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AeroBRIDGE: A Wind-Tunnel-to-Flight Testing Translation Program for Fixed-Wing Advanced Air Mobility Aircraft

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Distributed electric propulsion (DEP) has emerged as a key enabling technology for fixed-wing Advanced Air Mobility (AAM) aircraft because of its potential to improve aerodynamic efficiency, low-speed performance, and operational flexibility through favorable aero-propulsive interactions. Although wind-tunnel testing provides a controlled environment for evaluating these interactions, a significant challenge remains in translating ground-based aerodynamic measurements into practical flight-test configurations and aircraft-level validation. This paper presents AeroBRIDGE, a wind-tunnel-to-flight testing translation program developed to establish a systematic methodology for transitioning DEP configurations from controlled wind-tunnel experiments to flight testing on a fixed-wing unmanned aircraft system platform. The AeroBRIDGE methodology combines parametric wind-tunnel configuration screening, aerodynamic and integration-based down-selection, staged aircraft modification, and incremental ground, taxi, and flight testing within a unified ground-to-flight evaluation framework. The program uses a modular DEP wind-tunnel model to evaluate candidate aero-propulsive configurations, including variations in propeller diameter, motor count, propeller placement, propeller tilt, flap deflection, and advance ratio. Selected configurations are then intended to transition to an instrumented Avistar 30 flight-test platform that will be modified with a 12 inches chord rectangular wing matching the wind-tunnel model chord. This paper describes the AeroBRIDGE program architecture, wind-tunnel screening approach, baseline Avistar 30 flight-test platform, planned re-winged DEP aircraft, and phased test methodology. Initial wind-tunnel results demonstrate repeatable DEP model operation and show strong coupling between propeller operating conditions, installation geometry, and wing aerodynamic performance. Baseline Avistar 30 characterization establishes the aircraft geometry, instrumentation architecture, mass properties, and propulsion-system performance required for future re-winged and DEP-integrated testing. The resulting framework provides a practical path for connecting controlled aerodynamic experimentation with flight-test implementation and supports future development of DEP-enabled fixed-wing AAM aircraft testing methodologies.

I. Introduction

Recent advancements in electrified propulsion technologies have generated significant interest in fixed-wing and vertical-lift aircraft concepts for Advanced Air Mobility (AAM), an emerging transportation paradigm intended to expand the movement of people and goods beyond locations currently accessible through conventional aviation systems. The projected global market for AAM vehicle sales is expected to exceed $120 billion by 2030, while autonomous and remotely piloted aircraft markets spanning military, agricultural, enterprise, and public-safety applications are projected to approach $90 billion globally over the same period. A major enabling technology behind many of these

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next-generation aircraft concepts is Distributed Electric Propulsion (DEP), which leverages favorable aero-propulsive interactions between propellers and lifting surfaces to enhance aerodynamic efficiency, control authority, and operational flexibility. As a result, DEP-based configurations have become a major focus of both academic and industrial research efforts. Applications include increasing wing loading for cruise efficiency [1–4], super Short Takeoff and Landing (STOL) aircraft [5], tilt-wing and deflected slipstream Vertical Takeoff and Landing (VTOL) aircraft [6–8], and even new wing-in-ground effect aircraft [9].

Although substantial progress has been made toward understanding the fundamental aerodynamics of DEP-enabled low-speed aircraft, significant challenges remain in translating controlled experimental observations into practical flight-test implementation and operational vehicle design. Wind-tunnel testing provides a highly controlled environment for evaluating aero-propulsive interactions and isolating the effects of critical design parameters such as propeller diameter, propeller placement, motor count, propeller tilt angle, and flap deflection. However, these measurements do not fully capture the complexities of integrated aircraft operation, including propulsion-system integration effects, atmospheric disturbances, flight dynamics, control-system interactions, structural flexibility, and operational constraints encountered during flight. Conversely, flight testing captures the complete aircraft-level response within a realistic operating environment, but it is significantly more resource intensive and less suited for broad parametric design exploration. Consequently, a critical gap exists between controlled ground-based aerodynamic experimentation and practical flight validation for DEP-enabled AAM systems.

To address this gap, a systematic framework is needed that can establish a direct translation pathway between wind-tunnel measurements and flight-test implementation while simultaneously creating a feedback loop between controlled experimentation and operational observations. Such a framework would enable researchers to identify which aerodynamic trends observed in wind tunnels persist in free-flight conditions, quantify the limitations of isolated ground testing, and formulate practical design methodologies for DEP-enabled aircraft development. More importantly, the establishment of a unified ground-to-flight testing methodology can support the development of realistic and holistic design challenges necessary for accelerating the integration of AAM systems into the National Airspace System.

The present work introduces AeroBRIDGE, a wind-tunnel-to-flight testing translation program for fixed-wing AAM aircraft employing distributed electric propulsion. The AeroBRIDGE framework is structured to use controlled wind-tunnel testing for DEP configuration screening, aerodynamic characterization, and flight-risk reduction prior to implementation on a fully instrumented flight-test aircraft. The flight platform selected for the present effort is an Avistar 30 unmanned aircraft system (UAS), which serves as a modular testbed for both baseline aerodynamic characterization and future DEP integration studies. Within the AeroBRIDGE framework, wind-tunnel testing is used to guide configuration down-selection and identify candidate DEP architectures for transition into flight-test evaluation, thereby establishing a systematic connection between ground-based aerodynamic measurements and aircraft-level operational validation.

The following sections define the overall AeroBRIDGE ground-to-flight testing translation methodology for DEP-enabled fixed-wing AAM systems (Sec. II), describe the wind-tunnel DEP configuration-screening matrix developed for aerodynamic evaluation and flight-test down-selection (Sec. III), present the baseline Avistar 30 flight-test platform (Sec. IV), detail the planned re-winged Avistar 30 DEP flight-test article (Sec. V). Subsequent sections describe the phased ground, taxi, and flight-test methodology, proposed translation metrics, and expected program products (Secs. VI & VII). Concluding remarks and planned future work are provided in Sec. VIII.

II. AeroBRIDGE Program Overview

The AeroBRIDGE program was developed to establish a repeatable and practical methodology for translating DEP aerodynamic configurations from controlled wind-tunnel experiments to flight testing on a fixed-wing AAM-relevant UAS platform. The primary objective of the program is to create a structured framework through which candidate DEP configurations can be identified, screened, integrated, and ultimately evaluated in flight. In doing so, the program seeks to bridge the gap between isolated aerodynamic measurements obtained in controlled laboratory environments and the integrated aircraft-level behavior observed during real-world flight operations. Rather than treating wind-tunnel testing and flight testing as independent activities, AeroBRIDGE establishes a connected testing ecosystem in which insights from each environment inform and refine the other.

