

Mitigation of ultraviolet solar radiation involving calcite

Tanvi Nare^{1*}, Prachi Thakkar^{1*}, Darshini Kumar^{1*}, Somya Mulla^{1*}, Kevin Jones¹

¹ Independence High School, Ashburn, Virginia

SUMMARY

Stratospheric aerosol injection (SAI) is a technique that involves dispersion of ultraviolet (UV) radiation-reflecting aerosols into the stratosphere to block solar radiation and promote global cooling. This investigation explores the use of calcite powder for SAI by measuring its ability to deflect ultraviolet radiation from the sun. Calcite is a common and radiation-resistant form of calcium carbonate (CaCO_3) that is safe for humans and wildlife compared to alternative aerosols. The experiment took place on a high-altitude balloon (HAB) payload. We evaluated the UV blockage of three sets of laminated calcite sheets with varying concentrations based on the readings from two UV sensors. We hypothesized that the sheet with the highest calcite distribution would block the most UV radiation. The results indicated that both sheets with calcite were effective in blocking UV radiation. These findings pose further investigations of the concentration of calcite needed for SAI and sets the foundation for future investigations in the field of SAI using calcite and other substances that are lower risk for humans and wildlife.

INTRODUCTION

A recent study has compared the economic impacts of global temperature increases of 2.8°C and 4.5°C from pre-industrial temperatures over the next 75 years (1). A 4.5°C increase in global temperature could cost the United States \$520 billion per year (1). If efforts are made to limit the rise in temperatures to only 2.8°C , the United States could reduce economic losses by \$224 billion (1). This will benefit not only the United States, but also the rest of the world.

Solar geoengineering, also known as solar radiation management (SRM), involves deflecting solar radiation from the atmosphere to help prevent global warming. The use of stratospheric aerosols, such as sulfuric acid, has been previously attempted; however, sulfuric acid can damage the ozone layer and cause heating in the lower stratosphere (2, 3). Limited research has been conducted on other aerosols. One such alternative aerosol is calcium carbonate. Calcite SRM could be a revolutionary technique in mitigating the effects of climate change, thus reducing industrial economic losses.

Calcite is a form of calcium carbonate (CaCO_3) with a distinct hexagonal crystal structure that is different from other forms of calcium carbonate (4). It is radiation resistant for wavelengths of light greater than 200 nm, undergoing no structural changes under radiation, proving it suitable for SRM. While all forms of CaCO_3 contain primarily ionic bonds, calcite's structure is less densely packed which allows the substance to recover initial configurations after radiation

exposure without permanent structural alterations (5). Calcite can be used in the atmosphere at a low cost with minimal technical risk and is commercially available while being much safer than alternatives such as sulfur dioxide and sulfuric acid (2). Sulfur dioxide and other sulfur-based compounds can harm human respiratory systems and form acid rain through atmospheric interactions, thereby harming wildlife and ecosystems (6). It also has high potential for erosion of the ozone layer (7). Simulations have found that sulfur dioxide injection into the atmosphere can cause large-scale warming in the stratosphere, which would alter major weather patterns (8). Calcite has been found to require less loading, or a lower atmospheric concentration, for the same amount of deflection because it absorbs less terrestrial infrared radiation and therefore has a greater ability to scatter solar light; moreover, it results in less aerosol-induced heating of the stratosphere, mitigating concerns about ozone loss (7). This makes it more atmospherically suitable and less harmful to human life and wildlife (7). Many engineering and research firms already possess the technology to employ calcite SRM, such as solid aerosol dispersers and high-altitude aircraft, indicating that this technique can feasibly be implemented within the next fifteen years (9). SRM could reduce the highest global temperature that would be reached even when implementing other aggressive greenhouse gas reduction strategies, instead maintaining temperatures at a steady level and eventually helping to decrease them (10).

This study investigates calcite as a method of solar radiation management, which, if effectively utilized, would protect human life and wildlife while reducing economic losses. If proven to work in solid form, it can be investigated for use as an aerosol in the future. This experiment took place on a high-altitude scientific balloon flight to test the hypothesis that the amount of ultraviolet (UV) radiation reaching the LTR390 and GUV-A-212SD sensors would decrease with increasing densities of calcite powder. Our findings that .05 and .1 grams of calcite block more radiation than a blank sheet support the hypothesis and provide a deeper examination of a highly plausible method of solar geoengineering, offering insight into how to mitigate climate change on Earth. This lays a foundation for investigating more large-scale methods of solar radiation management using calcite in the form of an aerosol, and shows that there are substances to use that will not harm human life and wildlife ecosystems.

