.

A utilitarian analysis could be used to analyze the benefits and drawbacks of using cloud seeding for addressing water shortages. As a background, utilitarian analysis focuses on maximizing the happiness of all people involved in an action, or from a technology (Reuter, n.d.). However, there are also drawbacks to this method of analysis since it focuses on a people-centric perspective. Climate change is a global and environmental issue, and although it has impacts on people, it affects the planet's ecosystems much more. Since utilitarianism only focuses on the happiness of people, it can overlook the needs of nature. With regards to the issue of cloud seeding, the extra shade from the reflective clouds has helped offshore reefs recover from bleaching, and the extra moisture collected gives redwoods and other tall trees the moisture needed to survive in a drying environment (Temple, 2017). In my STS thesis, I hope to explore and analyze the benefits and drawbacks of geoengineering more and choose a side to argue for based on evidence of the analysis.

Conclusion:

In conclusion, my thesis research will focus on two problems and solutions to the overarching problem of climate change; the aviation industry and sustainable aircraft, and geoengineering benefits and drawbacks. I will also explain benefits and nuances to utilitarianism and other STS analysis methods as they apply to my research topics of interest.

Works Cited:

Bijker, W. (2017). Constructing Worlds: Reflections on Science, Technology and Democracy (and a Plea for Bold Modesty). *Engaging Science, Technology, and Society*, *3*, 315–331. https://doi.org/10.17351/ests2017.170

Crutzen, P. J. (2006). Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma? *Climatic Change*, *77*(3), 211–220. https://doi.org/10.1007/s10584-006-9101-y

Gadikota, G. (2021). Carbon mineralization pathways for carbon capture, storage and utilization. *Communications Chemistry*, *4*(1), 1–5. https://doi.org/10.1038/s42004-021-00461-x

Human Health Impacts of Climate Change. (n.d.). National Institute of Environmental Health Sciences. Retrieved October 29, 2024, from https://www.niehs.nih.gov/research/programs/climatechange/health_impacts

Lee, D. S., Fahey, D. W., Skowron, A., Allen, M. R., Burkhardt, U., Chen, Q., Doherty, S. J., Freeman, S., Forster, P. M., Fuglestvedt, J., Gettelman, A., De León, R. R., Lim, L. L., Lund, M. T., Millar, R. J., Owen, B., Penner, J. E., Pitari, G., Prather, M. J., … Wilcox, L. J. (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmospheric Environment*, *244*, 117834. https://doi.org/10.1016/j.atmosenv.2020.117834

NASA Science Editorial Team. (2020, March 10). How Climate Change May Be Impacting Storms Over Earth's Tropical Oceans. *NASA Science*. https://science.nasa.gov/earth/climate-change/how-climate-change-may-be-impacting-storms-over-earths-tropical-oceans/

Nicholson, S. (2020, September 30). Solar Radiation Management. *Wilson Center*. https://www.wilsoncenter.org/article/solar-radiation-management

Rueter, S. (n.d.). *Ethical Theories: Virtue Ethics, Utilitarianism, and Deontology*. Philosophos.Org. Retrieved November 8, 2024, from https://www.philosophos.org/ethical-theories-virtue-ethics-utilitarianism-deontology

Royal Society of London (Ed.). (2009). *Geoengineering the climate: Science, governance and uncertainty*. https://royalsociety.org/-/media/policy/publications/2009/8693.pdf

Temple, J. (2017, April 20). Scientists Consider Brighter Clouds to Preserve the Great Barrier Reef. *MIT Technology Review*. https://www.technologyreview.com/2017/04/20/5006/scientists-consider-brighter-clouds-to-preserve-the-great-barrier-reef/

US EPA, O. (2021, August 23). *End-of-Life Solar Panels: Regulations and Management* [Guidance (OMB)]. https://www.epa.gov/hw/end-life-solar-panels-regulations-and-management