The AeroBRIDGE framework is organized around a staged ground-to-flight translation philosophy intended to progressively reduce technical and operational risk prior to DEP flight implementation. The program begins with parametric wind-tunnel screening of candidate DEP configurations, where variations in propulsion arrangement, aerodynamic geometry, and control-surface interactions can be systematically evaluated under repeatable conditions.

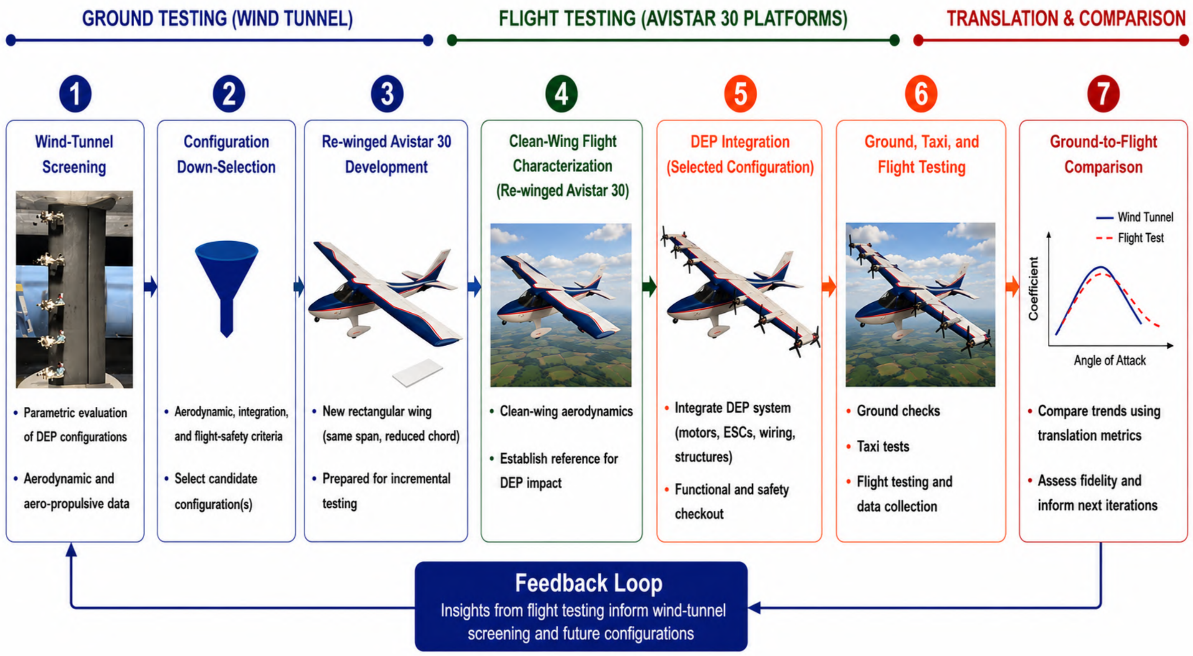

Fig. 1 AeroBRIDGE program architecture.

Based on aerodynamic performance trends, integration feasibility, and flight-safety considerations, promising configurations are then down-selected for transition into flight testing. Following this process, a modified flight-test article based on the Avistar 30 platform is developed to support incremental evaluation of DEP integration effects. The staged testing methodology includes baseline flight characterization of the original Avistar 30 configuration, clean-wing characterization of the modified re-winged aircraft, integration of the selected DEP architecture, and subsequent ground, taxi, and flight testing of the DEP-enabled configuration. Finally, aerodynamic and operational trends observed during flight testing are compared against wind-tunnel observations using defined translation metrics intended to assess the consistency and limitations of the ground-to-flight transition process. Figure 1 presents the overall AeroBRIDGE program architecture and illustrates the progression from wind-tunnel configuration screening to flight-test implementation and ground-to-flight comparison.

Within the AeroBRIDGE methodology, the wind tunnel serves primarily as a configuration-screening and risk-reduction environment in which candidate DEP architectures can be evaluated efficiently prior to flight implementation. The wind-tunnel campaign is designed to enable broad parametric exploration of DEP-related variables while minimizing the cost and operational burden associated with repeated flight testing. Configurations selected through this process are transitioned to the Avistar 30 flight-test platform, which has been chosen because of its modularity, accessibility, and suitability for incremental aerodynamic modification. To improve geometric consistency between the wind-tunnel and flight-test environments, the Avistar 30 will be modified with a new rectangular wing that preserves the original aircraft span while reducing the wing chord to better match the wind-tunnel model geometry. The final propulsion-system layout and motor configuration implemented on the flight-test article will be determined based on the results of the ongoing wind-tunnel configuration-screening campaign, thereby maintaining a direct connection between controlled aerodynamic testing and eventual flight evaluation.

III. Wind-Tunnel Configuration Screening for Flight-Test Down-Selection

A. Purpose of Wind-Tunnel Testing within AeroBRIDGE

Within AeroBRIDGE, wind-tunnel testing is used primarily to screen DEP configurations before flight-test integration. The wind-tunnel test campaign supports the selection of motor count, propeller diameter, propeller placement, propeller tilt, and flap deflection combinations that are suitable for transition to flight testing. The wind-tunnel results are not treated as the final validation of the DEP system, but rather as a controlled dataset for reducing the configuration space and informing flight-test design.

B. DEP Wind-Tunnel Model

The wind tunnel test article uses the existing DEP CRM model available at MSU. Figure 2 shows the CAD model and experimental setup. The wing section of a Cessna 182 (C-182) Skylane is used as the baseline geometry for integration with the DEP system. The C-182 is a 1950s era design, still in production today with over 20,000 aircraft built. The wing is a conventional strut-braced all-metal design using the 12% thick NACA 2412 with a single slotted flap. The modular wind tunnel model setup is 3D printed with internal metal reinforcement. The main element trailing edge is independently replaceable to allow alternate flap designs or ailerons to be tested. The model design allows variation in flap Position, propeller tilt, propeller position (x/c, z/c), propeller diameter, propeller spanwise spacing, number of motors, and slat position. Table 1 summarizes the wind-tunnel DEP configuration-screening matrix for flight-test down-selection.

Table 1 Experimental parameters for aero-propulsive interaction study.

