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COMPARISON OF THE EMISSIONS OF CURRENT EXPENDABLE LAUNCH VEHICLES AND FUTURE SPACEPLANES

Abstract

Reusable, single-stage-to-orbit lifting body aircraft, or spaceplanes, have long been proposed as a revolutionary next step in space access. Recent advances have significantly reduced the technological barriers in the development of these vehicles, with forecast operational dates as soon as 2020. This paper compares the emissions of current expendable launch vehicles (ELV) with these future reusable spaceplanes. Their unique flight trajectory and novel hybrid propulsion systems, usually utilising liquid hydrogen and oxygen, are completely different to those used in the expendable launch vehicles of today. The Delta IV rocket was chosen for this study because it has two variants that only use hydrogen and liquid oxygen, and their emissions can therefore be directly compared. The effect on the environment is now a major contributor to potential drivers and obstacles in the development of a new technology, and spaceplanes are no different. An investigation into the effect of this new operating paradigm and technology is important to identify roadblocks in the commercial development of the vehicles. The trajectory for the Delta IV rocket is obtained from the performance data given in the user manual by the manufacturer. The flight path and open loop control law for the spaceplane are generated using an in-house trajectory optimisation tool. The emission examined in this study is water. Water is an important greenhouse gas, with well-known effects on the environment and is produced by the combustion of hydrogen and oxygen. The fuel emissions of both vehicles are based upon complete combustion of the available hydrogen and oxygen. Most rockets run fuel rich, so it is assumed that this additional fuel is not involved in the combustion. The emissions are integrated across the entire trajectory and analysed in terms of the altitude profile of released emissions. The resultant emissions profiles are also normalized against the final payload mass to orbit. The analysis doesn't take into account the mission events such as stage burn up or splashdown, and rockets with solid rocket boosters were not considered. The methodology generated for this study will be extended to other propellants, such as Kerosene and solid fuels, as well as other vehicle and mission types (two-stage to orbit systems, hypersonic vehicles) in future studies. This technique will provide insight into the environmental cost associated to these future vehicles, which has a growing impact on governmental support and commercial viability.