RESULTS

This experiment was performed to investigate the effect of calcite aerosols on reducing UV radiation via SRM. Other aerosols such as sulfur dioxide have harmful effects on the environment (7). However, CaCO_3 has shown promise as an

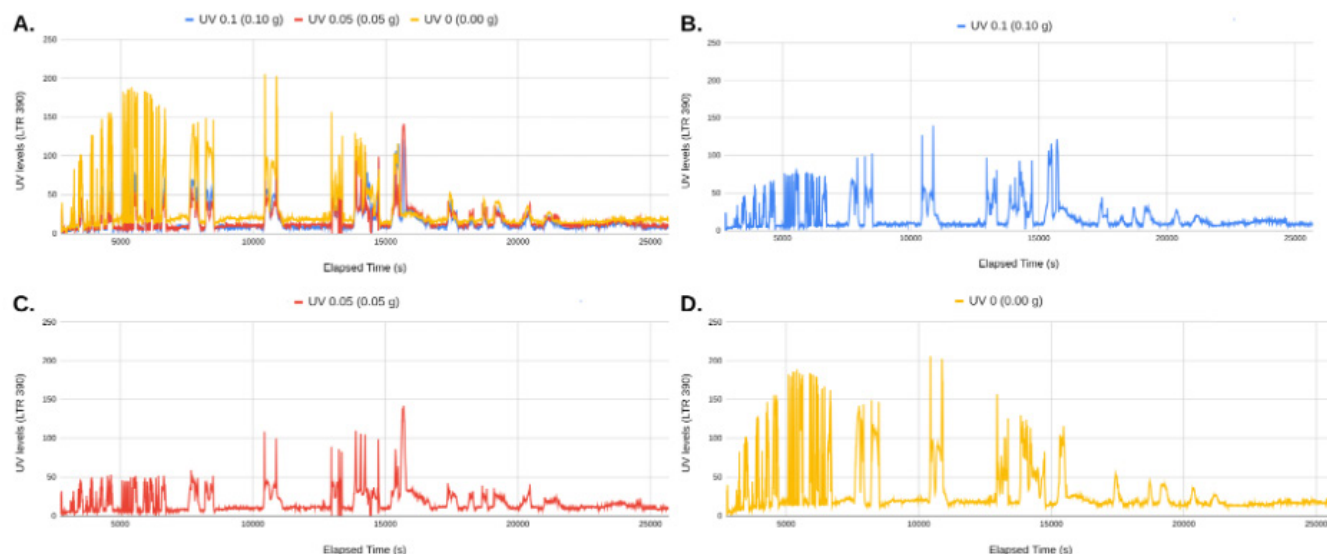


Figure 1. Both calcite concentrations reduce ultraviolet (UV) penetration to LTR-390 sensors as compared to the negative control. A.) UV intensity levels measured by LTR-390 sensors over approximately 7-hour flight time from floating to landing for laminate sheets coated with different calcite concentrations. Sheets containing B.) 0.10 g (UV 0.1, blue), C.) 0.05 g (UV 0.05, red), and D.) 0.00 g (UV 0, yellow) of calcite were launched to a stratospheric level of 24,000 meters (N=1).

agent to block out harmful solar radiation (2). Specifically, this experiment analyzed calcite, the most radiation-resistant form of CaCO_3 , as a prime agent of UV mitigation.

To investigate the effects of calcite on the mitigation of solar radiation, we tested three sets of laminated sheets with varying concentrations of calcite (0.00g, 0.05g, and 0.10g) using two different types of UV sensors – LTR-390 and GUA-S12SD – contained in a payload box launched into the stratosphere (24,000 meters). Payload boxes are containers meant to hold a specific payload that is launched on a high-altitude balloon, in this case being an experimental payload. However, it would be worthwhile to test at different stratospheric heights to determine if conditions and atmospheric patterns at different heights impact the data, but not at any heights outside of the stratosphere.