Parameter	Value / Range	Unit / Note
Fixed Dimensions		
Chord Length (c)	12.0	in
Total Available Motor Space	27.75	in
Propulsion Variables		
Propeller Diameter (D)	{4, 5, 6, 7}	in
Number of Motors (N)	{6, 5, 4, 3}	–
Propeller Tilt	0 – 50	deg
Flap Position/Angle	0 – 50	deg
Normalized Position		
Longitudinal Position (x/c%)	6.25% – 14.17%	Parallel to chord
Vertical Position (z/c%)	10.42% – 22.92%	Perpendicular to chord

Baseline experiments of the DEP-CRM were conducted with the five propeller configuration. Each propeller was driven by a Axisflying Blackbird V4 2060KV brushless motor. Each motor was powered using a constant voltage laboratory grade power supply with an adjustable current limit to ensure stable operation during visualization runs. A ModalAI VOXL M0138 ESC was used to regulate the motors speed and was connected to a PC via a serial interface configured for Transistor-Transistor Logic (TTL) signaling. To maintain a fixed rotational speed during testing, VOXL's native RPM control firmware was utilized, along with a custom python based interface to manage command dispatch and real-time interaction with the ESC. The controller dynamically adjusted the ESC throttle in response to real time RPM feedback, ensuring consistent test conditions. Telemetry data including rotational speed, input voltage, current draw, temperature, and power consumption were continuously monitored and recorded throughout the test.

Experiments were conducted in the closed-circuit wind tunnel at Mississippi State University (MSU), shown in Fig. 3. With test section dimensions of 28-in. × 40-in. × 160-in. (height × width × length), the low-speed, low-turbulence tunnel can reach speeds of up to 230 ft/s and has turbulence levels of less than 0.1% at all test conditions, based on hot-wire measurements. The wind tunnel is equipped with two Mensor CPT6100 pressure transducers. One transducer is responsible for measuring the gauge pressure before and after the converging nozzle preceding the test section for velocity calculations while the other measures the absolute barometric pressure of the ambient air. A Veris

Fig. 2 Experimental setup. (a) isometric view of the clean wing CAD model; (b) isometric view of the motor mounted wing CAD model; (c) sectional view of main, and flap elements with the motor and guide plates (to set flap/motor position); (d) clean wing model setup in the wind tunnel; (e) motor mounted wing model attached on a 6 axis load cell in the wind tunnel.

HN2NMSTA2 probe is used to capture humidity and temperature measurements in the tunnel. The temperature is used to obtain dynamic viscosity and combines it with barometric pressure and humidity to calculate flow density. Aerodynamics forces and moments of the wing assembly were measured using the 6-axis ATI Omega force and torque sensor. The sensor is calibrated to measure forces of up to 2500 N in the x- and y-axis and 6250 N in the z-axis, and torques of up to 400 N-m in all three axes. Resolution for the forces are $(1/2)$ N in the x- and y-axis and $(3/4)$ N in the z-axis while that for torque is $(1/20)$ N-m in all three axes. Data output frequency of up to 10 kHz is possible with the sensor. The load sensor is affixed to a Model Positioning System (MPS) that allows for a ±45 degree rotation of the wing model. A 6-axis ATI Nano force and torque sensor, calibrated to measure forces of up to 17 N and torques of up to 0.12 N-m in all three axes, was used to measure the thrust produced by the propeller. LabVIEW is used alongside a PLC controller to combine and measure from all sensory inputs connected to the wind tunnel. Standard wind tunnel corrections to account for blockage and streamline effects are coded into the LabVIEW VI.

Fig. 3 MSU's low-speed, low-turbulence wind tunnel.

C. Configuration Transition Criteria

Candidate configurations from the wind-tunnel campaign will be evaluated for flight-test transition using the following criteria:

1) Stable motor operation and repeatable RPM control.
2) Favorable lift increment at relevant flap and advance-ratio conditions.
3) Acceptable pitching-moment behavior.
4) Practical integration on the Avistar 30 re-winged aircraft.
5) Acceptable mass, power, wiring, cooling, and ESC requirements.
6) Safe propeller, wing, fuselage, and ground-clearance margins.
7) Compatibility with the planned flight-test instrumentation.
8) Relevance to takeoff, landing, and cruise performance objectives.

D. Initial Wind-Tunnel Observations

Initial wind-tunnel work has demonstrated operation of the DEP model and supporting instrumentation [10]. Results demonstrated that the DEP-CRM produced highly repeatable and stable aerodynamic measurements, validating the experimental setup for detailed aero-propulsive investigations. Baseline testing of the clean wing showed that increasing Reynolds number delayed stall slightly, while flap deflection increased lift and nose-down pitching moment up to an optimum near 30 degree flap deflection, beyond which flow separation reduced aerodynamic effectiveness. Comparisons with XFoil predictions showed good agreement in lift trends, although experimentally measured drag was higher due to guide plate interference effects in the modular flap system. Additional testing revealed that the motor and pylon installation itself altered the wing aerodynamics, delaying stall and modifying lift characteristics while also increasing drag due to installation effects. Dynamic thrust measurements further confirmed consistent performance across all five propellers, validating the closed-loop motor control methodology and enabling accurate quantification of thrust losses and wing–propeller coupling effects.

Sample results showing the effect of propeller tilt on the aerodynamics are provided in Figs. 4, 5, and 6 for a wing at $Re = 300,000$ with a 0 deg flap, 20 deg flap, and 40 deg flap, respectively. A positive tilt angle means that the motor rotates down. As the tilt angle increases, there is a loss in lift near stall. At lower angles of attack, a larger tilt angle reduces the force in the x-direction due to the direction of the thrust vector. Increasing the tilt angle also decreases the pitching moment over most of the angle of attack range. As the flap increases, the effect of the motor tilt is reduced. Parallel studies that varied advance ratio also showed that propeller operating conditions strongly influenced wing performance. Lower advance ratios (higher propeller thrust levels) significantly increased lift and simultaneously reduced drag by accelerating flow over the wing and energizing the boundary layer, demonstrating the aerodynamic benefits of DEP-induced slipstream effects. Overall, the results established that DEP systems exhibit strong aerodynamic-propulsive coupling, where propulsion parameters such as thrust level, tilt angle, and installation geometry substantially modify lift, drag, and stability characteristics.

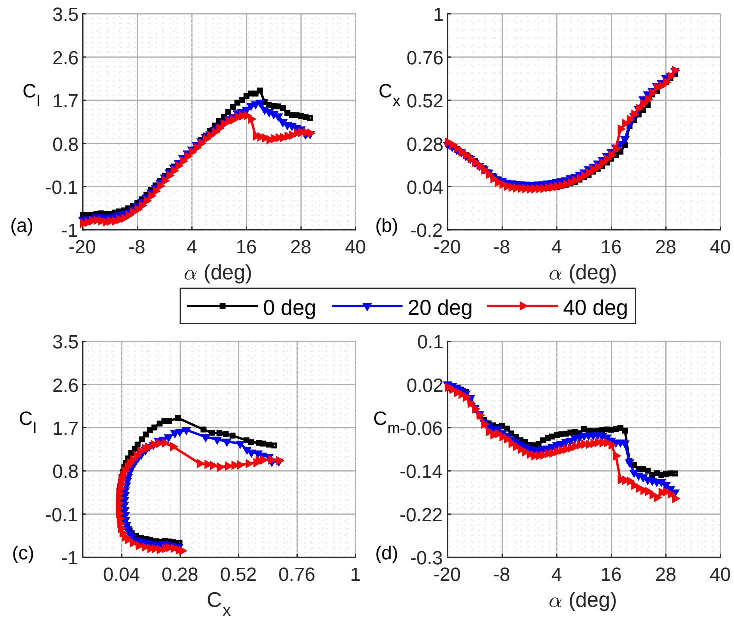

Fig. 4 Effects of propeller tilt at $Re = 300,000$ for a 0 deg flap ($J = 0.75$).

