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Small Catapult-Assisted Horizontal-Launch Reusable RBCC SSTO Spaceplane for economical short-duration LEO access

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Abstract

This article discusses the conceptual design, flight trajectory calculations, and utilization of the future horizontally-launched reusable Single-Stage-to-Orbit (SSTO) spaceplane for small payloads and short-duration manned/unmanned access to Low-Earth-Orbit (LEO). The 10,000 lb spaceplane uses 5,000 ft catapult-assist horizontal-launch facility and conducts powered approach and landing on conventional horizontal runways following the gliding atmospheric re-entry. To increase the economy of operation, the launch facility located at high elevations (4,000+ ft) equatorial region is required, such as, plateaus in Kenya and Tanzania in Africa and/or Ecuador in South America. A 500-lb payload, including crew, is envisioned. The propulsion cycle is a Rocket-based Combined Cycle (RBCC) turbo-ram-rocket design that provides optimistic 1,000 sec average specific impulse with LO_2 (rocket mode only) and requires high-energy-density fuel of combined I_{sp}=700 sec. Ablation materials are used for re-entry cooling, however incurring high weight penalty. Catapult system would be able to accelerate the spaceplane to high transonic speeds followed by the supersonic turbo-ram 2g max-Q climb initiated after sufficient altitude is gained. The 3g catapult-system with the average launch power of 20,000+ HP represents the zeroth-stage significantly increasing the transportation efficiency while enabling the SSTO design. The 12,500 lb thrust rocket propulsion mode initiated at about 200,000 feet and M=5 accelerates the spaceplane into the 200-km prograde LEO. Powered flight lasts about 6 minutes followed by

coasting and orbit acquisition. Thrust vectoring for attitude control and orbital maintenance/maneuvers is conventional using monopropellants. Dynamic differential equations incorporating global ISA model, atmospheric drag, thrust changes, and active pitch and roll steering maneuvers for orbit injection are integrated using Ordinary Differential Equations (ODE) numerical solvers. One of several possible uses of this small-payload spaceplane is in removing space junk, transportation, and mini satellite deliveries.