The levels of UV radiation detected by the sensors varied across the three calcite densities (**Figure 1, Figure 2**). The two UV sensor types quantified ultraviolet radiation using different outputs. The LTR-390 sensors quantified UV intensity directly as a UV index, while the GUA-S12SD sensors produced a voltage output, which increased with increasing UV intensity. Despite these different measurement scales, both sensor types showed the same overall trend throughout the flight: the control sheet containing 0.00 g of calcite produced the highest UV readings, while the 0.05 g and 0.10 g calcite sheets produced lower readings, indicating greater attenuation of ultraviolet radiation (**Figure 1, Figure 2**). As the payload ascended and remained at high altitude, UV levels increased before declining during its descent. Spikes in UV intensity were observed in both datasets; however, the LTR-390 sensors detected these spikes earlier in the flight, beginning at approximately 16,000 seconds, whereas similar increases in the GUA-S12SD voltage output occurred later (**Figure 1, Figure 2**). Although the sensors used different measurement units, they showed consistent reductions in UV

transmission through the calcite-coated sheets relative to the control.

To evaluate the effectiveness of the three calcite concentrations in blocking ultraviolet radiation throughout the flight, we performed a one-way analysis of variance (ANOVA) in R (version 4.5.1) on UV index measurements collected by the LTR390 sensors. The ANOVA indicated a statistically significant difference among the three treatment groups ($p < 0.05$), demonstrating that at least one calcite concentration differed in UV-blocking performance from the others. Pairwise comparisons were then conducted using Tukey's post hoc test. The mean difference between the UV 0.1 and UV 0.05 calcite groups was 0.19 ($p = 0.647$), indicating no significant difference between these two concentrations. In contrast, both calcite treatments differed significantly from the 0.00 g control ($p < 0.000001$). We found that the UV-blocking ability differed significantly among the three calcite conditions (one-way ANOVA, $p < 0.05$). Tukey's post hoc test revealed no significant difference between the 0.05 g and 0.10 g calcite treatments (mean difference = 0.19, 95% CI: -0.31 to 0.69, $p = 0.647$). In contrast, both calcite treatments differed significantly from the 0.00 g control. The mean difference between the 0.00 g and 0.05 g treatments was 13.46 (95% CI: 12.96–13.97, $p < 0.000001$), while the mean difference between the 0.00 g and 0.10 g treatments was 13.27 (95% CI: 12.77–13.78, $p < 0.000001$) (**Figure 3**).

This study investigated how the concentration of calcite affected the amount of solar radiation (measured as UV rays) detected by UV radiation sensors. The comparison between UV 0.1 (0.10 g) and UV 0.05 (0.05 g) yielded a mean difference of 0.19 ($p = 0.647$), indicating no statistically significant difference between these two groups. However, the ability of UV 0 (0.00 g) to block UV radiation differed from that of both UV 0.1 and UV 0.05, with mean differences of approximately 13.4 and 13.3, respectively ($p < 0.000001$). The results confirm