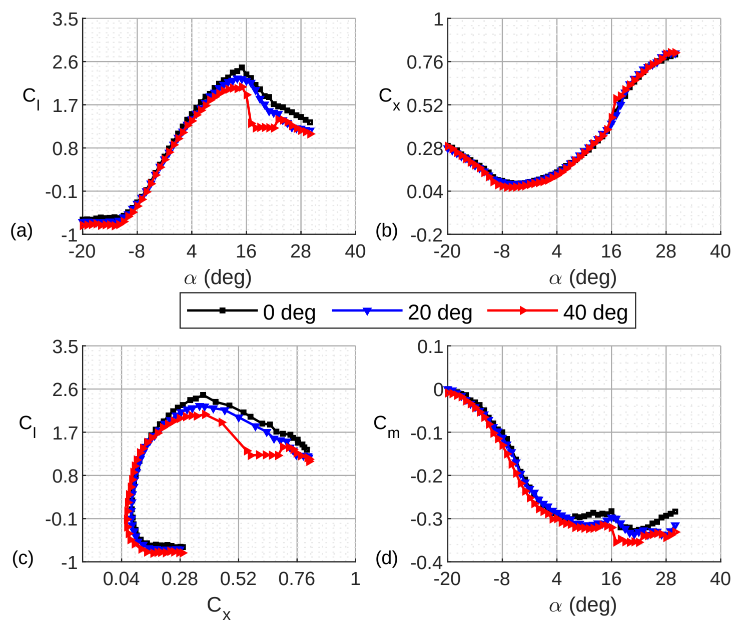

Fig. 5 Effects of propeller tilt at $Re = 300,000$ for a 20 deg flap ($J = 0.75$).

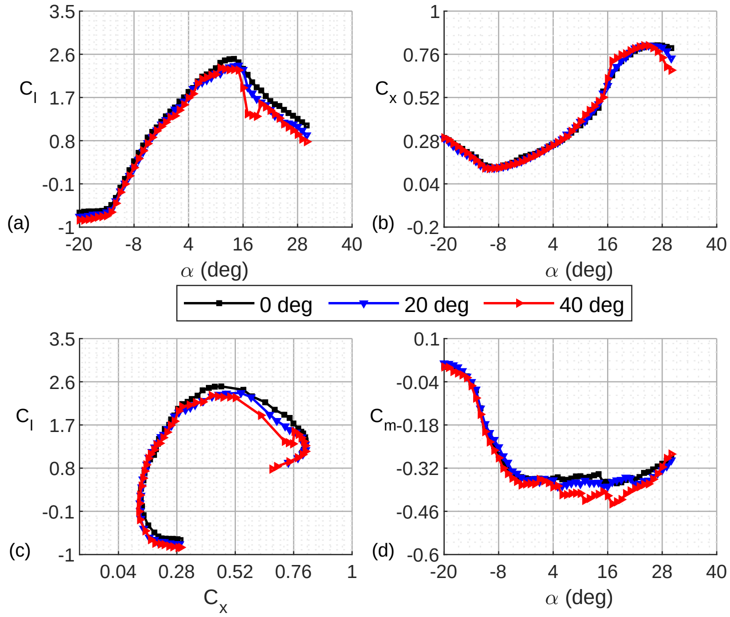

Fig. 6 Effects of propeller tilt at $Re = 300,000$ for a 40 deg flap ($J = 0.75$).

IV. Flight-Test Platform: Baseline Avistar 30

The flight-test platform for AeroBRIDGE is based on an existing instrumented Avistar 30 UAS. The baseline aircraft shown in Fig. 7 has a 90.5 in wingspan and a conventional high-wing configuration. The original wing has a 16 in chord. The aircraft provides sufficient size, payload volume, and operational flexibility for integration of the planned DEP flight-test article.

The Avistar 30cc is instrumented and actively being flight tested at Indiana University. For AeroBRIDGE, the aircraft will be re-winged with a new DEP-compatible wing that mirrors the configuration being tested in the MSU wind tunnel. The re-winged aircraft will retain the baseline 90.5 in span while using a 12 inches chord to provide a closer geometric match to the wind-tunnel model.

Fig. 7 The flight-ready, baseline 90.5 in (2.3 m) wingspan Avistar 30 unmanned aircraft.

A. Baseline Aircraft

The Avistar 30cc was selected from the Great Planes Avistar aircraft family, which includes the smaller Avistar Elite [12] and the approximately 50% larger Avistar 30cc [11]. The Avistar Elite has been extensively used in prior flight testing, ground measurement, and modeling work [13, 14]. However, its size limits integration of a representative DEP system. The larger Avistar 30cc was therefore selected for this program. Like the Avistar Elite, the Avistar 30cc is a commercial-off-the-shelf, fixed-wing, high-wing trainer aircraft that is robust, reconfigurable, and suitable for UAV research [15–19]. Prior instrumentation and flight-test work on the Avistar 30cc [20, 21] provide the baseline for the AeroBRIDGE DEP flight-test platform. Table 2 presents the geometric specifications of the baseline Avistar 30cc, and Fig. 8 shows top and side views of the aircraft.

To support research flight testing, the Avistar 30cc was modified from its baseline consumer configuration. The landing gear was configured in a manufacturer-supported tricycle layout, flap functionality was enabled, control-surface linkages were strengthened, and the original electronics were replaced with research-grade flight systems. The propulsion system, including the motor, propeller, and ESC, was also upgraded to improve performance and reliability. The resulting airframe component specifications are given in Table 3.

Prior to instrumentation, the aircraft was inspected and flown in an uninstrumented state to verify structural condition and provide pilot familiarization. These checkout flights included takeoff, landing, slow-speed, upset-behavior, and flap-configuration practice.

Fig. 8 Top and side views of the Great Planes Avistar 30cc [taken from Great Planes [11]].

