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On the recovery of CH4 on the launch pad: cryogenic challenges towards an environmentally responsible access to space

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Abstract
The renewed interest in the exploration of the solar system, the Moon and possibly Mars coupled with the explosive development of military and commercial satellites for Earth monitoring, LEO communication and strategic resiliency through the use of large constellations have fueled the sprawling development of a broad range of cryogenic fueled launchers. Such launch systems, and the economic model which drives these endeavors, are more often characterized by being partially or even fully reusable with a high tempo capabilities to increase the number of launches per year and to reduce the costs while increasing the guarantees of a democratic access to space, when compared to the legacy and institutional launch providers.

All these foreseen activities with high launch frequencies may rise the question of the environmental impact of the commercial space endeavor (see [1][2]) in terms of global warming gas emission, use of pure raw materials (i.e. aerospace grade high performance alloys) and pollutants emissions. The need is clearly to address these issues in a quantitative and controlled way in order to minimize the environmental impact while fostering the development and contribution to the success of such space activities as an economy growth driver, which will benefit all humankind in the long run. Within this framework the use of liquid methane (CH4) is investigated since the launcher design tradeoff between reliability, simplicity and reusability for cost reduction often leads to the selection of liquid CH4as fuel for the cryogenic propulsion system. As customary for all cryogenic fluids the handling operations (tanking, venting etc.) will inevitably lead to the release by vaporization of large quantities of CH4 on the launch pad and the higher the launch frequency the larger the environmental impact of an uncontrolled venting of the propellant occurring during these phases.

The focus of this work is the evaluation of techniques to recover the CH4 being used to chill-down the launch pad facilities and the rocket launcher during the propellant loading operation as long as, in the case of reusability, during the unloading of a recovered stage in order to minimize the environmental impact of a CH4 release. Different schemes and strategies for CH4 recovery and reuse are investigated and a preliminary tradeoff are proposed. The analysis will consider cryogenics constraints as long as hardware availability and cost in order to identify the suitable solutions to be further developed.

References
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