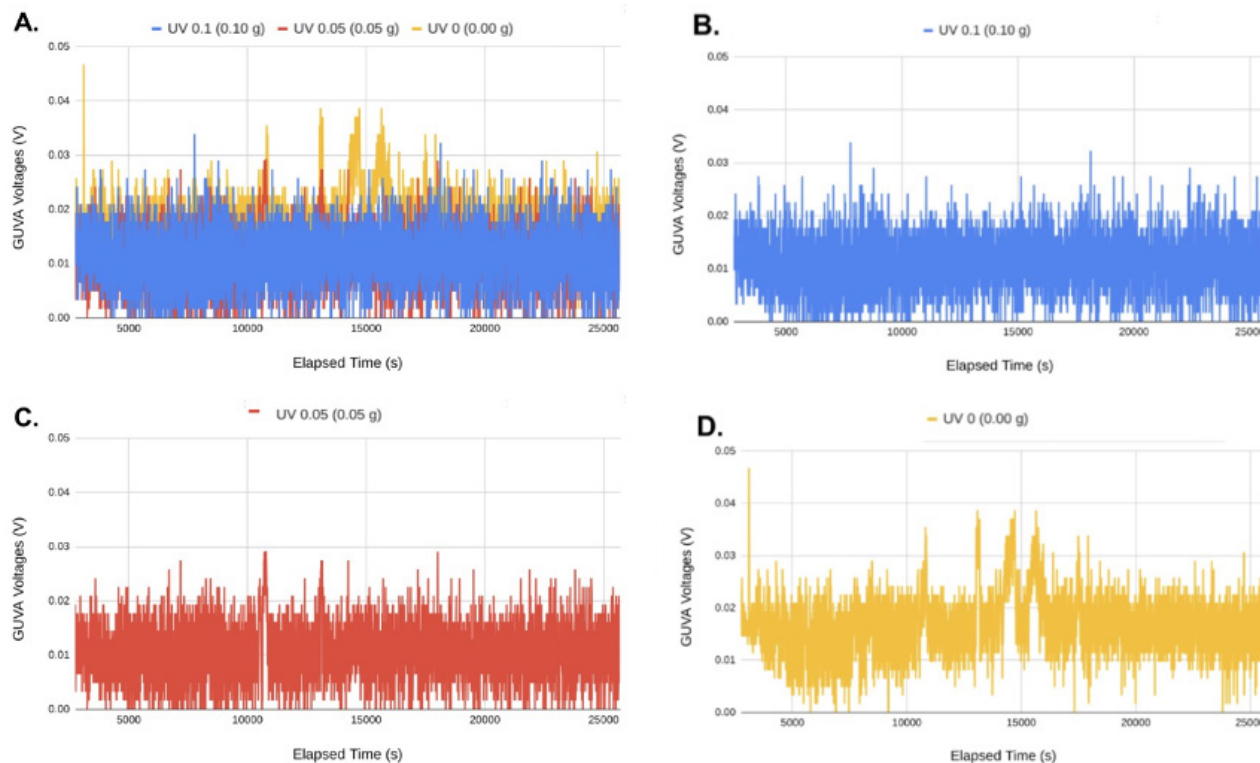


Figure 2. Both calcite concentrations reduce voltage corresponding to ultraviolet (UV) radiation measured by GUVV-S12SD sensors as compared to the negative control. A.) Voltage corresponding to UV radiation measured by GUVV-S12SD sensors over approximately 7-hour flight time from floating to landing for laminate sheets coated with different calcite concentrations. Sheets containing B.) 0.10 g (UV 0.1, blue), C.) 0.05 g (UV 0.05, red), and D.) 0.00 g (UV 0, yellow) of calcite were launched to a stratospheric level of 24,000 meters (N=1).

that the 0.10 g and 0.05 g concentrations of calcite were both effective at blocking UV radiation, significantly more so than the control of 0 g calcite.

The confidence interval graph shows that the UV 0.05 vs. UV 0.1 bar crosses the zero line, indicating that their difference in mean is not significant (Figure 3). However, the UV 0 vs. UV 0.1 and UV 0 vs. UV 0.05 bars are far from the zero line and do not cross. This implies that UV 0.1 (0.10 g) and UV 0 (0.05 g) both block more UV radiation compared to the control, although a significant difference is not convincingly shown between UV 0.1 and UV 0.05.

DISCUSSION

Our hypothesis was partially supported. Calcite does deflect UV radiation; however, increasing densities were not shown to block increasing amounts of UV radiation in this study.

Our research indicates possibilities for using calcite in future SAI endeavors. While calcite is not biodegradable, it is a naturally occurring inorganic compound that is safe for humans (4). Further research is needed to determine the effects of calcite on the atmosphere and its surrounding environment. Aerosols such as sulfur dioxide have already been shown to impact the atmosphere negatively, and it must be determined whether calcite could have similar effects (7).

While spreading the calcite on each of the laminate sheets, an uneven distribution may have occurred throughout the sheet due to an improper spreading technique. After

spreading, we observed that not all the calcite powder could

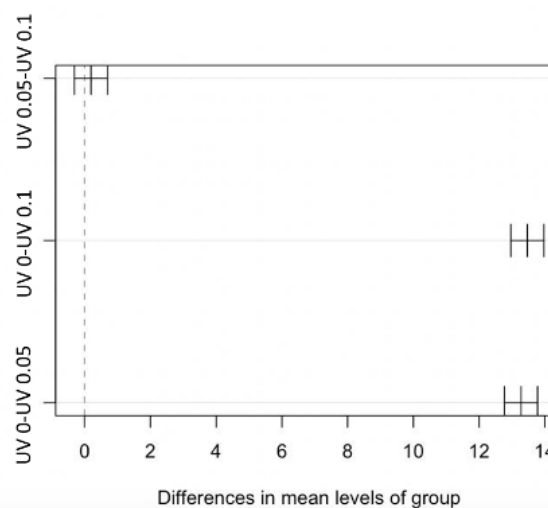


Figure 3. Calcite significantly blocked UV radiation from the sun. Ninety-five percent family-wise confidence interval plot graph showing results of one-way ANOVA test between three calcite concentrations ($\alpha = 0.05$) on UV index measurements collected by the LTR390 sensors. The UV-blocking capabilities of UV 0 (0.00 g) compared to UV 0.05 (0.05 g), as well as UV 0 compared to UV 0.1 (0.10 g), were significantly different ($p < 0.000001$). No significant difference was observed between groups UV 0.1 and UV 0.05 ($p = 0.647$). N=1 for each condition..