Table 2 Baseline Avistar 30 geometry

Parameter	Value
Wing	
Chord	16.0 in (406 mm)
Span	90.5 in (2300 mm)
Area	1448 in^2 (93.4 dm^2)
Aspect Ratio	5.7
Airfoil	Avistar
Horizontal Tail	
Mean Chord	9.2 in (234 mm)
Span	30.7 in (780 mm)
Area	282 in^2 (18.3 dm^2)
Aspect Ratio	3.3
Airfoil	Flat, 12.4 mm Thick
Longitudinal Layout	
Wing LE to Stab LE	41.3 in (1048 mm)
Aircraft Length	77.25 in (1962 mm)

Table 3 The baseline Avistar 30 airframe components.

Component	Specification
Construction	Built-up balsa and plywood structure, aluminum wing tube, aluminum landing gear, ABS canopy, and plastic film sheeting.
Flight Controls	
Controls	Aileron (2), elevator, rudder, throttle, and flaps (2)
Transmitter	Futaba T14MZ
Receiver	Futaba R6014HS
Servos	(7) Hitec HS-5645MG
Regulator	SmartFly SportReg
Receiver Battery	(2) Thunder ProLite RX 2S 7.4 V 900 mAh
Propulsion	
Motor	Hacker A60-5S V4 28-pole Outrunner
ESC	Castle Creation Phoenix Edge HV 120
Propeller	APC 20×10E
Motor Battery	Thunder Power ProLite 25c 8S 29.6 V 6,800 mAh
Motor Power Switch	Emcotec SPS 60/120

B. Baseline Aircraft Instrumentation

The baseline Avistar 30 is equipped with a flight control and data acquisition system capable of collecting high-rate flight-test data. The instrumentation includes inertial, GPS, airspeed, control-command, propulsion-system, and power-system measurements. Specifically, the aircraft is instrumented with an Al Volo FC+DAQ [22] flight control and data acquisition system [23], which operates at 400 Hz and integrates a 9-DOF XSens MTi-G-710 [24] GNSS/INS. Pilot commands are logged from receiver PWM signals, and propulsion-system data are recorded through an interface with the Castle Creations ESC. A 100 A Hall-effect current sensor was also installed between the ESC and battery to monitor current input [25]. The avionics are similar to those previously used on the Avistar Elite, providing continuity with earlier Avistar-series research. Instrumentation specifications are given in Table 4 and Fig. 9 shows the avionics, RC, and propulsion-system layout. The system records aircraft motion, GPS position, pitot-static airspeed, magnetic heading, control-surface deflections, propulsion-system voltage, current, RPM, and power. These measurements support aircraft state estimation, reconstruction of pilot or autopilot inputs, propulsion-system monitoring, and performance analysis.

Table 4 Baseline Avistar 30 instrumentation.

Component	Specification
Main System	Al Volo FC+DAQ 400 Hz
RF Module	Digi International 900 MHz XBee Pro S3B Module
RC Multiplexer	Acroname RxMux
Sensors	
Inertial + GPS	XSens MTi-G-710 GNSS/INS
Airspeed	Al Volo Pitot-Static Airspeed Sensor
Propulsion	Al Volo Castle ESC Interface
Motor current	Allegro ACS758LCB-100B
Power	
Regulator	Built into FC+DAQ
Battery	Thunder Power ProLite 3S 11.1V 1,350 mAh

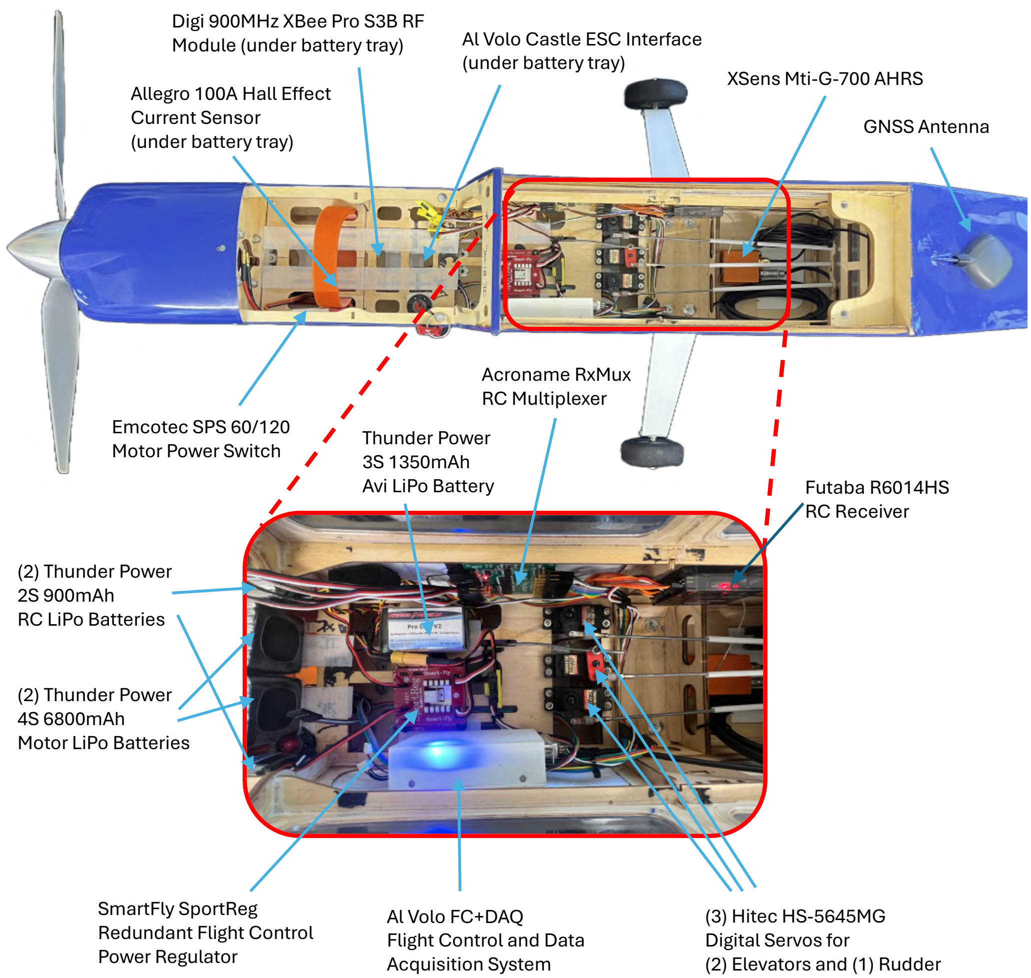

Fig. 9 The internal instrumentation layout of the baseline Avistar 30cc.

C. Baseline Ground Characterization

Ground characterization of the baseline Avistar 30 aircraft includes mass-property measurements, center-of-gravity measurement, control-surface calibration, propulsion-system checks, and planned moment-of-inertia testing. These data establish the baseline configuration before re-winging and provide reference values for later comparison with the clean re-winged and DEP-integrated configurations.

