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A SYSTEMATIC ASSESSMENT AND COMPARISON OF REUSABLE FIRST STAGE RETURN OPTIONS

Abstract

Interest in the reusability of rocket powered first stages for launch vehicles has strongly increased since the successful landing, recovering and reflight of SpaceX and Blue Origin booster stages. The multidisciplinary project AKIRA was initiated by the German Aerospace Center (DLR) in 2017 to investigate key technologies linked to reusable launch vehicles. This paper focuses on the comparison of different return options investigated within AKIRA. Return options that are taken into account include vertical take-off, vertical landing (VTVL) stages and winged vertical take-off, horizontal landing (VTHL) stages such as recovering parts of the first stage. Among the respective methods various options are considered and compared: return-to-launch-site, downrange landing, In-Air-Capturing and flyback with turboengines. The characteristic flight conditions of the aforementioned return options considering ascent loads, atmospheric re-entry loads, dry mass increase, performance losses and launcher design are evaluated methodically. Since RLVs require additional operational equipment and measures compared to expendable launch vehicles, the required supplementary hardware, infrastructure and workload are identified. Furthermore, necessary modifications to existing hardware are evaluated and cost estimation methods are applied to obtain preliminary operational costs of landing ship operations, capturing aircraft operations and transportation operations. Further, production and development cost estimations with an adapted version of the cost model TRANSCOST are performed and the results are critically discussed. Finally, the return options are compared with respect to their impact on performance, masses, return loads, operations and costs.