be spread onto each sheet, as some calcite was lost on the spreading tool. This may have led to the true concentration on each sheet being slightly more or less than intended. This could have inconsistently increased the amount of UV light passing through each laminate sheet. Moreover, the spikes in the data noted by the GUVAS-12SD and LTR390 sensors may have occurred due to varying sensitivity in the two kinds of sensors, as well as possible uneven spreading along the calcite sheet (**Figure 1, Figure 2**).

Moreover, there is a possibility that the epoxy between the electrical connections of the payload was not secure. This is because the two-part epoxy utilized did not have an adequate mixing nozzle, resulting in several attempts with epoxy that did not cure properly. While the epoxy mixed in the final attempt was deemed to cure appropriately, there could still have been some untested, uncured epoxy that interfered with the electrical components of the payload, thus resulting in an unpredictable statistical error.

For further study, it is necessary to test both lower and higher concentrations of calcite to determine the optimal balance of minimizing the amount of the calcite required to reach a standard threshold for blocking UV rays. It would also be worthwhile to test at different stratospheric heights to determine if conditions and atmospheric patterns at different heights impact the data, but not at any heights outside of the stratosphere.

Our experiment was limited to utilizing an even distribution of calcite powder, as opposed to an aerosol, which would be implemented for SAI. An aerosol could not be accurately tested within the high-altitude balloon (HAB), as the suspension of particles within the air would be influenced by the surrounding atmospheric conditions and circulatory patterns. More research must be conducted in open-air settings that are more similar to real-world SAI applications to determine how calcite is influenced by stratospheric conditions and interactions with other atmospheric particles. Additionally, our test was conducted at one location and one specific time of day. In the future, it is worth conducting similar studies at many different latitudes and times of day to account for variation in UV radiation levels. Furthermore, it is unclear how the concentration of calcite powder on the laminate sheets corresponds to its density in aerosolized form. As mining large amounts of calcite from chalk or limestone deposits for SAI use may result in a significant carbon footprint, it is imperative that further testing be done to determine optimal aerosol density to maximize global temperature reduction while limiting environmental impact (11).

If calcite SAI is not determined to be a viable application to reduce global temperatures, other aerosols, such as black carbon, aluminum, and barium titanate, may also be studied using the same guidelines put forth in this study. Each aerosol could be tested in a computer simulation based on chemical and physical properties (12). The simulation could estimate the optimal particle coverage across the globe as well as its overall efficiency based on its properties.

Notably, there is a significant amount of social controversy surrounding SAI. Current SAI efforts like Make Sunsets, a company focusing on delivering sulfur dioxide gas to the atmosphere to promote global cooling, have received constant backlash from social media and governmental agencies. The

government of Mexico has banned Make Sunsets in their airspace, and the United States Environmental Protection Agency has heavily investigated the company due to its lack of regulation and scientific backing, as they are launching harmful substances such as sulfur dioxide without investigating its impacts on biological life without looking into safer substances, and sufficient preliminary research has not yet been conducted, outside of modeling studies, to support the efficacy of SAI techniques (6).

It is vital to conduct preliminary SAI research to ensure that a last-minute solution to the ongoing climate crisis will be available. Specifically, small-scale testing, such as the HAB payload testing done in this study, and the preliminary design of various aerosol distribution systems could serve as a promising direction for developing future solutions using SRM.

Additional research is needed to determine the viability and safety of calcite SAI regarding its impact on aquatic and land-bound life. Specifically, the effects of calcite SAI on weather patterns and soil conditions, as well as the potential adverse health effects from inhalation of atmospheric calcite aerosol in locations across the globe, must be researched to fully realize whether calcite SAI is viable for climate change remediation. Societal and ethical effects including international tensions, as well as global issues such as uneven warming and cooling, must be further investigated (13). Importantly, SRM is not an alternative for reducing greenhouse gas emissions and should be used as a supporting remedial tool if implemented (10). The information found in this study is crucial as world leaders attempt to stop and potentially reverse the effects of climate change and global warming. This displays that there are safe substances that could be used for SRM, showing that SRM may in fact be a viable option for stopping global warming if global temperatures reach an extreme point, which can help convince both lawmakers and the general public.