Ground testing to date has included physical measurements, parametrization of control-surface deflections to PWM commands, and propeller performance testing. The measured component masses and test-pilot-preferred center-of-gravity location are presented in Table 5. Moment-of-inertia testing is planned using a previously developed apparatus [26]. Performance testing of the APC 20×10E Thin Electric propeller used on the Avistar 30cc was performed in the UIUC low-turbulence subsonic wind tunnel [27]. Fig. 10 and 11 present static and dynamic propeller performance.

Together, these baseline geometry, instrumentation, mass-property, and propulsion data establish the reference configuration for later comparison with the clean re-winged and DEP-integrated AeroBRIDGE configurations.

Table 5 Baseline aircraft inertial specifications.

Parameter	Value
Weight/Mass Properties	
Fuselage	10.37 lb (4.707 kg)
Right Wing	1.99 lb (0.905 kg)
Left Wing	2.10 lb (0.951 kg)
Wing Tube	0.30 lb (0.138 kg)
(2) RC LiPo Batteries	0.23 lb (0.103 kg)
Avionics LiPo Battery	0.22 lb (0.099 kg)
(2) Motor LiPo Batteries	2.71 lb (1.232 kg)
Gross Aircraft Weight	17.93 lb (8.135 kg)
Flight Properties	
Wing Loading	28.5 oz/ft^2 (87.1 gr/dm^2)
Center of Gravity Behind LE	5.125 in (130.2 mm)

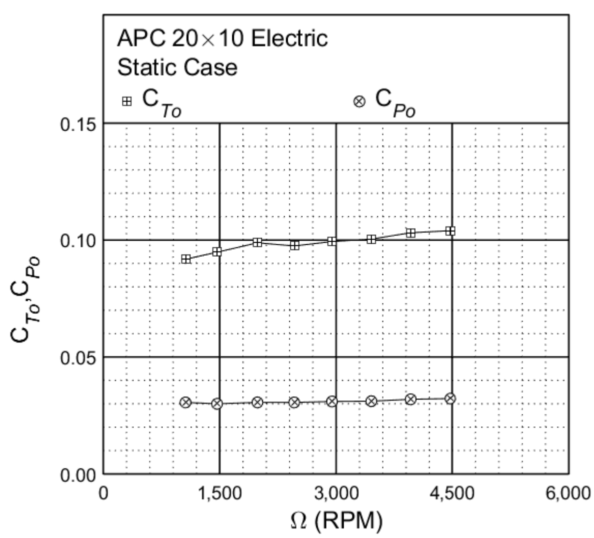

Fig. 10 Static performance of the APC 20×10 Thin Electric propeller: thrust and power coefficient.

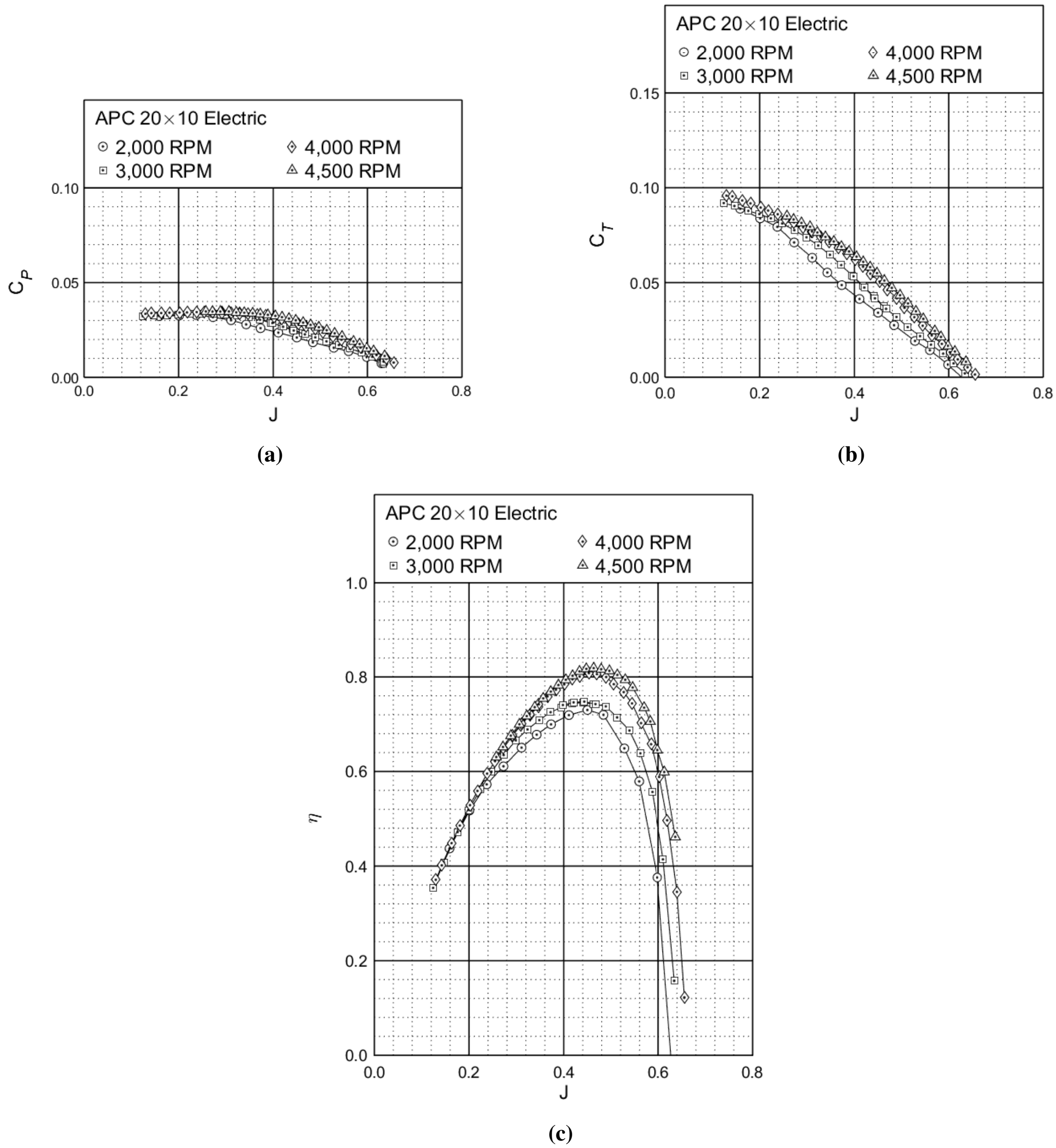

Fig. 11 Performance of the APC 20×10 Thin Electric propeller: (a) thrust coefficient, (b) power coefficient, and (c) efficiency.

