Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: SYSINT / REUSYS / AEROFLIPHY
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Type: Oral
Status of corresponding author: Regular

Title

Analysis of sonic boom propagation and population disturbance of hypersonic vehicle trajectories

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Abstract

Flying above the speed of sound leads to the creation of a shockwave phenomenon known as sonic boom. During the whole flight, this shockwave propagates away from the vehicle and a portion of it hits the ground and impacts the people possibly living in the affected area. Because of a shockwave's sudden appearance with no warning, being regularly exposed to them can lead to adverse effects on the population like being startled, annoyed and experiencing sleep disturbances. Additionally, sufficiently strong sonic booms can have a negative impact on a number of factors such as wildlife and structural integrity of buildings. [1]
With the advent of more hypersonic space vehicles / aircraft in the future, these effects must be considered in the trajectory optimization and minimized to mitigate the effects on the population.
In this study, different types of hypersonic space vehicles are analyzed regarding their sonic boom propagation and impact on the general population. Conventional computational methods are used to calculate the sonic boom strength (i.e. overpressure), its duration and the lateral extent along the vehicle's trajectory. Subsequently, a geographical impact area can be computed. In combination with statistical models from past studies involving the general population, an approximation of the expected disturbed people can be derived. The calculation of the population is performed based on the GPWv4 population density database [2].
The baseline vehicle will be DLR-SART's concept for a future high-speed rocket-propelled Earth point-to-point transportation system called SpaceLiner [3]. It is a two-stage vertical take-off, horizontal landing system which is designed to carry up to 50 passengers between two distant places on Earth (e.g. Europe – Australia) within about 90 minutes. For this case, multiple feasible routes are investigated with a focus on mitigating the population disturbance of the sonic boom, while still complying with all of the vehicle's structural and thermal constraints. Utilizing multi-objective optimization methods with evolutionary algorithms, it is possible to compute trajectories which minimize the population along the flight-path while also reducing thermal parameters like the peak heat flux. Minimizing the overall population during the flight leads to trajectories that mostly fly over scarcely populated areas like the polar regions and oceans. However, sometimes it is not possible to avoid populated continental land masses and even some ocean areas are quite populated (e.g. Oceania). For these parts of the trajectory, the sonic boom overpressure should be as small as possible.
The SpaceLiner's sonic boom propagation shall be compared to different vehicle types that are in concept or development stages, with a special focus on vehicles which might fly in and out of Europe. While the selection is not final, it shall include (winged) orbital re-entry systems (e.g. Dream Chaser, Space Rider, Starship) and potentially hypersonic aircraft. For these vehicles, both reference missions and missions adapted for minimum population disturbance are investigated.

References

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