MATERIALS AND METHODS

Payload Construction

An experimental payload box, primarily made of polycarbonate with dimensions of 4" x 4" x 8" (10.16 cm x 10.16 cm x 20.32 cm), was provided by the NASA TechRise committee. Precipitated lab-grade CaCO_3 powder was obtained from Flinn Scientific. The obtained Flinn Scientific CaCO_3 powder was likely in the form of calcite as its listed specific gravity is 2.7, which is within the range of pure calcite (2.69-2.7) as opposed to the other forms of CaCO_3 like aragonite (2.9-2.95) (14, 15). The powder is laboratory grade, indicating a high purity suited for experimental use (14).

Three GUVAS-12SD sensors and three LTR390 sensors were obtained from Adafruit to measure UV transmission. The GUVAS-12SD measured UV light in a wavelength between 240 nm to 370 nm and the LTR390 measured UV light between 280 nm and 430 nm. The LTR390 sensors directly collected data on UV levels. The GUVAS-12SD sensors collected UV data in the form of voltage output, with a higher voltage corresponding to higher UV input. The payload interface board was provided by the NASA TechRise committee. The Metro M4 Express microcontroller and the MicroSD Breakout Board+ were obtained from Adafruit. Additional materials include a Kingston 32 GB High Endurance UHS-I microSDHC Card and small UV lights provided by NASA TechRise. Sensors

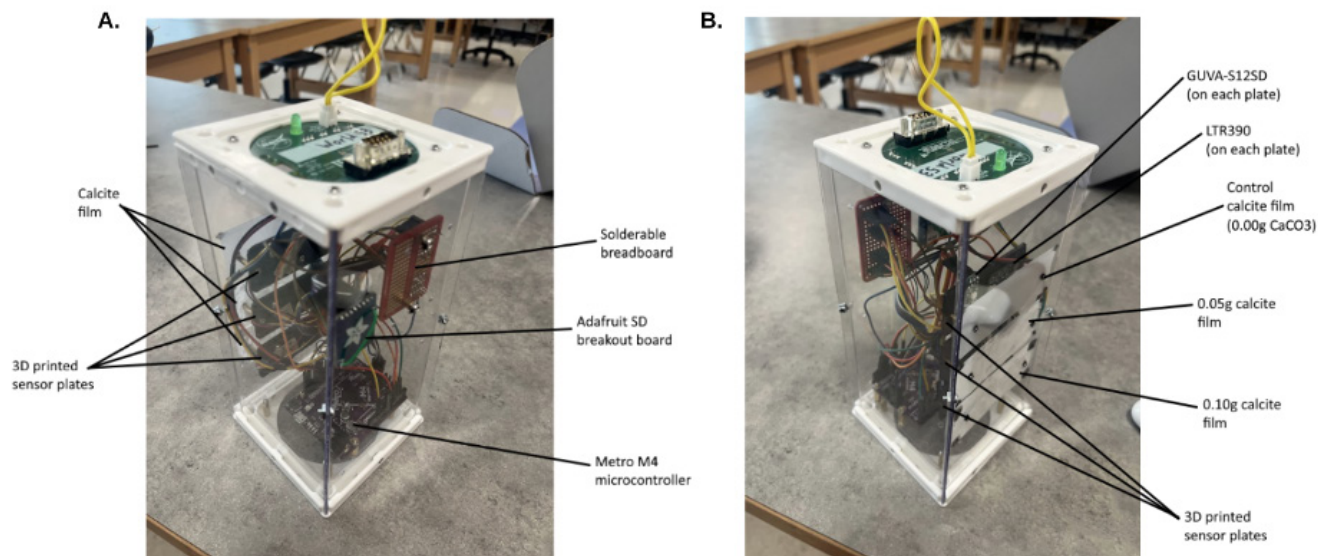


Figure 4. Three-quarter back and front view of final experimental payload components. A.) Annotated photograph showing the major components of the experimental payload. Microcontroller, breakout board, solderable breadboard, 3D printed sensor plates, and calcite film were mounted with brass standoffs to the experimental payload box.

were tested individually for overall functionality after being wired to a plastic breadboard and a Metro M4 microcontroller. CircuitPython code was uploaded to the Mu Editor software to determine the amount of UV light each sensor was receiving. A UV LED was placed in front of each sensor, and if the UV readings of each sensor increased as the distance of the UV LED decreased, the sensor was deemed viable. Once all sensors were deemed viable, each sensor was wired together with the Metro M4, the flight printed circuit board (PCB), and an Adafruit MicroSD Breakout board, which would collect data from each sensor on a 32 GB MicroSD card. The wires were connected via a solderable breadboard. Once wired and soldered, 2-part epoxy resin was spread onto each wire connection to prevent wires disconnecting during flight.