V. Re-Winged Avistar 30 DEP Aircraft

The Avistar 30 will be modified with a new rectangular wing to provide a closer geometric connection between the wind-tunnel and flight-test configurations. The new wing will retain the baseline aircraft wingspan of 90.5 in while reducing the chord to 12 inches, matching the wind-tunnel model chord and providing a direct reference for ground-to-flight translation. This configuration will serve as the AeroBRIDGE flight-test article for transitioning a wind-tunnel-selected DEP arrangement to flight.

A concept rendering of the re-winged Avistar 30 DEP configuration is shown in Fig. 12. The rendering shows the 12 inches chord wing installed on the original Avistar 30 fuselage, along with the planned DEP installation concept. The motor arrangement shown should be considered representative until the wind-tunnel configuration-screening effort is complete.

The final DEP installation will be selected from the wind-tunnel test matrix, which varies propeller diameter, motor count, propeller tilt, flap angle, and propeller position. The flight configuration will be chosen to balance aerodynamic performance with practical flight-test constraints, including motor mounting, ESC placement, wiring layout, power-system requirements, structural reinforcement, propeller and ground clearance, and instrumentation access.

The DEP-integrated configuration will require additional propulsion-system measurements beyond those used on the baseline aircraft, including individual motor RPM, voltage, current, power, and ESC telemetry, similar to previously developed DEP instrumentation [28]. Airspeed measurement will also be updated based on baseline checkout-flight results, including possible relocation or extension of the pitot-static probe to reduce wing-flow-field interference. These updates will support both flight safety and comparison of the re-winged DEP flight-test behavior with wind-tunnel trends.

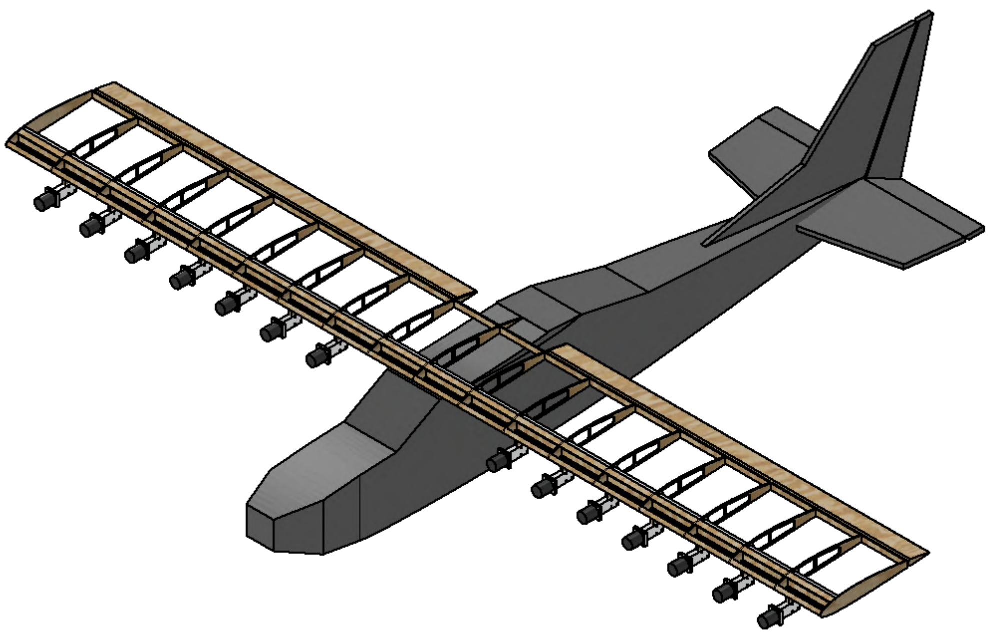

Fig. 12 Concept rendering of the planned DEP re-winged Avistar 30 aircraft.

VI. AeroBRIDGE Test Methodology

The AeroBRIDGE test methodology is structured to transition a DEP configuration from wind-tunnel testing to flight testing through a controlled build-up process. The methodology uses the baseline Avistar 30 configuration to establish a flight-test reference, the clean re-winged configuration to isolate the effects of the new 12 inches chord wing, and the DEP-integrated configuration to evaluate the selected aero-propulsive arrangement in flight. This approach is intended to reduce risk, isolate configuration effects, and provide a practical basis for comparing wind-tunnel and flight-test trends.

A. Flight Test Build-Up Approach

The AeroBRIDGE flight-test campaign will use a phased build-up approach to verify each configuration before progressing to the next level of complexity. The major activities are:

1) **Baseline Avistar 30 checkout testing:** Verify operation of the aircraft, instrumentation, propulsion system, and data-acquisition system before modification. This phase includes ground checks, taxi testing, and flight checkout. *Completed in previous work.*
2) **Baseline Avistar 30 ground characterization:** Establish reference aircraft properties, including mass properties, center-of-gravity location, control-surface calibration, propulsion-system performance, and planned moment-of-inertia measurements. *Partially completed in previous work.*
3) **Clean re-winged aircraft ground testing:** Test the aircraft after installation of the new 12 inches chord wing without DEP. This phase includes weight and balance, structural inspection, control-surface checks, taxi testing, and flight-readiness review.
4) **Clean re-winged aircraft flight testing:** Evaluate the aircraft with the new wing before DEP integration to isolate the effects of the re-winged geometry. Planned flight activities include takeoff, landing, trimmed level flight, slow flight, flap-configuration checks, and basic handling assessment.
5) **DEP-integrated aircraft ground testing:** Verify the selected DEP installation prior to taxi and flight testing. This phase includes motor operation, RPM tracking, power-system performance, vibration behavior, thermal characteristics, and instrumentation functionality.
6) **DEP-integrated aircraft taxi testing:** Evaluate acceleration, braking, steering, controllability, and propulsion-system performance under operational ground conditions before flight.
7) **DEP-integrated aircraft flight testing:** Conduct incremental envelope expansion of the DEP-integrated aircraft. Initial flights will focus on controllability, trim, propulsion-system monitoring, and safe recovery. Later flights will evaluate DEP effects on takeoff, landing, cruise, flap settings, and repeatable maneuver performance.

Flight-test automation [29] will be used where appropriate to improve repeatability and reduce pilot-to-pilot variability. Automated maneuvers will support repeated test points at prescribed airspeeds, attitudes, throttle settings, flap settings, and DEP configurations, which is important for comparing flight-test data with wind-tunnel trends.

B. Ground-to-Flight Translation Metrics

The AeroBRIDGE program will compare wind-tunnel and flight-test behavior using translation metrics that capture trends rather than requiring exact one-to-one agreement between ground and flight environments. These metrics will be used to evaluate whether the aerodynamic and performance trends observed during wind-tunnel screening persist when integrated into the full aircraft system.

