The Bartlett School of Construction & Project Management

An Update on Engineering Issues Concerning Stratospheric Aerosol Injection for Geoengineering

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Abstract

Solar Radiation Management (SRM) geoengineering is a proposed response to anthropogenic global warming (AGW)[1]. Stratospheric aerosol injection (SAI) is one proposed method, reliant on lofting particles into the stratosphere. Engineering reviews related to this technology approach have been sparse, with most major primary analyses now at least five years old. We attempt to bridge this gap – with a short, mainly qualitative review of recent developments in fields of engineering with potential applicability to stratospheric aerosol injection. Our analysis shows that a new conventional aircraft design is still likely to be the most dependable and affordable technology solution, with hybrid airships a potential challenger. Rockets, gas guns and MAGLEV/coilguns show some potential, although they lack the level flight capability preferred for direct aerosol distribution, without substantial additional engineering. Should very high-altitude access be required, rockets, hybrid rockets, and light-gas guns offer the required capability. Costs and performance for tethered balloons remain highly uncertain. No other methods are found to be promising. Nevertheless, the extreme accessibility of disposable balloons suggests that this method may be used primarily for reasons of political leverage, as opposed to being an optimal engineering solution.

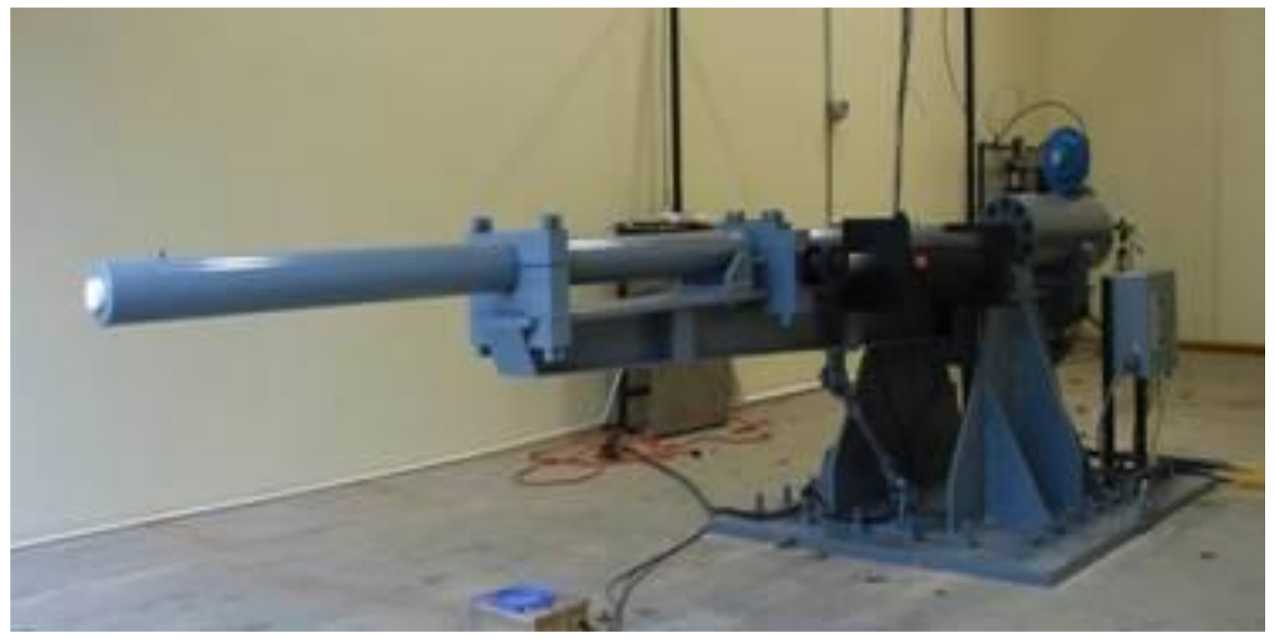
[1] National Academy of Sciences, Climate Intervention: Reflecting Sunlight to Cool Earth, (National Academies Press: Washington, DC 20001, 2015); J. G. Shepherd et al., Geoengineering the Climate: Science, Governance and Uncertainty, (Royal Society: London 2009).

Hypersciences use ram accelerator technology to drill rock. This mining cannon uses inexpensive propellant and experiences low barrel wear, despite having a high rate of fire. Their technology is also be developed for space launches.