Matte and clear laminate sheets were tested for UV transmission, and Uinkit Matte Thermal Laminating Sheets were selected, as they transmitted the most significant amount of UV light to the selected sensors. To uniformly distribute the calcite placed in front of the sensors, 0.10 g and 0.05 g powdered calcite were mixed with deionized water to form a paste, which was then spread on separate 1.25" x 3.25" (3.175 cm x 8.255 cm) laminate sheet pieces. These specific calcite concentrations were selected because the readings provided by the LTR-390 sensor were on a UV index scale. As a result, precise measurements between UV indexes of 0 and 1 could not be determined; thus, a smaller concentration of calcite powder had to be used in this procedure (16). There was a control, unmodified laminate sheet without calcite or spread deionized water. After drying, each set of sheets was heat laminated for mounting onto the payload. Three sensor mounting plates were designed in Inventor and 3D printed with polyethylene terephthalate glycol (PETG) filament. This material was chosen due to its lightweight yet durable composition that can withstand a high-altitude balloon flight as 3D printed PETG has a tensile strength above 25 mPa (17). One GUVVA-S12SD and one LTR390 were bolted onto each

sensor mounting plate for redundancy. The sensor mounting plates were mounted behind each calcite sheet with 1" (2.54 cm) brass standoffs.

After soldering and epoxying the electrical components, final payload testing took place before the full epoxying of all components into the box. Testing was conducted both with and without the Metro M4 microcontroller connected to the computer to ensure the payload ran as expected and to verify there were no wiring issues, particularly with the power buses.

Calcite sheets were placed along one side of the payload box and affixed with epoxy. The wired sensors were bolted onto the mounting plates. The mounting plates were bolted behind the calcite sheet with brass standoffs. The Metro M4 microcontroller and payload interface board were mounted using standoffs, and the breakout board was secured with zip ties through the holes in the box to maintain stability and prevent damage throughout flight (Figure 4, Figure 5).

Experimental Methods

This payload was launched on a high-altitude balloon to a height of 24,000 meters, which places the payload well into the stratosphere and is where SAI would be implemented on a larger scale. The payload and all sensors were powered on while on the ground before flight, and stayed on as the balloon ascended, floated at maximum altitude, and descended. All operations ceased after the landing of the balloon. The payload was launched on June 16, 2025, at 8:37 AM in Page, Arizona. The temperature was around 28.3 degrees Celsius with winds blowing 9.25 kph northeast. At this more equatorial latitude, the UV radiation may generally be higher than in other regions. However, due to the morning launch time, the radiation would have been slightly lower than peak hours at midday. The flight lasted about four hours, but data was collected throughout the duration of the flight as well as for three hours after landing. The sensors collected data on the quantity of UV radiation penetrating the calcite sheets.

ACKNOWLEDGMENTS

This experiment was a part of NASA TechRise 2024–25 Challenge, as it was funded and flight tested by NASA's Flight Opportunities Program. However, NASA has not independently verified or validated any data, results, or conclusions arising from this research. NASA expressly disclaims any liability or responsibility for the accuracy of information or conclusions drawn herein.

