Proposal Title: Turboelectric Distributed Propulsion Test Bed Aircraft

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Abstract:

The NASA Subsonic Fixed Wing (SFW) project has identified ambitious goals for the next three generations of aircraft, N+1, N +2, and N+3. For the N+3 generation, these include a 60% reduction in total mission energy consumption. For a current state-of- the-art baseline, this represents a 70% reduction in fuel burn and will require exploring new, radical configurations and propulsion technologies. One configuration that shows significant promise is the Hybrid Blended Wing Body (HBWB) using a turbo electric distributed propulsion (TeDP) concept, for a total fuel burn reduction of 70% to 72%. The revolutionary TeDP concept uses electric motor driven fans to provide thrust, with gas turbine generators providing electric power for the system. Ten to fifteen electric motor driven fans are distributed in a continuous line across the upper surface of the HBWB near the trailing-edge and ingest the boundary layer, while the gas turbine generators are mounted near the wing tips.

The TeDP concept has several distinct advantages, including boundary layer ingestion (BLI), re-energizing the wake of the airframe with the fan thrust stream, decoupling the propulsion from the power source, a very high effective bypass ratio, excellent redundancy, and differential thrust for stability and trim. TeDP also poses significant challenges, including increased inlet distortion and close coupling between the aerodynamics and propulsion of the airframe. As thrust changes, mass flow increases or decreases above or below the design mass flow for the inlet, changing blockage and spillage, pressure distributions, and circulation effects. The effects of aero/propulsive coupling will be especially important for approach and landing configurations, high angle-of-attack (AOA), approach to stall, and stall. Changes in individual fan thrust can also affect adjacent fan inlet conditions and performance.

RHRC proposes the development of a TeDP system for a small test bed aircraft. A flying demonstrator for TeDP concepts allows early investigation of complex aerodynamics, propulsion, and systems vital to the success of a TeDP configuration. The flying test bed reduces the development risk of a larger, dedicated TeDP configuration by testing technologies at a smaller and relatively cheaper scale. Although differences in vehicle size, thrust level, Reynolds number and cruise speed exist, several technologies scale well from the subscale test bed to the full scale aircraft. These include the effects of BLI, aerodynamic/thrust coupling, AOA, differential thrust effects on adjacent fan performance, inlet area design, and power generation topology.

Prior to implementation on the flying test bed aircraft, several TeDP concepts need to be investigated to reduce risk. The overall objective of the proposed Phase II program will be to test a wind tunnel model with a set of 5 BLI electric ducted fans mounted on a 2D straight wing. The Phase II program will examine multi-fan effects on aerodynamic/propulsive coupling, BLI,

circulation effects, and reenergizing the wake with the thrust stream using both CFD and experimental testing. The effect of thrust levels and mass flow on both the overall wing and sectional aerodynamic characteristics including lift, drag, and pitching moment will be studied. The program will explore the effect of varying thrust levels on the aerodynamics of approach/landing configurations, high AOA, and stall. Additionally, inlet design will be investigated. The Phase II program will produce an extremely unique, first of its kind data set for multi-fan TeDP BLI configurations. The proposed flying test bed aircraft and data sets produced under the proposed program will directly contribute to meeting the SFW N+3 goals.