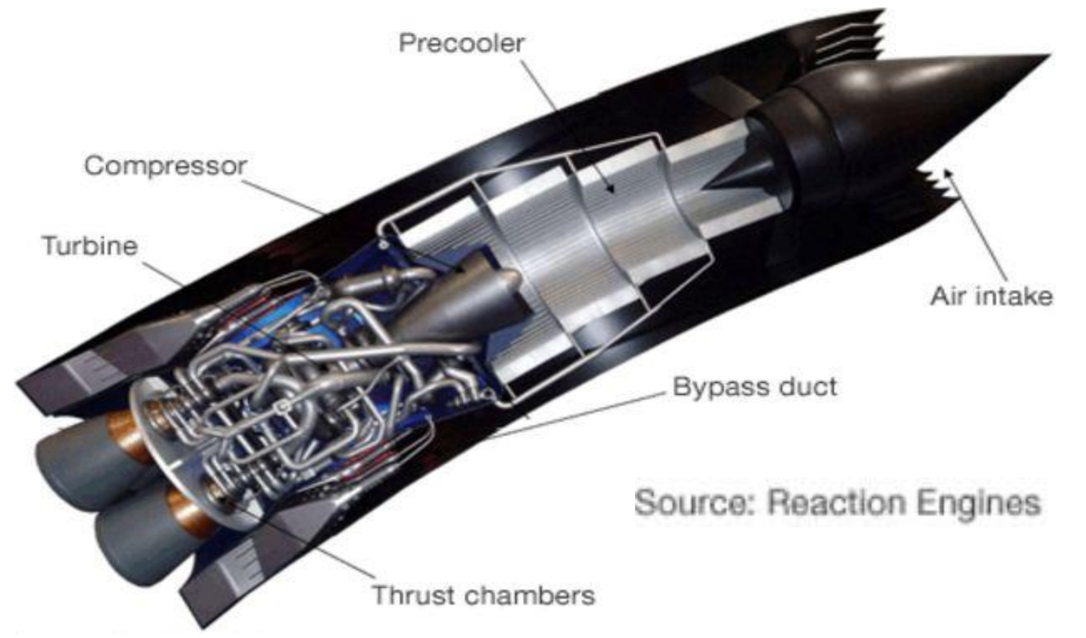
Several companies are developing hyperloop systems. These combine maglev and vacuum tube technology to allow trains or pods to reach sonic speeds.

Virgin Galactic use the White Knight Two aircraft from Scaled Composites to carry SpaceShipTwo to its launch altitude. Similar two-stage launch technologies could be used to overcome the challenges of developing an aircraft optimised for both ascent and high-altitude cruise.

SpaceX Starship is designed for reusability and large scale production. It can be used for sub orbital flights, and promises to dramatically cut cost per kilo of payload, compared to other launch systems.



Utron (defunct) has developed a gas gun, it has much lower propellant costs than a conventional gun. The gentler acceleration reduces shell casing mass, and therefore improves payload fraction.



Reaction Engines have developed the SABRE hybrid engine. This combines rocket and jet engine technologies, aiming to make single-stage-to-orbit flight possible. Because the engine is air-breathing at low altitudes, oxidising agent tank space is minimised.

Conclusion

A new generation of aircraft remains the most likely option at scale, potentially with unconventional propulsion. However, hybrid airships are a credible challenger. Both of these types of platforms benefit from the ability to carry out stable, level flight.

- Rockets and MAGLEV/coilguns are promising outsiders, due to rapid independent development – with gas guns also promising in principle, but lacking current development progress. None of these approaches are naturally optimised for stable, level flight - which is optimal for aerosol direct distribution. Nevertheless, the low-g launches of rockets and MAGLEV make them inherently suitable for launching gliders.
- Should very high altitude access be required, light gas guns, rockets, and rocket-hybrid aircraft are useful standby technology alternatives. Railguns have inherent disadvantages, but cannot be comprehensively ruled out, for extreme altitudes.
- Tethered balloons have only an outside chance of success, suffering with highly uncertain costs and performance – and no independent development. Free balloons are a wildcard technology, which facilitate early and rogue deployment, due to their near-zero capital costs.
- We discount towers.