Potential translation metrics include:

1) Lift increment due to DEP operation.
2) Trim change due to DEP and flap settings.
3) Pitching-moment trends.
4) Power required at comparable flight conditions.
5) Effective advance ratio or thrust coefficient.
6) Stall or approach speed changes.
7) Takeoff ground-roll and climb-performance changes.
8) Cruise performance changes.
9) Repeatability across test runs.
10) Data-quality metrics, including airspeed consistency, current-sensor calibration, and RPM tracking.

Wind-tunnel data will be used to define expected trends with motor count, propeller diameter, propeller placement, propeller tilt, flap deflection, and advance ratio. Flight-test data will then be used to evaluate those trends in the re-winged and DEP-integrated aircraft configurations.

VII. Expected AeroBRIDGE Program Products

The AeroBRIDGE program is expected to produce both physical test assets and a repeatable methodology for translating DEP aerodynamic configurations from wind-tunnel testing to flight testing. These products are intended to support the present fixed-wing AAM test program while also providing a foundation for future ground-to-flight research efforts involving DEP and other aero-propulsive aircraft configurations.

1) **Matched wind-tunnel and flight-test methodology for DEP aerodynamic translation:** A primary product of AeroBRIDGE will be a structured methodology for using wind-tunnel results to inform flight-test configuration selection, test planning, and data comparison. Rather than treating the wind-tunnel and flight-test efforts as separate experiments, the program will define how ground-test parameters, such as propeller diameter, motor count, propeller placement, propeller tilt, flap deflection, and advance ratio, are transitioned into a flight-test configuration and evaluated in an integrated aircraft environment.
2) **Re-winged Avistar 30 flight-test platform for fixed-wing DEP testing:** The program will produce a modified Avistar 30 flight-test aircraft with a 12 inches chord rectangular wing that provides a geometric link to the wind-tunnel model. This aircraft will serve as a modular flight-test platform for evaluating fixed-wing DEP configurations. The re-winged configuration will retain the operational advantages of the baseline Avistar 30 while enabling installation of the selected DEP system.
3) **Selected DEP configuration transitioned from wind tunnel to flight:** A DEP configuration will be selected from the wind-tunnel screening matrix and integrated onto the re-winged Avistar 30. The selected configuration will be chosen based on aerodynamic performance, pitching-moment behavior, integration practicality, and flight-test safety. This product represents the central transition step in the AeroBRIDGE program, moving from controlled ground-test screening to aircraft-level flight evaluation.
4) **Ground, taxi, and flight-test dataset for DEP evaluation:** The program will generate a dataset spanning baseline aircraft testing, clean re-winged aircraft testing, and DEP-integrated ground, taxi, and flight testing. These data will include aircraft state, airspeed, control-surface deflections, propulsion-system measurements, power-system measurements, and relevant environmental conditions. The dataset will support comparison between wind-tunnel and flight-test trends and will provide a basis for evaluating the effectiveness of the translation methodology.
5) **Lessons learned for future fixed-wing AAM flight-test programs:** The program will document practical lessons related to configuration down-selection, flight-test vehicle modification, DEP integration, instrumentation, airspeed measurement, power-system monitoring, test build-up, and flight-test operations. These lessons will help inform future fixed-wing AAM test programs where ground-test results must be transitioned to flight in a safe, repeatable, and technically meaningful manner.

Together, these products will establish AeroBRIDGE as a practical ground-to-flight translation program for fixed-wing DEP aircraft. The resulting methodology, test article, dataset, and operational lessons will provide a foundation for future studies that compare wind-tunnel predictions with flight-test behavior for increasingly complex AAM configurations.

VIII. Summary and Future Work

This paper presented AeroBRIDGE, a wind-tunnel-to-flight testing translation program for fixed-wing Advanced Air Mobility aircraft with distributed electric propulsion. The program was developed to address the gap between controlled wind-tunnel measurements of aero-propulsive interactions and integrated flight-test evaluation on a complete aircraft system. Rather than treating wind-tunnel testing and flight testing as separate activities, AeroBRIDGE establishes a structured pathway in which wind-tunnel results are used to screen candidate DEP configurations, guide flight-test vehicle development, and inform a staged ground, taxi, and flight-test campaign.

The wind-tunnel component of the program provides the configuration-screening foundation for AeroBRIDGE. The DEP wind-tunnel model enables controlled variation of propeller diameter, motor count, propeller tilt, flap angle, and propeller position. Initial wind-tunnel results demonstrated repeatable operation of the DEP model and showed that propeller operating condition and installation geometry can significantly affect wing aerodynamic performance. These results reinforce the need for a systematic down-selection process before transitioning a DEP configuration to flight. In the AeroBRIDGE framework, wind-tunnel data are therefore used primarily for risk reduction and configuration selection, rather than as a substitute for aircraft-level validation.

The flight-test component of the program is based on an instrumented Avistar 30 UAS. The baseline aircraft provides a practical and reconfigurable platform for incremental flight-test development. Baseline characterization has established the aircraft geometry, airframe configuration, instrumentation architecture, mass properties, and propulsion-system performance. These data provide the reference configuration against which the clean re-winged and DEP-integrated configurations will be compared. The existing flight-test instrumentation, including aircraft state, airspeed, control-command, propulsion-system, and power-system measurements, provides the foundation for future DEP flight testing.

A key element of the AeroBRIDGE program is the planned re-winged Avistar 30 DEP aircraft. The modified aircraft will retain the baseline 90.5 in wingspan while using a 12 inches chord rectangular wing to match the wind-tunnel model chord. This geometric connection is intended to improve the relevance of the wind-tunnel-to-flight comparison while preserving the operational advantages of the existing Avistar 30 platform. The final DEP motor configuration will be selected from the wind-tunnel screening matrix based on aerodynamic performance, pitching-moment behavior, integration practicality, and flight-test safety considerations.

The AeroBRIDGE test methodology uses a phased build-up approach to reduce risk and isolate configuration effects. The planned sequence progresses from baseline Avistar 30 checkout and ground characterization, to clean re-winged ground and flight testing, to DEP-integrated ground, taxi, and flight testing. This staged approach allows the effects of the new wing and the DEP system to be evaluated separately before the fully integrated configuration is flown. Flight-test automation will be used where appropriate to improve repeatability and support comparison with wind-tunnel trends.

Future work will complete the wind-tunnel configuration-screening matrix, finalize the DEP configuration for flight, fabricate and test the 12 inches chord re-winged aircraft, integrate the selected DEP system, and conduct the planned ground-to-flight translation campaign. The resulting methodology, test article, and dataset are expected to provide a foundation for future fixed-wing AAM flight-test programs in which wind-tunnel results must be transitioned to practical aircraft-level evaluation.

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