REFERENCES

1. Cho, Renee. "How Climate Change Impacts the Economy." *State of the Planet*. 20 June 2019. <https://news.climate.columbia.edu/2019/06/20/climate-change-economy-impacts/>. Accessed October 1 2025.
2. Keith, David W., *et al.* "Stratospheric Solar Geoengineering without Ozone Loss." *Proceedings of the National Academy of Sciences*, vol. 113, no. 52, 12 December 2016, pp. 14910–14914. <https://doi.org/10.1073/pnas.1615572113>.
3. Dai, Zhen, *et al.* "Experimental reaction rates constrain estimates of ozone response to calcium carbonate geoengineering." *Communications Earth & Environment*, vol. 1, no. 63, 15 December 2016. <https://doi.org/10.1038/s43247-020-00058-7>.
4. Tropf, William. "Calcium Carbonate, Calcite (CaCO₃)." *Handbook of Optical Constants of Solids*, vol. 3, 1997, pp. 701–715. <https://doi.org/10.1016/B978-012544415-6.50126-6>.
5. Zhevtun, Ivan, *et al.* "Reflectivity and Radiation Resistance of Calcium Carbonate (Calcite)." *Optical Materials*, vol. 157, no. 116040, November 2024. <https://doi.org/10.1016/j.optmat.2024.116040>.
6. EPA Press Office. "EPA Demands Answers from Unregulated Geoengineering Start-Up Launching Sulfur Dioxide into the Air." *EPA*. <https://www.epa.gov/newsreleases/epa-demands-answers-unregulated-geoengineering-start-launching-sulfur-dioxide-air>. Accessed April 8 2026.
7. Vattioni, Sandro, *et al.* "Injecting solid particles into the stratosphere could mitigate global warming but currently entails great uncertainties." *Communications Earth & Environment*, vol. 6, no. 132, 21 February 2025. <https://doi.org/10.1038/s43247-025-02038-1>.
8. Wunderlin, Elia, *et al.* "Side Effects of Sulfur-Based Geoengineering Due To Absorptivity of Sulfate Aerosols." *Geophysical Research Letters*, vol. 51, no. 4, 28 February 2024. <https://doi.org/10.1029/2023GL107285>.
9. Smith, Wake & Wagner, Germot. "Stratospheric aerosol injection tactics and costs in the first 15 years of deployment." *Environmental Research Letters*, vol. 13, no. 12, 23 November 2018. <https://doi.org/10.1088/1748-9326>.
10. NOAA Science Council. "Solar radiation modification: NOAA State of the Science factsheet." *Climate.gov*. <https://www.climate.gov/news-features/understanding-climate/solar-radiation-modification-noaa-state-science-factsheet>. Accessed October 8 2025.
11. Kittipongvises, Suthirat. "Assessment of Environmental Impacts of Limestone Quarrying Operations in Thailand." *Environmental and Climate Technologies*, vol. 20, no. 1, 28 November 2017, pp. 67–83. <https://doi.org/10.1515/ruect-2017-0011>.
12. Wiesenstein, Debra K. "Laboratory Experiments on Particles for Solar Geoengineering Demonstrate Limits of Models." *Harvard John A. Paulson School of Engineering and Applied Sciences*. <https://seas.harvard.edu/news/laboratory-experiments-particles-solar-geoengineering-demonstrate-limits-models>. Accessed September 28 2025.
13. Scientific Advisory Board. "SOLAR RADIATION MODIFICATION." <https://www.un.org/scientific-advisory-board/sites/default/files/2025-05/250403-SRM-Rev-8.pdf>.
14. Flinn Scientific. "Calcium Carbonate Safety Data Sheet (SDS)." *Flinn Scientific*. https://www.flinnsci.com/sds_195-calcium-carbonate/sds_195/. Accessed 10 April 2026.
15. CDC. "Calcium Carbonate." *NIOSH*. <https://www.cdc.gov/niosh/npgd0090.html>. Accessed 1 July 2026.
16. Siepert, Brian, *et al.* "Adafruit LTR390 UV Sensor." *Adafruit*. 4 March 2024. <https://learn.adafruit.com/adafruit-ltr390-uv-sensor/overview-2>. Accessed April 1 2026.
17. Durgashyam, Katragadda, *et al.* "Experimental investigation on mechanical properties of PETG material processed by fused deposition modeling method." *Materials Today: Proceedings*, vol. 18, no. 6, 2019. <https://doi.org/10.1016/j.matpr.2019.06.082>.

Received: October 14, 2025

Accepted: April 13, 2026

Published: October 10, 2026

Copyright: © 2026 Nare, Thakkar, Kumar, Mulla and Jones. All JEI articles are distributed under the Creative Commons Attribution Noncommercial No Derivatives 4.0 International License. This means that you are free to share, copy, redistribute, remix, transform, or build upon the material for any purpose, provided that you credit the original author and source, include a link to the license, indicate any changes that were made, and make no representation that JEI or the original author(s) endorse you or your use of the work. The full details of the license are available at <https://creativecommons.org/licenses/by-nc-nd/4.0/deed.en>.